Hort Innovation

Final Report

Creating value from edible vegetable waste

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Delivery partner:

CSIRO

Project code:

VG15076

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Funding statement:

This project has been funded by Hort Innovation, using the Vegetable research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Publishing details:

ISBN 978 0 7341 4541 3

Published and distributed by: Hort Innovation

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www.horticulture.com.au

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Content

Summary

A significant portion of the vegetables produced are lost across the whole value chain in Australia. The vegetable industry has an opportunity to recover vegetables lost to the supply chain and convert them into value added food ingredients and products as well as nutritional supplements for the growing health and wellness market. Capitalising on the potential of vegetable mass as a new raw material supply of value-added ingredients and products allows better capture of economic value and re-directs material that otherwise goes to landfill or to products of lesser value (e.g. compost, animal feed). This project investigated the potential of selected processing technologies (i.e. separation, drying and extrusion, fermentation) for recovery of edible vegetable mass material for production of safe and nutritious ingredients and foods and supplements. Collaboration between various stakeholders across the value chain is required to create a pathway to new export markets for vegetable-based ingredients and foods from under-utilised vegetable biomass. Extension activities, pre-feasibility of establishing regional processing hubs and business models for farmers interested in commercialization of the research outputs.

Activity 1: Extraction of health promoting components

Integrated "zero-waste" extraction strategies for health active compounds from broccoli and carrot biomass were established and scaled to pilot scale. For broccoli, extraction, separation and stability of sulforaphane-rich factions from broccoli were established. Membrane based separation technology was optimized and scaled to pilot scale to also yield a variety of products with specific profiles of health active compounds. Potential health-promoting fractions included (i) broccoli pomace, (ii) broccoli extract and iii) broccoli water. For carrot, conditions for stabilization of β-carotene rich fractions were investigated. A precipitation method was developed and to produce four potential health-active fractions and scaled to pilot scale, which included (i) carrot pomace, (ii) β-carotene ingredient, (iii) functional sweeter and (iv) carrot water. The composition and functionality of all broccoli and carrot fractions have been described. A novel cold membrane-based concentration process (forward osmosis) was used to produce broccoli and carrot juice concentrates.

Activity 2: Processing and formulation of value added products

Processes for transforming fresh broccoli and carrot into shelf stable, safe, nutritious, functional ingredients and products have been developed. Broccoli and carrot powders were manufactured using a combination of selected pre-treatments and drying processes for optimal retention of the natural colour, flavour and the natural goodness of vegetables. These powders are a more convenient vegetable format that is nutrient dense, has reduced volume and longer shelf life. A 7.5 gram portion of the powder provides 1 serve of vegetable. Extruded snacks and products containing 20-100% vegetable were also developed. The extruded snack containing 20% vegetable is a healthy snack containing 1 serve of vegetable in ~40g serve snack pack. The consumer survey demonstrated acceptance (liking and intent to purchase) at 80-85% on the new vegetable snack products, which confirmed the potential to use the new broccoli and carrot powders as ingredient for healthier food product options.

Activity 3: Fermentation

The objective of this activity was to develop fermentation based technology for value adding to underutilized broccoli and carrot biomass. Accordingly, laboratory scale lactic acid bacteria fermentation processes were developed for carrot and broccoli puree using commercial starter cultures. The fermentation process thus developed enabled products free of spoilage and pathogenic organisms with live lactic acid bacteria count of ~109 CFU/gm. Fermentation resulted in excellent color retention in carrot and in up to 85% increase in antioxidant capacity (oxygen radical absorbance capacity, ORAC) and up to 66% increase in total polyphenol content of carrot. Fermentation of broccoli similarly resulted in a significant improvement in protein content, dietary fiber, ORAC antioxidant capacity and total polyphenol content with the effect dependent on the fermentation culture. The fermented carrot puree and broccoli puree products can be used as functional ingredients in beverages, smoothies, dipping, sauces, baby food and food for the elderly with potential pre- and probiotic benefit.

Activity 4: Business development

Activities undertaken to facilitate the adoption of technology developed by the project included mapping the value chain and developing business models. A report titled 'value chain mapping and business model development' by Dianne Glen of Corelli Consulting was submitted and an oral presentation of the report was given to Hort Innovation, VegNet and at an investment seminar. In addition, targeted discussions with growers interested in value-addition and potential customers across the value chain to develop food and beverage applications using the ingredients produced by the project technology are in various stages of discussions.

Activity 5: Stakeholder engagement

Extension focused on engaging with stakeholders along the value chain from growers through to retailers and the general public showcasing project outcomes (powders, concentrates, fermented products, extruded products). Activities including workshops, on-farm technology demonstrations, and media articles aimed at connecting grower networks to the wider food and nutraceutical industry to facilitate capture of value along the supply chain were developed and executed. Extension activities facilitated interest in the formation of collaborative networks for creation of new business value propositions through regional value-adding hubs.

Activity 6: Regional manufacturing hubs

This activity was a pre-feasibility study for the development of an innovation manufacturing hub that supplies fruit and vegetable ingredients from regional fresh produce to local and export markets. Specialist F&V (fruit & vegetable) ingredients to be manufactured in the hub may include powders, liquid concentrates, fermented ingredients and fibre powders. The approach taken in this project consisted of a high level evaluation of the various critical business and regional aspects that justify the establishment and operation of the hub.

Keywords

vegetable waste; food ingredients; broccoli; carrot; nutritional products; fractionation; powders; extruded snacks; fermented products; collaborative networks

Introduction

Food losses and waste worldwide is significant global issue. Australian food losses in grain, horticulture, meat, fish and seafood production was $2.9 billion in 2014-2105, with $1.8 billion attributed to horticultural losses (Turning Food Loss into Profit Workshop, Canberra, April 2015, Workshop Report). Vegetable loss and waste is a major waste of nutrients, energy and water and a lost opportunity for industry.

Significant vegetable wastage occurs on farm and due to a wide range of activities post-farm gate. Food losses and waste can occur post-harvest including during packaging, processing, transport and distribution, retailing and consumption. There is a need to develop new technologies that enable improved recovery of edible material for production of safe and nutritious foods. Separation and extraction of known nutraceuticals and food fractions enriched in nutraceuticals has been a common approach to extract value from second grade material and side streams of food processing. An alternative is use the whole of the food loss/waste stream as a new source of raw ingredients for the production of value added ingredients and products. The high fibre-rich vegetable-based ingredients and food formulated containing these ingredients are expected to have good prebiotic potential and contribute to a healthy gut and microbiome. Fermented products are one of the top ten trends in the food markets. Fermented products are also likely to have desirable health benefits for gut health.

This project aimed to optimize the value from the edible waste in the vegetable supply chain, by creating healthy food ingredients and products. This was significant for the industry as the project was expected to provide the enabling technologies that would increase the economic value derived from vegetable production and reduce vegetable waste disposed to landfill. The research focused on the development of value-added ingredients and products from Brassica (broccoli) and carrots. The intent was to work with the vegetable industry to develop an understanding of the issues and interests of the farmers growing Brassica and carrots (as well as other vegetables of interest). This was used to guide the development of the relevant knowledge and processes that had potential to enable the vegetable industry to (i) extract and separate nutraceuticals from vegetable waste, (ii) process and formulate edible vegetable streams that would otherwise be wasted into value added waste into fiber-rich healthy food powders and healthy extruded products and (iii) develop the next generation fermented vegetables.

To facilitate the translation and adoption of the technology by the industry, complementary activities were embedded into the project. The major activities were (i) extension activities which included facilitated stakeholder workshops aimed at helping forge collaboration across the value chain, (ii) the development of business models for farmers interested in commercializing the outputs of the projects and (iii) the provision of pre-feasibility options for establishment of regional food processing hubs, including an analysis of the market landscape for horticultural value added products. A desired outcome is new industries and employment based on new edible food ingredients/products from vegetables that will provide more returns to the farmer.

Methodology

In undertaking this project, we worked with the vegetable industry (in collaboration with Hort Innovation) to to develop an understanding of the issues and interests of the vegetable growers (Brassica and Carrot). We then developed the industry-relevant knowledge and processes that will enable the vegetable industry to produce a range of value added food ingredients and products, and nutritional supplements. To support the translation and commercialization of the processing technologies for manufacture of the value added vegetable products, we undertook extension activities with farmers and stakeholders across the value chain, including the development of options for business models for farmers and pre-feasibility studies on the establishment of regional processing hubs. Further details of the approaches used are given below.

Activity 1: Extraction of health promoting components

Heat and shear based pre-processing steps subsequent to different biomass size reduction steps were investigated for both broccoli and carrot. Conditions resulting in the highest formation and release of sulforaphane or β-carotene were implemented to conduct extraction and fractionation of health-active compounds. For both substrates, the extraction and fractionation was first developed and refined at laboratory scale before up-scaling to small pilot scale. For broccoli, a two-stage membrane process comprising microfiltration followed by nanofiltration were used to arrive at a sulforaphane-rich fraction and a broccoli water fraction. For carrot, a simple acid precipitation step was implemented to derive a β-carotene rich food ingredient and the supernatant was further processed with nanofiltration methods. These methods were developed, implemented and applied to selected fractions.

Activity 2: Processing and formulation of value added products

The 100% broccoli and carrot powders were made from whole vegetables, and produced using a combination of selected pre-treatment and drying process to optimise retention of natural colour, flavour and nutrient composition. The extruded broccoli and carrots were made from either 100% vegetable powder or combined with rice flour for formulations containing 80, 60, 40, 20 % broccoli or carrot powder. A Clextral co-rotating, intermeshed twin-screw extruder (EV32, Firminy, France), was used for the production of extruded products. Nutritional composition (Energy, protein, fat, ash, carbohydrate, dietary fiber) of the products were analysed at a NATA certified laboratory (National Measurement Institute). The initial consumer survey of the extruded vegetable snacks with 86 consumers was conducted during Hort Connections 2018 (Brisbane) and at CSIRO Agriculture and Food, Werribee. The sensory evaluation of the vegetable powders and extrudates were further evaluated by a total of 82 consumers (average age 39.3±13.8 years).

Activity 3: Fermentation

Five commercial vegetable fermentation starter cultures namely Lyofast, Cutting edge, Wilderness family naturals, Caldwell's and Mad Millie were evaluated for the fermentation of carrot and broccoli puree and their performance was compared with CSIRO developed starter cultures. The different cultures were compared based on fermentation rate and effect on microbial safety and product quality. The best performing cultures were selected for further process development and characterization. The physiochemical, nutritional and microbiological safety and quality attributes of the fermented products were fully characterized. Untargeted and targeted metabolomics analyses of the products prior to and after fermentation were also conducted. A microbial challenge study was conducted on broccoli fermentation with a selected culture (Caldwell), to evaluate whether the process controls incidental contamination of the raw material by pathogenic organisms. Based on a preliminary microbial challenge study on carrot fermentation, a heat treatment step of the raw material was introduced into the process for risk mitigation.

Activity 4: Business development

Targeting early adopter growers, the approach used to map value chains and business models was to review published data and interview targeted participants across the value chain to undertake a situational analysis of the potential product categories and map the high level value chain. The value chain and business models were benchmarked and a range of business models to value-add to vegetables were recommended taking into consideration drivers of uptake of value-adding technology, requirements of value-adding business, risks and risk mitigation and management strategies and approaches to address gaps identified in the exiting value chains.

Activity 5: Stakeholder engagement

Extension activities focused on engaging with stakeholders along the value chain from growers through to retailers and the general public showcasing project outcomes (powders, concentrates, fermented products, extruded products). Fifteen activities specifically aimed at connecting to grower networks, included 'taking the extruder to the farm' visits in three Victorian locations. A series of 6 workshops (attended by 250) were planned and executed. The development of a series of ten fact sheets, 25+ media articles and interviews, and presentations at industry forums further promoted the project.

Activity 6: Regional manufacturing hubs

This activity examined the considerations required to build a detailed business case for commercial feasibility. The business case activities assessed the following: (1) market opportunities; (2) business models for the hub; (3) venture infrastructure and cash flow; (4) aspects of competitiveness and risk associated to setting up the venture; (5) flow-on regional benefits; (6) hub ownership models and governance options; and (7) a sensitivity analysis for scenario modelling and forecasting.

Outputs

The major tangible deliverables include the written reports (provided as Appendices) for the activities listed below:

Activity 1: Extraction of health promoting components

- Integrated extraction and separation strategies leaving no non-utilised fractions comprising health active fractions from broccoli and carrots were demonstrated as prototypes.
- Juice concentrates produced with low temperature membrane process demonstrated for both carrot and broccoli juice
- Draft specification sheets for the major health active fractions have been developed.

Activity 2: Processing and formulation of value added products

- Report (including specification sheets) for (i) broccoli and carrot powders and (ii) extruded vegetable snacks

Activity 3: Fermentation

- Lactic acid bacteria fermentation processes for carrot and broccoli puree
- Fermented carrot and broccoli purees
- Fermented carrot and broccoli freeze dried powders
- 2 product fact sheets for dissemination of project results

Activity 4: Business development

- Report titled 'value chain mapping and business model development' by Corelli Consulting and an oral presentation of the report by Dianne Glen of Corelli Consulting to Hort Innovation (Greg Murdoch and Roxanne Portolesi).
- The report was presented at a VegNet event in March, 2018 (East Gippsland) and at the investment seminar 'A value chain for vegetable waste – from farm to fork - Creating value from vegetable waste (10 May, 2018, Werribee, Victoria).

Activity 5: Stakeholder engagement

- Report for stakeholder engagement and extension activities

Activity 6: Regional manufacturing hubs

- Report on commercial-feasibility study for establishment of regional manufacturing hubs

Appendix 7 –Monitoring & Evaluation

- Report on M&E

Outcomes

There would be a reduction in vegetable losses in at least one of the vegetable supply chains investigated within 3 years of the project completion. A desired outcome is new industries and employment based on new edible food ingredients/products from the underutilised vegetables that will provide more returns to the farmer.

Activity 1: Extraction of health promoting components

The prototype extracts developed are expected to contribute to the reduction of vegetable losses along the supply chain as underutilized biomass (eg, seconds, excess production) will be diverted as a feedstock for extraction.

Activity 2: Processing and formulation of value added products

Expected outcomes from this activity would be the following: (i) Reduction in vegetable losses in at least the broccoli and carrot value chain within 2-3 years following commercialization of powders and extruded snacks, (ii) New business or extension of existing business for farmers/growers/packers from being a fresh vegetable supplier to supermarket to becoming food ingredient processor and supplier to the food service and food manufacturing companies, (iii) Wider choices for consumers for healthier more nutritious foods containing nutrient dense vegetable ingredients, and options to increase vegetable intake in their diet, (iv) Increased returns to farmers for excess produce, damaged crops and second grade produce and (v) Less waste and less burden to the environment due to less waste to land fill

Activity 3: Fermentation

The fermentation project activity enabled the development of two fermentation processes for stabilization and value adding to broccoli and carrot. The products have desirable quality attributes and can be used as functional ingredients in processed foods and beverages. The processes enable conversion of second grade produce into high value products as well as enable the utilization of the traditionally inedible parts which account for about 60% of broccoli biomass. Thus, the outcome of this activity contributes towards the reduction of the over 30% food loss in the vegetable value chain improving economic and environmental sustainability. The outcomes of this activity is already attracting interest from local vegetable farmers who have seen the benefit of using the technology for converting their 'of spec' produce into value added products for local and international market.

Activity 4: Business development

The outcomes were (i) Farmer - Early project activity on brassica ingredients initiated between farmer and retailer (customer) for new product developmet, (ii) East Gippsland Food Cluster – using the pre-feasibility assessment for an East Gippsland vegetable value-adding hub to further engage with stakeholders (local and state government, FIAL, grower value-adders) to achieve establishment of a processing hub, (iii) Northern Queensland – interest in development of a future value-adding hub by growers based on the pre-feasibility report, (iv) several companies interested in developing food and beverage products using the developed vegetable ingredients. Over 5 companies are evaluating the ingredients including interest for vegetable containing snack products.

Activity 5: Stakeholder engagement

Extension and stakeholder engagement activities have served as a catalyst for stimulating interest in potential new business opportunities for underutilised vegetables and fruits. This includes facilitating; (i) the connection of growers to the wider food and nutraceutical industry for capture of value along the supply chain to enable alternative pathways to commercialization, (ii) formation of collaborative networks for creation of new business value propositions through regional value-adding hubs.

Activity 6: Regional manufacturing hubs

This work is facilitating the current engagement with potential stakeholders across government and the horticultural industry including: (1) Potential customers of the hub (e.g. Ingredient suppliers (2) Potential owners or users of the hub (e.g. Farmers) (3) Grower and food processor clusters & potential feedstock suppliers (e.g. in Victoria and Queensland); (4) Interested government funded programs (e.g. Food Waste CRC, FIAL) and (5) Councils, State Governments and Federal Government.

Monitoring and evaluation

Relevant SIP outcome(s)	- Increased farm productivity and decreased production costs through better utilisation of resources - Increased supply chain integration and development through improved supply chain management, development of collaborative models and partnerships - Improved capability of levy payers to adopt improved practices and new innovation through improved communication and extension programs, grower innovation support,
End-of-project outcomes	- Improve the export capability of Australian vegetable growers - Identify value-adding opportunities such as novel ingredients, food and beverage products and supplements to achieve price premiums for underutilised second grade vegetables - Reduce on-farm food waste including alternative uses such as value-added foods and beverages, and nutraceuticals amongst others - Support product differentiation that align with Australian consumer needs - Enhance the sustainability of the industry by adding value to underutilised vegetables - Support collaboration between growers and stakeholders along the supply chain to improve its efficiency - Support innovation that advance and grow the vegetable industry - Input into National Food Waste Strategy (through involvement in Government strategy committees)
Intermediate outcomes	- Visits to farms at the start and through life of the project to understand farmers interests and issues - On-farm technology (extruder to the farm) demonstrations - Connection with HI and VegNet /RMCG to reach farmer networks - Facilitated stakeholder workshops that led to understanding of project outputs - Meeting with stakeholders and farmers to advance government (Local / state) agendas for regional hubs - Media exposure on value adding to underutilised vegetables - Show-casing research outputs with HI at Hort Connections 2018 (including broccoli latte) - Formation of collaborative networks with stakeholders along the supply chain which resulted in connecting farmers to customers (ingredient/ food manufacturing companies, retailers and nutraceutical companies) - Interactions with KPMG and Ernst & Young to communicate outputs to the food industry - Awards: State (Victoria) and National Level awards for Industry Impact (AusVEG) - Overall: The intermediate outcomes have helped initiate strategy planning to facilitate uptake of technologies including the feasibility assessment and commercial planning for future farmer business opportunities
Outputs	- Milestone Reports & Presentations at Conferences - Specification sheets for new products developed in the project - Significant number of radio and TV interviews, web-based communications - Pre-feasibility study for establishment of regional hubs - Product concept samples provided at business meeting with prospective customers (with HI). This includes customer samples produced by growers using technology developed in VG15076 - Prototype samples made available at various events (eg Science Week at Victorian market, August 2017; Facilitated stakeholder workshops – 2017 & 2018; Hort Connections 2018, AgCatalyst 2018, Active Integrated Matter Conference in Feb 2018)
Activities	- Research and development on new ingredient/ food and beverages using broccoli and carrots – on laboratory and pilot scale – nutritional supplements, vegetable powders and extruded snacks, fermented products - Consumer testing of selected new ingredients and products - Understanding the risks/pathways for commercialisation /business models, with a focus of farmers/grower business - Extension– eg. workshops, farm visits, attendance at farm innovation days, developing communication material - Business development activities – facilitation of stakeholder networks, meetings with potential end users of ingredients/ food and beverage products with farmers - Pre-feasibility studies with a range of stakeholders for establishment of regional processing hubs

1. To what extent has the project achieved its expected outcomes?

Current feasibility development activities have identified opportunity for utilisation of produce and conversion to value added ingredients & products in the range of 100,000 to 250,000 Kg p.a., with finished product market sales value in the order of $10M p.a. for each of three separate regional production value-adding interest groups. These initiatives are subject to current development planning and investment activity.

2. How relevant was the project to the needs of intended beneficiaries?

Producer engagement by the project at forums and visits has initiated three key development interests in Werribee South, East Gippsland and Townsville region. In addition to other grower interests.

3. *How well have intended beneficiaries been engaged in the project?*

Opportunity has been provided for individual meetings with project team, at CSIRO and in production regions.

4. To what extent were engagement processes appropriate to the target audience/s of the project?

Engagement process operated at two levels, firstly opportunity awareness and sharing information, then followed by individual group strategy meetings and project development type meetings fit-for-purpose relating to producer interests. Agendas related to value-added development strategy and feasibility activity relating to new business development strategy, products and markets. This has included introductions and meetings with prospective customers

Recommendations

That there be further translation and commercialization activities to facilitate wider adoption of the research outputs.

That there be further dissemination of findings to various audiences including communication of results in publications and technical industry reports as appropriate and presentations of findings and conferences.

Activity 1: Extraction of health promoting components

Further Technical Development is recommended. This includes producing the fractions for sensory and product development trials as this will help ingredient/food/supplement manufacturers conduct consumer acceptability testing on the fractions. Market testing of the developed fractions will help reduce the risks for potential commercializing partners. Longer term, health substantiation demonstrating the bioavailability and health-active properties after consumption would further enhance the consumer and market appeal of the fractions.

Commercialisation/Uptake: Findings should be actively communicated to relevant companies/co-operatives to develop follow-on projects specific to the company/co-operative needs.

Activity 2: Processing and formulation of value added products

To assist in the realization of the expected outputs and impact of this activity, the following are highly recommended: (i) That HI provide funds for technology transfer and commercialization, to vegetable levy payers interested in commercializing the technology and products developed (e.g. vegetable powders and extruded snacks) in order that the expected outcomes and impacts are realized, (ii) That HI support the provide funds for the development and realization of the regional processing hub, to have critical mass and have the quantity and capacity in one processing hub to produce the volumes required for an economically viable business and (iii) That HI facilitate customer engagement and extension activities to support and further develop the initial business plan developed within this project.

Activity 3: Fermentation

Two small scale fermentation processes were successfully developed in this activity for stabilization and value addition to broccoli and carrot biomass. To support commercialization of the technologies, it is recommended that

- the processes are further optimized and scaled up to large pilot scale
- further studies are conducted on the impact of variations in cultivar, growing season, growing condition etc. on the fermentation processes and the quality of the products
- further studies are conducted on the physicochemical and microbiological stability of the fermented purees and powders during storage
- studies are conducted on potential health benefits of the products
- studies are conducted on the functional properties of the fermented purees and powders for applications in finished products

Activity 4: Business development

HI should facilitate and provide programs to aspiring growers to successfully commercialise the technology including, developing entrepreneurship and corporate preparedness to undertake new business opportunities, understanding the market opportunities and their drivers of revenue and market cycles, understanding the complexities of the route to market, establishing systems for provenance and traceability, and mentoring and coaching in contract negotiation skills, especially with overseas customer. In addition, HI should consider providing aspiring growers with financial assistance to access contract manufacturing facilities to produce prototype samples of ingredients derived from their produce to supply potential food and supplement companies to develop prototype food and beverage products.

Activity 5: Stakeholder engagement

Extension activities have considered innovation as both a societal and a scientific process and have used a transdisciplinary approach to engage various stakeholders along the horticulture value chain. HI should consider the importance of stakeholder engagement and extension activities as an integral part of innovation projects to catalyse the development of new collaborative partnerships and networks for stakeholders.

Activity 6: Regional manufacturing hubs

Extend the information gathered to key stakeholders including other local and overseas cornerstone customers requiring local F&V ingredients, growers, food processors, investors, government representatives, and innovators. This information is intended for use as a baseline for informed discussion, engagement and decision making of multiple parties, within a regionally focused feasibility STAGE 3 project, to identify key business options that justify ventures of this type in target regions in Australia.

Refereed scientific publications

No refereed scientific publications

Non-Refereed Presentations:

1. Augustin MA* & Sanguansri, L Food Loss & Waste – A Societal Challenge..CSIRO, Agriculture & Food; CSIRO, AIM Future Science Platform Conference, 19-21 Feb 2018
2. Juliano, P. Regional Food Processing Hub Development, Presentation to the Food & Fibre Leaders Luncheon, Warragul, VIC, 13 April 2018.
3. Terefe, N.S. Functional food ingredients from underutilized vegetable biomass via lactic acid fermentation. BESS conference on sustainable production of biomolecules, June 14-16, 2018, Singapore
4. Krause, D., Simons, L, McInnes, S. Building networks for creating our business case for reducing vegetable wastage: a case study, 19th IUFoST World Congress of Food science and technology, 23-27 October 2018, India, Poster presentation. (Selected for poster award)
5. Augustin MA & Sanguansri L. Reducing Food Loss & Waste: A Transdisciplinary Approach. 19th IUFoST World Congress of Food science and technology, 23-27 October 2018, India.

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Only selected references are provided here. A more comprehensive list of references can be found in individual reports.

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- Standards Australia (2004). Food Microbiology Method 11.1: Microbiology of food and animal feeding stuffs – Preparation of test samples, initial suspension and decimal dilutions for microbiological examination – General rules for the preparation of the initial suspension and decimal dilutions. AS 5013.11.1
- http://www.fao.org/save-food/resources/keyfindings/infographics/fruit/en/

Intellectual property, commercialisation and confidentiality

Part 1 -Pre-Existing/Background IP (BGIP) and Third Party IP (TPIP) to be used in the Project (As provided to HI)

Previous projects of the Parties:

1. Apple pomace stabilisation, drying, extrusion for high fibre and polyphenolic content
2. Fermented vegetable cultures and achieving high sulfurophane content
3. Fermented and combination of post fermentation processing technologies to reduce sugar in vegetable and fruit juice with added prebiotic and/or probiotic functionality (CSIRO)
4. Juice concentration with forward osmosis
5. Bioactive separation technology

BACKGROUND INTELLECTUAL PROPERTY (BGIP) AND THIRD PARTY INTELLECTUAL PROPERTY (TPIP) REGISTER								
	Date (ie date on which details were initially listed and/or modified)	Owner(s) of BGIP or TPIP (If TPIP - list the name of the organisation which provided it)	IP Category (eg plant variety, gene, formulation, software, thesis, report, data etc)	Specific Description of IP	Nature of IP (eg copyright, patent, trade mark, design, PBR) Form in which the IP subsists (eg device, process, formulation, document)	Registration/ application details (if registered) (eg registration number, date of registration and expiry)	Intended purpose and value of the IP that is provided	Used or may be used for Commercialisation of Project IP (yes/no) and, if **yes**, how it is used
1.	**7 AUGUST 2015**	**CSIRO**	**PROCESS & PRODUCT DATA**	**APPLE POMACE STABILISATION DRYING, EXTRUDED SNACKS & NUTRITIONAL POWDER**	**SECRET KNOW-HOW** **PROCESS & PRODUCT**		**VALUE-ADDITION TO FRUIT POMACE (AND SECOND GRADE PRODUCE) AS INGREDIENTS, SNACKS AND SUPLEMENTS**	**BACKGROUND IP WILL BE USED FOR CARROT AND BROCCOLI POMACE STABILISATION ONLY, SUBJECT TO AGREED COMMERCAILISATION TERMS WITH CSIRO. NO RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA IN ANY OTHER POMACE STABILISATION FIELD**
Details of restrictions on use (eg licence conditions, security conditions, encumbrances, confidentiality requirements, including any restrictions on publication of the BGIP/TPIP as part of publication of Project results and use of BGIP/TPIP which is part of Project IP): Processing information and specifications remain confidential secret know-how								
2.	**AUGUST 2016**	**CSIRO**	**CULTURE ,** **PROCESS** **DATA**	**VEGETABLE FERMENTATION CULTURESHIGH SULFUROPHAN LEVELS**	**SECRET KNOW-HOW, PATENT APPLICATION PENDING**		**VALUE-ADDITION TO FRUIT & VEGETABLE POMACE** **HIGH VALUE INGREDIEN**	**NO.** **HIGH SULFORPAHNE FERMENTATION AND CULTURE IP ARE 100% OWNED BY CSIRO, NO**

							TS, SUPPLEMENTS	**RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA** **OTHER CSIRO BACKGROUND IP ON FERMENTATION KNOW-HOW FOR VEGETABLE WILL BE USED FOR BROCCOLLI AND CARROT PUREE ONLY, SUBJECT TO AGREED COMMERCIAISATION TERMS WITH CSIRO. NO RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA IN ANY OTHER CONCENTRATE FIELD**
Details of restrictions on use: Processing information and specifications remain confidential secret know-how								
3.	**MARCH 2016**	**CSIRO**	**PROCESS AND CONDITIONS**	**FERMENTATION IN COMBINATION WITH POST PROCESSING TECHNOLOGY TO REDUCE SUGAR IN VEGETABLE AND FRUIT JUICE AND IMPART FUNCTIONALITY OF PROBIOTICS AND PREBIOTICS**	**SECRET KNOW-HOW, PATENT APPLICATION PENDING**		**PREMIUM FUNCTIONAL BEVERAGES, CONCENTRATES AND POWDERS**	**NO.** **FERMENTATION IN COMBINATION WITH POST PROCESSING TECHNOLOGY FOR SUGAR REDUCTION, PREBIOTICS AND PROBIOTICS IS 100% OWNED BY CSIRO, NO RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA**

4.	**JUNE 2016**	**CSIRO**	**PROCESS**	**CONCETRATION RETAINING FLAVOUR & AROMA VIA FORWARD OSMOSIS WITH DRAW SOLUTIONS**	**SECRET KNOW-HOW** **PROCESS & PRODUCT**		**PREMIUM CONCENTRATES AND BIOACTIVE INGREDIENTS**	**BACKGROUND IP WILL BE USED FOR CARROT AND BROCCOLI CONCETRATE ONLY, SUBJECT TO AGREED COMMERCAILISATION TERMS WITH CSIRO. NO RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA IN ANY OTHER CONCENTRATE FIELD**
Details of restrictions on use: Processing information and specifications remain confidential secret know-how								
5.	**20 JUNE 2014**	**CSIRO**	**PROCESS**		**SECRET KNOW-HOW** **PROCESS & PRODUCT**		**POLYPHENOLIC RICH EXTRACT AND CONCETRATE** **POLYPHENOL RICH APPLE EXTRACT**	**BACKGROUND IP WILL BE USED FOR CARROT AND BROCCOLI CONCETRATE AND EXTRACTS ONLY, SUBJECT TO AGREED COMMERCAILISATION TERMS WITH CSIRO. NO RIGHTS OR OGBLIGATIONS ARE GRANTED TO HIA IN ANY OTHER CONCENTRATE OR EXTRACT FIELDS**
Details of restrictions on use: Encumbrances include, application for apples is assigned to a CSIRO client, and application for olives is pending. Other fruit and vegetable fields are available for development and application.								

Part 2 - Intellectual Property to be developed (Project IP)

PROJECT INTELLECTUAL PROPERTY REGISTER							
No	Date (ie date on which details were initially listed and/or modified)	IP Category (eg plant variety, gene, formulation, software, thesis, report, data etc)	Specific Description of IP	Nature of IP (eg copyright, patent, trade mark, design) and the form in which the IP subsists (eg device, process, formulation, document)	Registration/ application details (if registered) (eg registration number, date of registration and expiry)	Intended purpose and value of the IP that is provided	Contains BGIP and/or TPIP (yes/no) and, if **yes**, description of the BGIP and TPIP
1.	**HIA REPORT 09 JUNE 2017**	**PROCESS**	**DRYING AND EXTRUSION OF BROCCOLI AND CARROT PRODUCTS**	**KNOW-HOW**		**INGREDIENT AND SNACK APPLCIATIONS**	**YES**
Details of restrictions on use of Commercialisation of Project IP (ie restrictions on BGIP and TPIP subsisting in Project IP):							
2.	**HIA REPORT 09 JUNE 2017**	**PROCESS**	**FERMENTATION OF BROCCOLI AND CARROT PRODUCTS**	**KNOW-HOW**		**HIGH VALUE PRODUCTS AND POWDERS**	**YES**
Details of restrictions on use of Commercialisation of Project IP:							
3.	**HIA REPORT 09 JUNE 2017**	**PROCESS**	**CONCENTRATION OF BROCCOLI AND CARROT PRODUCTS WITH FORWARD OSMOSIS**	**KNOW-HOW**		**PREMIUM CONCENTRATES**	**YES**
Details of restrictions on use of Commercialisation of Project IP:							
4.	**HIA REPORT 09 JUNE 2017**	**PROCESS**	**BIOACTIVE EXTRACTS FROM BROCCOLI AND CARROT**	**KNOW-HOW**		**FUNCTIONAL INGREDIENTS AND PRODUCTS**	**YES**
Details of restrictions on use of Commercialisation of Project IP:							
5.							
Details of restrictions on use of Commercialisation of Project IP:							

Acknowledgements

National Vegetable Extension Network (VegNET), East Gippsland Food Cluster

Appendices

APPENDIX 1: Activity 1: Extraction of health promoting components (Confidential)

APPENDIX 2: Activity 2: Processing and formulation of value added products

APPEDNIX 3: Activity 3: Fermentation

APPEDNIX 4: Activity 4: Business development

APPENDIX 5: Activity 5: Stakeholder engagement

APPENDIX 6: Activity 6: Regional manufacturing hubs

APPENDIX 7: Monitoring & Evaluation

Appendix 2: Processing and formulation of value added products

Creating Value from Edible Vegetable Waste

Project VG 15076

Final Report

Activity 2

Processing and formulation of value added products

Client

Horticulture Innovation Australia Limited

Level 8, 1 Chifley Square

Sydney, NSW, 2000

[Insert ISBN or ISSN and cataloguing-in-publication (CiP) information if required]

[CSIRO Agriculture and Food]

Citation

Sanguansri L, Ying DY, Sanguansri P, Cheng LJ, Jegasothy H, Jess Heffernan, McCann Thu and Augustin MA (2018). Creating value from edible vegetable waste: Processing and formulation of value added products. CSIRO, Australia.

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Acknowledgments

This project is funded by Horticulture Innovation Australia Ltd and CSIRO

Executive summary

Fruits and vegetable lost across the whole value chain is estimated at around 45% of production[1]. Most strategies exist in diverting or utilizing this produce into non-food applications e.g. animal food, composting, fertilizer or bioenergy. Limited strategies exist to recover and process the whole vegetable biomass for food applications. The main objective of this project activity is to develop proof of concept products (high-fibre broccoli and carrot based ingredients and products) utilizing the whole vegetable biomass, using drying and extrusion technologies, and stabilizing the biomass from deterioration during processing to retain nutrient quality.

New value added ingredients & products: Broccoli and carrot powders were developed and manufactured using a combination of selected pre-treatments and drying processes to retain the natural colour, flavour and goodness of vegetables. These powders will provide a more convenient vegetable format that is nutrient dense, reduced volume and longer lasting.

The vegetable powders can be added to standard meal preparations to increase vegetable intake or can be used as an ingredient for different food and beverage products such as smoothies, dips, sauces, spreads, soups, gravies, pasta, noodles, bakery products and extruded snacks.

Extruded products containing broccoli and carrot were produced. These products contained 20, 40, 60, 80 and 100% vegetable. The 100% extruded vegetable products can be used as a culinary ingredient in soup premixes or added to your standard meal preparation. The extruded snacks containing minimum 20% vegetable is an ideal convenient or on-the-go healthy snack containing 1 serve of vegetable in a ~40g serve snack pack.

Sensory evaluation and consumer survey: The sensory evaluation (82 consumers) and a separate consumer survey (68 consumers) provided insights into consumer acceptance of the powders and extruded products. The flavoured broccoli and carrot snacks had high consumer sensory acceptance and purchase intent. Consumers have also indicated numerous ways in which they would use the vegetable powders and the extruded products at home to increase vegetable intake. The flavoured broccoli and carrot extruded snack achieved 80 – 90% of consumers "really like or like the product" and also 'intend to purchase' the product if available in the market. The liking was mostly attributed to the crunchiness and flavour of extruded snack. The main reason for their 'intent to purchase' were the 'convenient format" and as a 'healthy snack' alternative.

Bringing the extruder to the farm: The potential to transform vegetable waste into high value nutritional products using a portable small scale extruder was demonstrated via on-farm demonstrations, while engaging farmers and growers in three different locations in Victoria. Three on-farm demonstrations were carried out in total at: Bonaccord, East Gippsland (21 September, 2017); Fresh Select, Werribee South (24 October, 2017); and Taranto Farms, Tyabb (28 March, 2018). A total of 57 local farmers and industry personnel participated in these three on-farm demonstrations. These have given the farmers and growers, processors and consultants in the field an opportunity to see how the extruder works and also for participants to be able to touch and taste the value added products made on-farm.

Pre-commercialisation Activities**:** The team responded to various expressions of interest from growers, processors, food ingredient manufacturers and distributors, and food and beverage companies to access and commercialise the project outcomes. Product specification sheets for the powders and extruded products were developed (Appendix 6.1 and 6.2), and made available to participants of the industry workshops conducted. The prototype products have been showcased at a number of stakeholder meetings, national events, conferences, media interviews and one-on-one potential customer discussions.

1 Introduction

The food loss in Australia's horticultural supply chain from farm to retail is estimated at ~45%[1]. This figure varies depending on type of product. The potential to collect, stabilise and process these losses from both on-farm and post-farm gate may provide opportunity for farmers and processors to get more value from their vegetable produce.

Vegetable growers are often faced with the challenge of how to capture the most value from their crops due to fluctuation of market demands and unpredictable weather patterns. Most strategies exist for diverting or utilizing this produce for non-food applications, e.g. animal food, composting, fertilizer or bioenergy. Limited strategies exist to recover and process the whole vegetable biomass for food applications.

The main focus of this activity is to use the biomass from whole vegetables (broccoli and carrots) or vegetable pomace (a by-product from juice production) for the production of value added nutrient dense ingredients and formulated products. This strategy aims for reducing waste by returning most of the previously under utilised vegetable biomass back into the food supply chain with the least processing steps required.

This activity explored the application of a combination of unit processes used in the food manufacturing industry, e.g. drying and extrusion, to stabilize the vegetable biomass and convert them into new value added ingredients, e.g. powders and extruded products.

Bringing the extruder to the farm (on-farm extrusion demonstration) was another activity that has been done to allow the growers and processors to see, feel and taste the new value added products being developed in this project.

1.1 Aim

To utilise the whole vegetable (broccoli and carrots) in creating high-fibre vegetable-based ingredients which may be formulated into healthy food products.

1.2 Objectives

1) To develop proof of concept products (high-fibre broccoli and carrot based ingredients) using drying and extrusion technologies, with the objective of stabilizing the vegetable biomass and avoid deterioration whilst aiming to retain nutrient quality.
2) To bring the extruder to the farm (on-farm extrusion demonstration) to allow growers and processors to see, feel and taste the new value added products being developed in this project.

2 Materials and Methods

2.1 Raw materials (broccoli and carrots) for processing

Fresh carrots and broccoli used in Trial 1 were purchased directly from a local farmer/packer or from a local supermarket. Diced carrots and broccoli florets used in Trial 2 were purchased from a commercial vegetable processor. For Trail 3, pureed vegetables were purchased from a commercial supplier.

2.2 Processing of vegetables into new product formats

For the carrots the stem and root ends were trimmed. For the broccoli the leaves were removed from the broccoli heads and cut into quarters. Whole trimmed carrots and broccoli heads (leaves removed) were cut into quarters and steam blanched in a combi-oven (Rational Combi-Dämpfer CCC, Germany) with the oven set at 100°C. The vegetables were placed on the perforated trays in a single layer and held in the combi-oven for ~2 min at 100°C, removed from the oven and submerged in ice water, and left until cooled to room temperature (~22°C). The blanched vegetables were then used for preparation of vegetable pomace (removing the juice) or diced before drying.

Different processing options were initially explored in the preparation of stabilised vegetable powders (Figure 1). Different product streams during processing (vegetable source options) were initially trialled for the manufacture of extruded products (Figure 2).

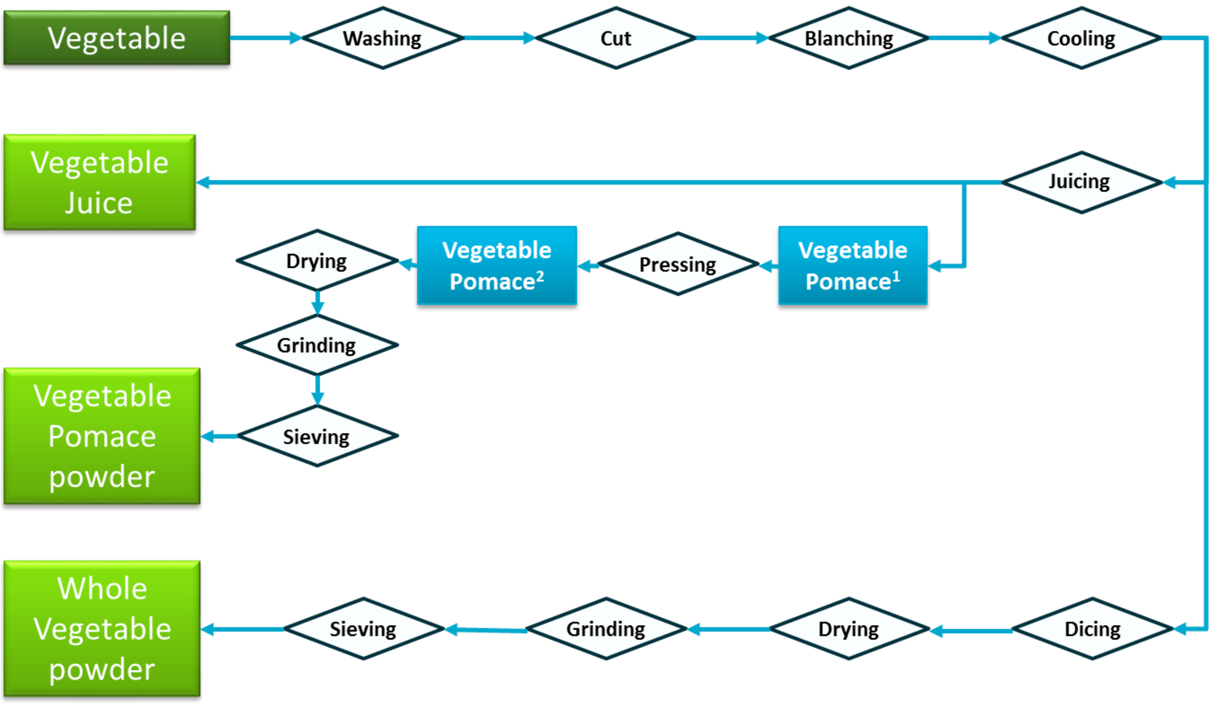

Figure 1 Process flow diagram of laboratory scale processing and stabilisation of broccoli and carrots

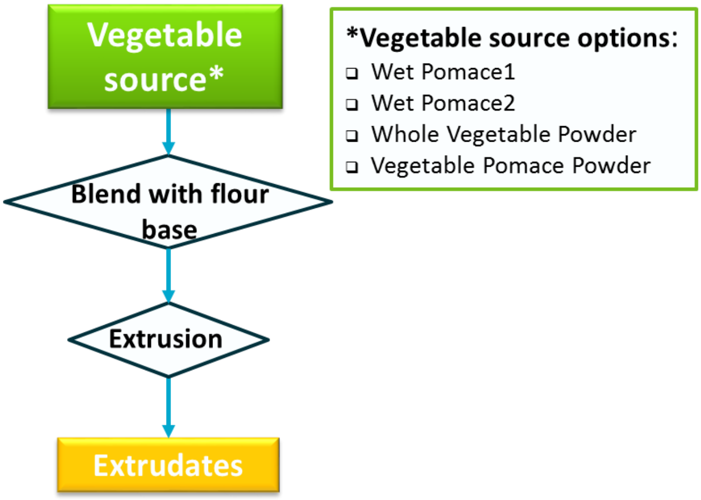

Figure 2 Process flow diagram of laboratory scale production of extruded products containing broccoli and carrots

2.2.1 Vegetable pomace processing and drying

A Nutrifaster Ruby 2000/MKII Juice Extractor (Australia) (Figure 3) was used to remove the juice and obtain vegetable pomace (Pomace1). The pomace from the first juice extraction was collected and transferred into a manual juice press (

Figure 4) to remove more juice and produce a drier pomace (Pomace2). The final vegetable pomace was dried, ground into powder, put through an 800 microns sieve. The powder was packed (500 and 1000 g packs) into triple laminated aluminium foil bags, and stored at 4°C until ready for analysis and for further processing.

Figure 3 First juice extraction for preparation of pomace1

Figure 4 Manual press used for making final pomace2

2.2.2 Whole vegetable powder processing and drying

Three powder production trials were carried out using vegetables pre-processed differently.

In trial 1, blanched vegetables were diced into 1 cm size, using a GEODICER MP-109 Vegetable Slicer (Figure 5). The blanched and diced vegetables were freeze dried, ground into powder, put through an 800 microns sieve. The powder was packed (500 and 1000 g packs) into triple laminated aluminium foil bags, and stored at 4°C until ready for analysis and for further processing.

Figure 5 Machine used for dicing the broccoli and carrots

In trial 2, fresh cut vegetables (sliced carrots and broccoli florets) were purchased from a commercial supplier. The pre-prepared fresh cut vegetables were freeze dried, ground into powder, put through an 800 microns sieve. The powder was packed (500 and 1000 g packs) into triple laminated aluminium foil bags, and stored at 4°C until ready for analysis and for further processing.

In trial 3: commercially processed vegetable purees were purchased from a commercial supplier. The pre-prepared puree was freeze dried, ground into powder, put through an 800 microns sieve. The powder was packed (500 and 1000 g packs) into triple laminated aluminium foil bags, and stored at 4°C until ready for analysis and for further processing.

2.2.3 Drying

Freeze drying trial using commercial operator, Bio-Tech Freeze Drying (26 Parkhurst Dr, Knoxfield VIC 3180, Australia), was mainly used for the production of vegetable powders for extrusion trials and the on-farm extrusion demonstration. The typical freeze dryer is shown in Figure 6.

Figure 6. The freeze dryer

Drum drying trials were conducted using a modified Buflovak lab size double drum dryer (Figure 7) to assess the drying behavior of broccoli and carrot puree into powder. The trials proved the feasibility of drying as a more cost effective option for conversion of broccoli paste or puree after pre-treatment into free flowing powder.

Figure 7. The drum dryer used for the trial

Conventional oven drying was also conducted using a Quantra drying oven (Qualtex Australia P/L) (Figure 8).

Figure 8. The drying oven

2.2.4 Extrusion

Lab-scale extrusion: Lab-scale extrusion trials were carried out using CSIRO Lab-scale Twin-screw Extruder (DSE32-II, Jinan Kredit Machinery Co., Ltd, Shangdong, China) (Figure 9). The temperature profile along the barrel from feed to die were set to 30, 60, 100, 200℃ respectively. The feed rate and screw speed were fixed at 30 kg/hr and 230 rpm, respectively. The dry feed moisture content was adjusted to around 20% (wet basis). The basic screw configuration from feed to the die was built with CE/37.5/37.5/8 and CE/25/45/8 to represent 8 conveying element with 37.5 mm length and 37.5° helix angle and 8 conveying element with 25 mm length and 25° helix angle. The twin screw profile is shown in Figure 10.

Figure 9 Photograph of CSIRO Lab Extruder

Figure 10 Photograph of the twin screw profile

Pilot scale extrusion: A pilot-scale Clextral co-rotating, intermeshed twin-screw extruder (EV32, Firminy, France) (Figure 11), was used for the production of prototype products for sensory trial and consumer evaluation. The extruder barrel temperatures from feed to die were set at 30, 50, 80, 80, 100 and 100 °C for the extrusion of 100% vegetables (broccoli and carrot) and 30, 50, 80, 120, 150 and 150°C for extrusion of 20% vegetables blended with 80% rice flour. The screw profile is listed in the table below (Figure 12). The screw speed was fixed at 350 rpm for all the extrusions and feed rate was fixed at around 25 kg/hr of dry powder blend.

Figure 11. Photograph of CSIRO Pilot Scale Extruder

Design of screw configuration			
Order	Quantity		Component parts
1	11	D	Feed screws
2	4	60°	Forwarding paddles
3	1	D	Feed screws
4	2	D	Single Lead screws
5	4	60°	Forwarding paddles
6	2	D	Single Lead screws
7	5	30°	Forwarding paddles
8	4	30°	Reverseing paddles
9	1	30°	Single Lead screws
10	6	60°	Forwarding paddles
11	5	60°	Reverseing paddles
12	1	D	Single Lead screws- Discharge
Where 1D= 19mm and one paddle length = 0.25 D			

Figure 12. The screw profile for the twin screw extruder

2.3 Analysis of raw materials and processed vegetable products

2.3.1 Compositional analysis

The moisture content of the samples were analysed using standard oven drying method. Briefly, 1 - 2g sample were dried at 105°C oven to a constant weight. The moisture content of the samples was calculated based on the weight loss of the samples before and after drying.

The nutritional composition of all samples were analysed at an accredited analytical laboratory (National Measurement Institute, Port Melbourne) using standard techniques for analysis of food materials and products.

2.3.2 Total polyphenol content - Folin-Ciocalteau method

The total phenolic content was determined using Folin-Ciocalteau method [2]. Briefly, 6g of wet sample or 1.5g of dry powder sample was weighed and put into 100mL glass bottle. 50mL 80% methanol with 1% formic acid in Milli-Q grade water extraction solution was then added. The mixture was placed in a cool room overnight with constant magnetic stirring. The sample was then sonicated for 5min then mixed using ultra-turrax at 16,000 rpm for 1min and left to settle. The supernatant was vacuum filtered through a Whatman medium speed filter paper (e.g. No 2). The residue in bottle was then mixed with 40mL extraction solution and repeated as above. The bottle and filter were rinsed using 10mL extraction solution. The combined filtrate was transferred to a 100ml glass flask and topped up to the mark with extraction solution. The extract was filtered through a 0.22µm filter and stored in 2mL UPLC vials until ready for UV-Vis spectrometer measurement.

A 50µL of sample extract in 2mL UPLC vial was transferred to a 15mL centrifuge tube using a pipette and then added with 250µL of 2N Folin-Ciocalteu reagent and 3.0mL MQ water, vortexed for 10s, then 1mL of 15% Na_2CO_3 solution was added. Finally, the solution was brought up to 5 mL by adding 750µL distilled water and vortexed for another 10s. The mixture was incubated at room temperature for at least 1hr then centrifuged at 10,000g force. A 3mL of supernatant was transferred to a cuvette and the absorbance (ABS) was read at 765nm using a UV-Vis spectrophotometer. The total polyphenol content (TPC) was assessed by the Gallic acid standard ABS – concentration curve. The total phenolic compounds (TPC) was expressed as Gallic acid equivalent (GAE) in µg/g.

2.3.3 Sulforaphane content of broccoli products

The sulforaphane content in broccoli powders was determined by extraction with ethyl acetate [3] followed by UPLC analysis for quantification [4]. To 0.25 g broccoli powder 5 mL millique water was added. The slurry was vortexed for a minute and sonicated in a bath for 5 minutes and the process was repeated one more time. The slurry was then mixed using ultraturrax (Crown Scientific, NSW, Australia) at 13,500 rpm for 2 minutes. Fifteen millilitres of ethyl acetate (Merk, Damstadt, Germany) was added to the slurry, mixed by vortexing and the mixture was shaken at room temperature for 1 hour in a horizontal shaker. It was then centrifuged at 5000*g*, at 10°C for 10 minutes using Sorvall centrifuge (RC-5C Plus, Sorvall Instruments, US) and the ethyl acetate fraction (supernatant) was removed. The extraction was repeated. The two ethyl acetate fractions were combined and dried using SpeedVac Concentrator (SC250EXP, Thermo Scientific, Australia). The dry residue was resuspended in 1 mL of 30% acetonitrile and then filtered with a membrane of 0.2 µm and analysed by Ultra Performance Liquid Chromatography (UPLC). The ACQUITY UPLC system was equipped with binary solvent manager and a PDA Detector (Waters Corp., US). Compounds were separated on a UPLC BEH300, C18, 1.7 µm column (2.1 x 50 mm) fitted with a BEH C18, 1.7 µm VanGuardTM column (2.1 x 5 mm). The column and samples temperature was maintained at 30°C and 10°C, respectively. The analysis was carried out isocratically at flow rate of 0.35 mL/min, employing the mobile phase which consisted of 80% solvent A (0.1% formic acid) and 20% solvent B (0.1% formic acid in acetonitrile). The total run time was 8 minutes. Sulforaphane was detected at 205 nm. An external standard method was used for the determination of sulforaphane. Sulforaphane reference material of high purity (100%) was purchased from Sigma-Aldrich (AU).

For quantification, a calibration curve was constructed by injecting sulforaphane standard solution (0.1 mg/mL in 30% acetonitrile) at different injection volumes (2, 4, 6, 8 µL). The area under the peak is plotted against the quantity (µg) of sulforaphane injected. The slope with the intercept forced through zero was determined by the linear regression model. The SF concentration in the sample was calculated by correlating the SF peak area with the concentrations using the linear regression coefficient shown on the SF calibration curve graph (Figure 13).

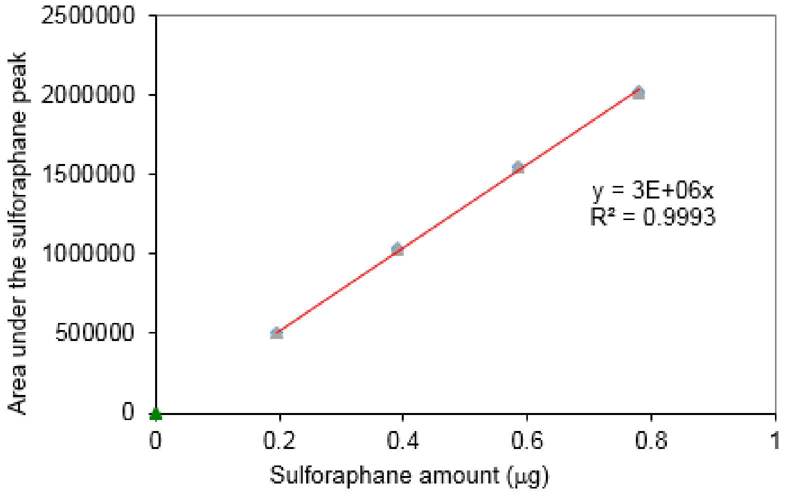

Figure 13. Sulforaphane calibration curve

2.3.4 Total carotenoids content of carrot products

Total carotenoid content was determined using the procedure of Biswas *et al* [(5)]. Carrots were either pureed or dried into powder and passed through a 500um sieve before analysis. Briefly, 0.5g puree or 0.1g powder were weighed into a 20mL glass tube. 5mL of chilled acetone was added and shaken for 15min at 4°C and then vortexed at high speed for 3min. The mixture was centrifuged at 1370g force for 10min. The supernatant was transferred into a 10mL glass flask. The residue was re-extracted with 5 ml acetone followed by centrifugation once again. Both supernatants were pooled and topped up to the mark with acetone, then passed through a 0.45µm syringe filter into a glass cuvette. The absorbance of the extract was determined at 449 nm wavelength in a UV-Vis spectrophotometer. All the extractions were carried out in duplicate. The total carotenoid concentration was determined from a standard curve using β-carotene.

2.3.5 Expansion index of extruded products

Expansion index, is a measure of how much the extruded product was expanded. It was calculated as the ratio of the product diameter over the die diameter. Ten diameter measurements were randomly taken from different sections of the extruded samples with a vernier calliper for each product sample. The average diameter was divided by the die diameter (2 mm) to obtain expansion index.

2.4 Sensory evaluation and consumer survey

The sensory evaluation was conducted to get a quantitative and qualitative assessment of sensory characteristics of the powders as an ingredient and the extruded products. Whereas the consumer survey of the broccoli and carrot snacks was conducted to understand the consumer acceptability of the new vegetable based snacks.

2.4.1 Sensory evaluation

For the sensory evaluation, 100% vegetable powders and 100% extruded vegetable products were presented without flavor addition. For the 20% vegetable snack, both un-flavoured and flavoured options were presented.

Flavor addition to the 20% extruded snack products were explored to improve the sensory profile and acceptability of the snacks. Different flavours that matched the flavour characteristics of broccoli and carrot were evaluated and screened by the team via taste tasting. chilli and garlic flavour was chosen for broccoli snack, and smoked paprika flavor was chosen for carrot snack. A total of 86 consumers were recruited for sensory profile evaluation of all products.

2.4.2 Consumer survey

For the consumer survey only the flavoured snack versions in 5g individual packs were presented for evaluation.

The consumer survey was evaluated by attendees at the Hort Connection 2018, Brisbane and by staff at CSIRO Agriculture and Food, Werribee. A total of 68 consumers participated in the survey.

2.5 Bringing the extruder to the farm

Planning involved preparation of a mind chart which included: health and safety risk assessment to identify potential risk and plan actions to mitigate risks, venue selection (Table 1), transportation of the extruder to the farm, materials and formulations required for the extrusion and other logistics and preparations required for the demonstration.

Table 1. Criteria for the site/venue selection for the on-farm extrusion demonstration

	Requirement	Details
1	Site access	• Existing road access for a **large trailer (2m x 3m) with station wagon**
2	Space	• A clean food processing workshop with a floor space of **(~ 3m x 10m) for a station wagon + trailer** • A large bench (1m x 2m) for temporary laying of extruded product
3	Power supply	• 1 of 3-phase **20A** electric power supply for the extruder; • 1 of 2-phase power supply for water pump
4	Water	• Tap water for cooling • Drink water for product barrel moisture adjustment

3 Results and Discussion

3.1 Proximate composition of fresh whole broccoli and carrots

The gross composition of the broccoli and carrots used in Trial 1 is shown below (Table 2).

Table 2 Typical proximate composition of fresh broccoli and carrots used in the experiments

COMPOSITION	BROCCOLI	CARROT
Moisture (%)	88.5	88.6
Protein (g/100g)	4.6	0.6
Fat (g/100g)	0.7	0.7
Ash (g/100g)	1.1	0.8
Total Carbohydrate (g/100g)	5.1	9.3

3.2 Stabilised powder ingredients from broccoli and carrots

Dried powders from whole vegetables or vegetable pomace were prepared from broccoli and carrots. Compositional analysis of the powders are presented in Table 3 (broccoli) and Table 4 (carrots)

Table 3 Typical nutritional composition of freeze dried broccoli powder and broccoli pomace powder

COMPOSITION	WHOLE BROCCOLI POWDER (TRIAL 1)	BROCCOLI POMACE POWDER (TRIAL 1)	WHOLE BROCCOLI POWDER (TRIAL 2)
Energy (KJ)	1110	1120	1250
Moisture (g/100g)	10.6	7.9	8.7
Protein (g/100g)	30.4	29.2	31
Fat (g/100g)	0.8	2.8	2.9
Ash (g/100g)	9.3	7.4	7.8
Carbohydrate (g/100g)	19.0	15.1	24
- Sugars (g/100g)	18 0	14 0	24
Sodium (mg/100g)	370	280	390
Dietary Fibre (g/100g)	29.7	37.6	26.1

Trial 1 (with blanching before dicing); Trial 2 (fresh cut no blanching).

Table 4 Typical nutritional composition of freeze dried carrot powder and carrot pomace powder

COMPOSITION	WHOLE CARROT POWDER (TRIAL 1)	CARROT POMACE POWDER (TRIAL 1)	WHOLE CARROT POWDER (TRIAL 2)
Energy (KJ)	1220	1220	1280
Moisture (g/100g)	7.3	5.7	6.9
Protein (g/100g)	6.7	6.0	6.3
Fat (g/100g)	0.7	0.8	1.0
Ash (g/100g)	7.4	5.8	6.8
Carbohydrate (g/100g)	51.0	48.9	56
- Sugars (g/100g)	41.0	37	52
Sodium (mg/100g)	980	640	1100
Dietary Fibre (g/100g)	27.1	32.4	23.1

Trial 1 (with blanching before dicing); Trial 2 (fresh cut no blanching).

The broccoli and carrot pomace powders (Trial 1) has lower protein, fat, ash and sugar, but a higher dietary fibre content compared to the whole broccoli and carrot powders (Table 3 and Table 4). The pomace powders has 4% less sugar content than the whole broccoli or carrot powder equivalent, while the dietary fibre content of the pomace powders were 5% and 8% higher than the whole broccoli or carrot powder equivalent, respectively. This is because the soluble components were partitioned into the juice during the preparation of the pomace which is a desirable outcome for a high fibre broccoli and carrot powder base ingredients.

3.3 Effect of processing and drying on selected minor components

Analysis of selected minor components in broccoli and carrots were conducted to see the effect of each unit process applied to the material such as heat treatment, juicing, drying and extrusion was conducted and preliminary results reported below.

3.3.1 *Effect of pre-processing on total polyphenol content (TPC)*

It should be noted that TPC has been used in industry as a rapid measure of total polyphenols. However changes in individual polyphenols and other components can also affect the apparent TPC obtained. Therefore TPC data obtained in these experiments have to be treated with caution and only used as a guide to process-induced changes. The measured TPC using this method can be influenced by the type of polyphenol present and cannot be directly related to the absolute polyphenol content of various products. For validation of absolute changes in polyphenol and quantification of each polyphenol, it will be necessary to do HPLC analysis or LC-MS.

The total polyphenol content (TPC) of the fresh broccoli was 4519 µg/g GAE (dry basis) (Figure 14). The TPC of the whole broccoli after blanching was 6107 µg/g GAE (dry basis). The increased TPC is likely due to the breakdown of plant cell wall structure after blanching, which made polyphenol more extractable for analysis. Broccoli pomace had a lower TPC than the whole broccoli, which is likely due to some of the polyphenol being partitioned into the juice. Dried powder (either whole broccoli or broccoli pomace) had a lower TPC than their corresponding material before drying. This may be attributed to the degradation or conversion of polyphenols during the drying process or changed binding of polyphenols to the matrix, which affected extractability with a solvent. Extrusion also caused a marked reduction in TPC, which could be due to loss in TPC during extrusion or binding of polyphenols to the matrix making it less extractable for analysis. Carrot followed a similar trend on the effect of pre-processing on TPC for the broccoli but with lower value overall (Figure 14).

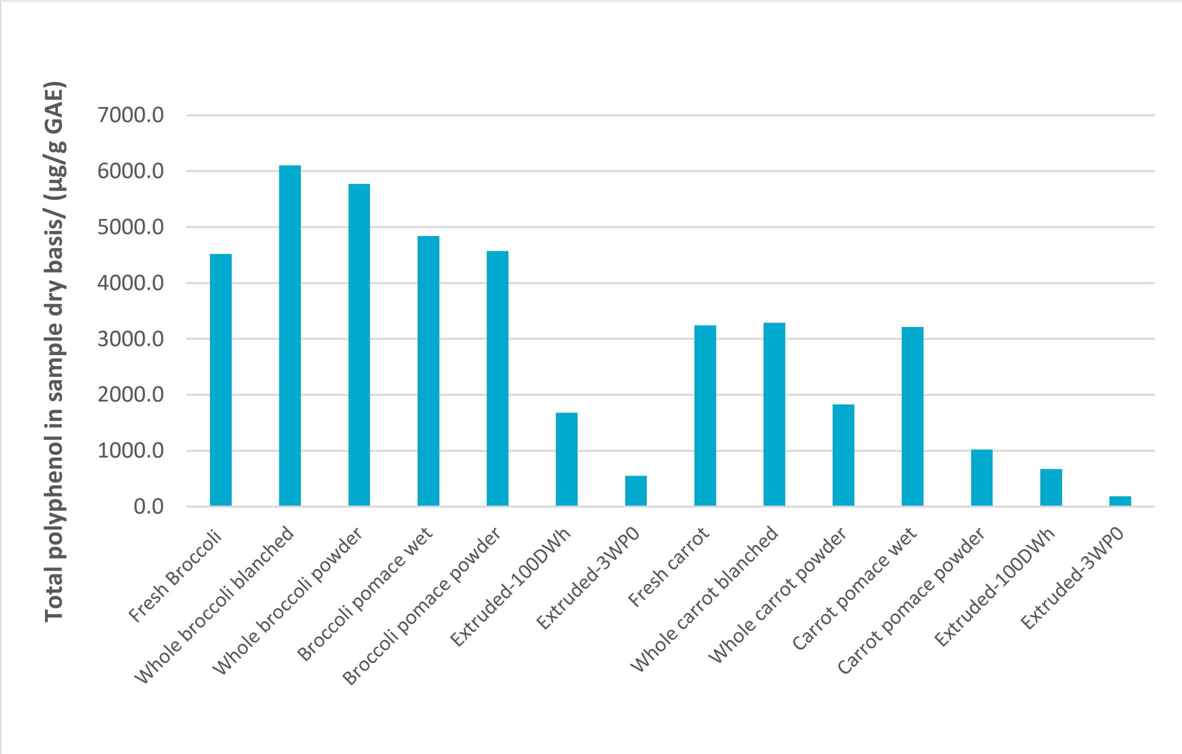

Figure 14. Total polyphenol content of broccoli and carrots before and after processing

3.3.2 *Effect of pre-processing on total carotenoids content*

Carrots is a rich source of carotenoids. Fresh carrot had 6574 µg/g (dry basis) of β-carotene equivalent (Figure 15). Blanching showed a significant loss in the carotenoid content measured at 3767 µg/g (dry basis) (Figure 15). Most of the loss in carotenoids were observed after heat treatment of the vegetables. There are some loss of carotenoids in broccoli during drying. With carrots, there appeared to be no loss but it is possible that the observed value is due a combination of carotenoids and brown Maillard products (which are co-extracted) which are formed due to the high sugar content of the carrots. Differences in the observed stability of carotenoids (using the method described) could also be due differences in the stability of the individual carotenoids present in broccoli and carrots. The stability can also be mediated by the inherent differences in the properties of different vegetable matrices, especially the sugar content of the vegetables.

The carrot pomace collected after juicing showed that most of the carotenoids partitioned into the pomace with carotenoid content being 6062 µg/g (dry basis). However after freeze drying the carrot pomace, the amount of carotenoids was reduced to 754 µg/g (dry basis).

The observation that apparent total carotenoid is not lost during freeze drying of blanched whole carrot and the significant loss in carotenoids in freeze dried carrot pomace warrant further investigation. It appears that soluble components removed during the juicing process for the production of pomace may have a significant effect on the analysis, or that carotenoids left in the pomace were less extractable.

For the extruded products (100% carrot powder) there was no further loss in carotenoids during processing. However in extruded snacks (3% vegetable powder) carotenoids were reduced during extrusion. The result from the broccoli samples followed a similar trend (Figure 15). Binding of carotenoids during processing requires further investigations whether this can affect shelf stability and bioavailability.

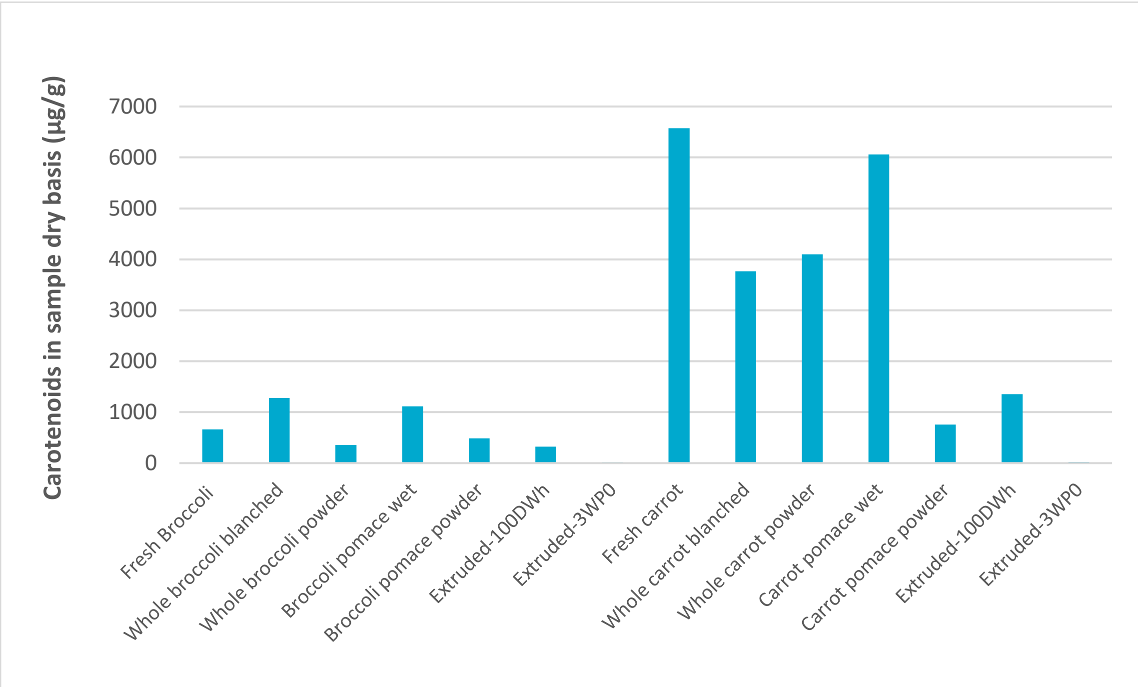

Figure 15. Carotenoids content of broccoli and carrots before and after processing

3.3.3 *Effect of extrusion and drying of SF*

The results below (Figure 166) clearly show the loss in SF during extrusion and subsequent drying of extruded products containing 100% and 20% broccoli powder. This is most likely due to exposure of the material to high temperature during extrusion process.

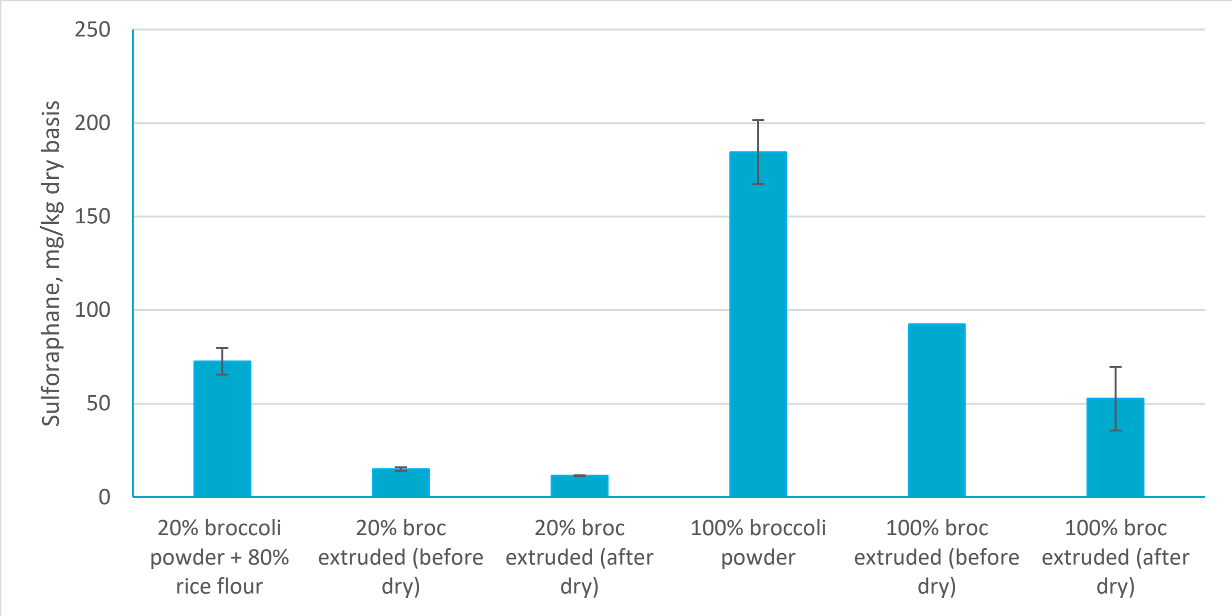

Figure 166 SF content in 20% broccoli powder and 80% rice flour blend before extrusion, after extrusion (before drying) and after drying the final extrudates.

3.3.4 Drying trials

In initial powder production trials (Trials 1 & 2) broccoli and carrots were freeze dried after heat treatment then ground into powders. In Trial 3, other drum drying option were explored as an alternative and more cost effective process compared to freeze drying. Broccoli and carrot puree were prepared after pre-treatment, and drum drying trials were conducted to assess its drying behavior. The drum drying trial was successful for conversion of broccoli and carrot puree into powder (Figure 17) and the powders can be ground to specification. Total polyphenol content of drum dried broccoli powder was 8,880 µg/g (dry basis) and the TPP content of the fresh broccoli before processing was 8,090 µg/g dry basis. Total polyphenol content of drum dried carrot powder was 2,030 µg/g (dry basis) and the TPP content of the fresh carrots before processing was 2,570 µg/g dry basis. Further trials is needed to optimize the drying condition.

Figure 17. Drum dried broccoli (left) and carrot (right) powders

3.4 Extruded broccoli and carrot product using wet vegetable pomace

The carrot and broccoli pomace obtained from the first juice extraction (Pomace 1: 10% TS for broccoli and 12% TS for carrot) was used for the first extrusion trial. To obtain 20% moisture content of the dry feed (mixture of wet pomace and rice flour) 10% of wet pomace (~12%TS) was blended with 90% of rice flour. The formulation resulted in a ~2.5% (dry basis) equivalent of vegetable incorporation in the final extruded snack.

The vegetable pomace obtained from the second juice extraction (Pomace 2: 13% TS for broccoli and 14% TS for carrot) was used in the second extrusion trial. This was an attempt to increase the amount of carrot or broccoli in the final extruded products. A pre-mix containing 15% wet pomace and 85% rice flour was used for the second extrusion trial. Adding 15% of wet pomace in the formulation achieved an equivalent of ~3% (dry basis) vegetable incorporation in the final extruded snack.

The first two initial trials were aimed at delivering the wet vegetable biomass in a rice flour based expanded snack to eliminate the need for drying the vegetable biomass thereby reducing cost of processing. However this strategy could only achieved addition of 10-15% wet weight in formulation. This level of vegetable addition (2.5 - 3% dry basis) in extruded vegetable snacks is equivalent to what is currently available in the market.

3.5 Extruded broccoli and carrot products using whole vegetable powders

The stabilised broccoli and carrot powders was used for the third extrusion trial. The dry feed formulation was prepared by dry blending the freeze dried whole vegetable powder and rice flour prior to extrusion. The vegetable powder to rice flour ratio were: 100:0, 80:20, 60:40, 40:60, 20:80, 0:100. A more detailed formulation is shown in Table 5. Photos of the extruded products containing different levels of broccoli or carrot powders is shown in Figure 18.

Table 5. Formulation of the extruded prototype products containing 20% to 100% broccoli or carrots

Sample Code	Freeze dried vegetable powder (%)	Rice flour (%)	$CaCO_3$ (%)	NaCl (%)
Broccoli samples	**Broccoli powder**			
Extruded-20DWh	20	78.5	1	0.5
Extruded-40DWh	40	58.5	1	0.5
Extruded-60DWh	60	38.5	1	0.5
Extruded-80DWh	80	18.5	1	0.5
Extruded-100DWh	98.5	0	1	0.5
Carrot samples	**Carrot powder**			
Extruded-20DWh	20	78.5	1	0.5
Extruded-40DWh	40	58.5	1	0.5
Extruded-60DWh	60	38.5	1	0.5
Extruded-80DWh	80	18.5	1	0.5
Extruded-100DWh	98.5	0	1	0.5

100% broccoli powder	80% broccoli powder	60% broccoli powder	40% broccoli powder	20% broccoli powder
				
100% carrot powder	80% carrot powder	60% carrot powder	40% carrot powder	20% carrot powder
				

Figure 18 Extruded products with 20% to 100% carrots or broccoli powders

3.5.1 Physical characteristics of prototype extruded products containing broccoli and carrot powder ingredients

The expansion index is a measure of the density and texture of the final extruded product. A higher expansion index relates to higher sample porosity which results in a more crunchy texture.

The expansion index of extrudates with added wet vegetable pomace (2.5 – 3% dry weight) in the first and second extrusion trials were 5.05±0.24 and 4.83±0.31 respectively for carrots and broccoli. These were slightly lower than the expansion index for 100% rice flour of 5.38±0.11.

The extrudates containing broccoli or carrot powders had a significant decrease in product expansion (Figure 19) as the amount of vegetable powder in the final product increased. The decrease in expansion index from 5.5 to 1.5 directly correlated with the amount of broccoli or carrot powders added from 20% to 100% in the final extruded product (Figure 19). This is due to the reduction in starch content and increased fibre content in the formulation as the vegetable powder replaced the rice flour in the formulation.

Further work is required to optimise formulation and the extrusion processing conditions to achieve extruded product characteristics e.g. optimum expansion index that correlates well with acceptable sensory properties.

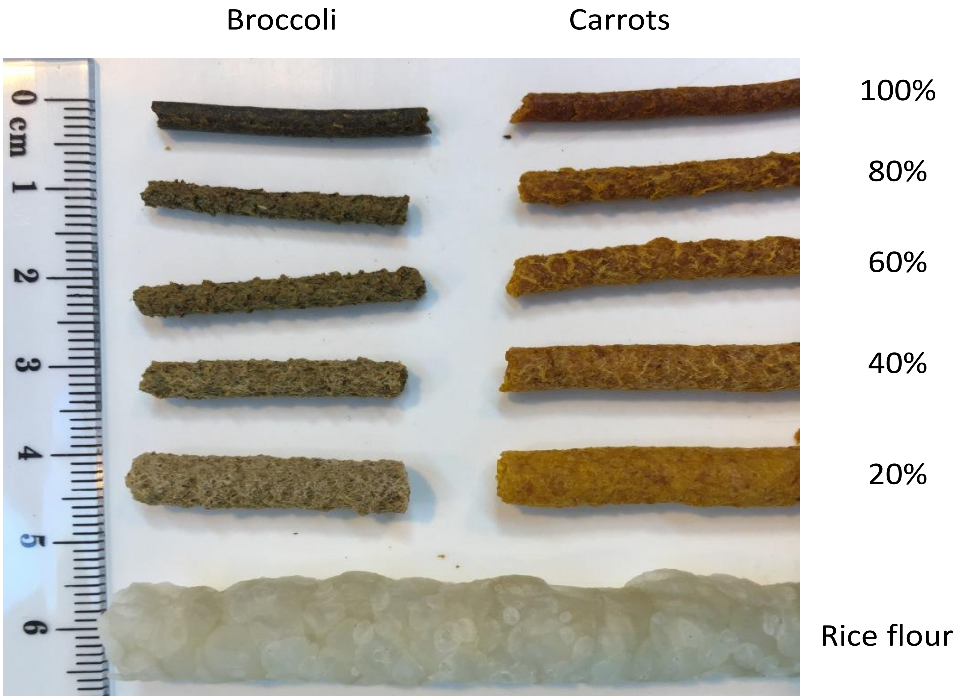

Figure 19 Close up photographs of extrudates containing 20-100% carrots and broccoli powders in comparison with the extrudates of rice flour without vegetable powders added

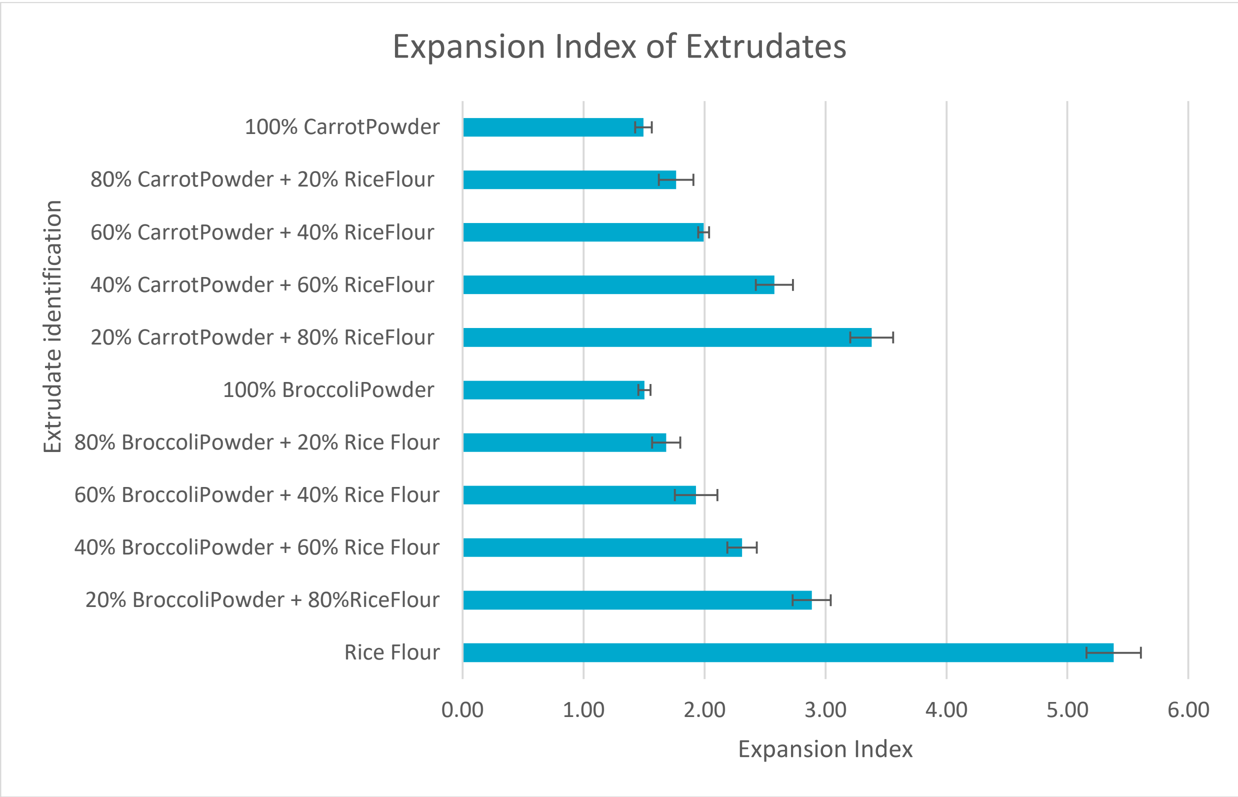

Figure 19 Expansion index of the extruded prototype products

3.6 Nutritional composition of extruded products containing broccoli and carrots

The nutritional information panel for two prototype extruded snacks containing whole broccoli and carrot powders is shown in Table 6, and for prototype products containing broccoli and carrot pomace is shown in Table 7.

Table 6 Nutritional composition of extruded products containing broccoli and carrot powder ingredients (100% or 20% vegetable powder content in final product)

COMPOSITION	100% BROCCOLI EXTRUDATE	20% BROCCOLI SNACK	100% CARROT EXTRUDATE	20% CARROT SNACKS
Energy (KJ)	1230	1520	1260	1530
Protein (g/100g)	29.9	13.2	4.3	7.6
Fat (g/100g)	3.5	1.5	1.3	0.9
Ash (g/100g)	7.4	3.3	6.5	3.1
Carbohydrate (g/100g)	23.0	70.0	56.0	78.0
- Sugars (g/100g)	*12.0*	*4.1*	*47.0*	*11.0*
Sodium (mg/100g)	58	200	1000	420
Dietary Fibre (g/100g)	24.8	6.8	23.7	4.7

Broccoli powder and carrot powder used was from Trial 2.

Table 7 Nutritional composition extruded snacks containing broccoli pomace and carrot pomace (3% vegetable powder content in final product)

COMPOSITION	SNACK WITH BROCCOLI POMACE	SNACK WITH CARROT POMACE
Energy (KJ)	1640	1640
Protein (g/100g)	8.10	8.80
Fat (g/100g)	0.90	0.90
- Saturated (g/100g)	*0.20*	*0.20*
Ash (g/100g)		
Carbohydrate (g/100g)	86	86
- Sugars (g/100g)	*1.0*	*<1.0*
Sodium (mg/100g)	20	10
Dietary Fibre (g/100g)	1.4	<0.5

[Note: Vegetable pomace was collected after juicing (Pomace 2) from Trial 1 was used for these formulations]

3.7 Analysis of total polyphenols from powders and extrudates during storage

Dried powders from Trial 2 prepared from whole broccoli and carrots, and extruded products were packed in aluminium foil bags and stored at 25°C and 40°C. Sample were taken at T=0 and at 3 months interval and stored at -18°C until ready for analysis. Total polyphenol content of samples were analysed using Folin-Ciocalteau method. Results are shown in Table 8 for broccoli powder and extrudates and in Table 9 for carrot powder and extrudates.

Table 8. Total polyphenol content of broccoli powders and extrudates after 12 month storage (µg/g GAE)

	T=0	T=3M	T=6M	T=9M	T=12M	TPP %CHANGE AT 12M
			Broccoli powder			
25°C	*8547.8*	*7759.7*	*7524.0*	*7339.*	*7931.9*	*93%*
40°C	*8547.8*	*9017.6*	*10225.5*	*10904.3*	*9893.0*	*116%*
			100% broccoli extrudates			
25°C	*15390.0*	*n/a*	*n/a*	*13899.6*	*11718.5*	*76%*
40°C	*15390.0*	*n/a*	*n/a*	*17583.1*	*14931.3*	*97%*
			20% broccoli extrudates			
25°C	*2814.7*	*n/a*	*n/a*	*2221.1*	*2029.6*	*72%*
40°C	*2814.7*	*n/a*	*n/a*	*3743.1*	*3318.5*	*118%*

Table 9. Total polyphenol content of carrot powders and extrudates after 12 month storage (µg/g GAE)

	T=0	T=3M	T=6M	T=9M	T=12M	TPP %CHANGE AT 12M
			carrot powder			
25°C	*1099.3*	*1138.1*	*1225.4*	*1603.6*	*1247.9*	*114%*
40°C	*1099.3*	*2108.0*	*2588.9*	*2939.3*	*2082.7*	*189%*
			100% carrot extrudates			
25°C	*3086.3*	*n/a*	*n/a*	*5692.6*	*2492.3*	*80.8%*
40°C	*3086.3*	*n/a*	*n/a*	*3141.1*	*4761.1*	*154%*
			20% carrot snacks			
25°C	*1221.1*	*n/a*	*n/a*	*1081.8*	*1340.7*	*110%*
40°C	*1221.1*	*n/a*	*n/a*	*1661.5*	*1178.2*	*96%*

There is no clear trend in the results of total polyphenol content analysis for broccoli powder and extrudates (Table 8), and for carrot powder and extrudates (Table 9). These results need to be interpreted with caution and should be verified using HPLC method to quantify the individual polyphenols and understand which polyphenols are decreasing or increasing and what new compound are being formed during storage, which reacts with the Folin reagent resulting in increased total polyphenol content. During storage at 40°C some Maillard reaction products are expected to be formed which may have resulted in the increase. Gan et al 2017 reported that drying of mung beans at 60 – 80 °C increased formation of Maillard reaction products responsible for the increase in total polyphenol contents and antioxidant capacity. Folin-Ciocalteau method used as a quality control measure for TPP content of vegetable powders may not be the best method for assessing quality during storage. Further work is needed to develop more accurate quantification of polyphenols, and alternatively a rapid non-destructive method should be explored.

3.8 Product development

The blend of dry ingredients used in the extrusion trials had no added flavours or additives, and mainly contained the vegetable powder or blended with a rice flour to increase expansion of the final vegetable snack product. Flavor addition to the basic extruded snack products were explored to improve the sensory profile and acceptability of the snacks. Different flavours that matched the flavour characteristics of broccoli and carrot were sourced from different commercial flavor supplier. The flavoured snacks were evaluated and screened by the team via sensory tasting. Chilli and garlic flavour and cheddar cheese flavor was chosen for broccoli snack, and smoked paprika flavor was chosen for carrot snack. The flavoured snacks were most preferred by consumers compared to the unflavoured versions previously presented in the initial survey.

3.9 Consumer Survey

The flavoured broccoli and carrot snacks were prepared and presented for tasting at several industry meetings and conferences, e.g. at the Industry engagement workshop (10th May 2018), the Hort Connections (18-20 June, 2018), AIFST (11-12 September, 2018), Vegetables WA Industry Summit (27 October, 2018). The consumer survey was collected from 68 volunteers who participated the survey mainly during Hort Connections (June 2018, Brisbane) and CSIRO Connect (Melbourne)

3.9.1 Flavoured vegetable extruded snack:

The number of liking and the interest to purchase was counted from the responses of the survey. The degree of liking was separated into 5 categories including ‘really liked’, ‘liked’, ‘didn’t like’, ‘really didn’t like’ and ‘unsure’. Likewise, the ‘interest to purchase’ was classed as ‘very’, ‘somewhat’, ‘not’, ‘not at all’ and unsure. The result of survey presented in Figure 20 is expressed as the percentage of each category, which was calculated as the number of each category per the total responses.

Result from Figure 20 showed that both flavoured broccoli and carrot extruded snack achieved 80 – 85% in the liking and the ‘interest to purchase’ from consumers, only 10 – 17% did not like and was not interested to buy and around 3% consumer could not make a decision. The liking was mostly due to the crunchiness and flavour of extruded snack. The dislike was mostly due to the shape/appearance of the broccoli extruded snack whilst the saltiness was highlighted for the dislike with the carrot extruded snack. The ‘interest to purchase’ was mostly due to ‘healthy snack’ or for ‘convenient’.

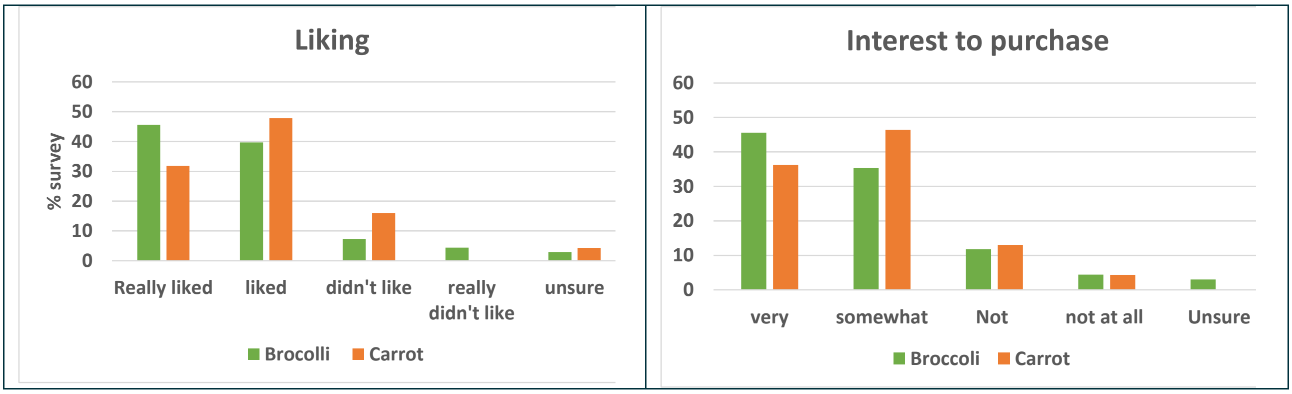

Figure 20: Consumer survey result of flavoured vegetable extruded snack

The consumer survey has demonstrated the acceptance of consumers (80-85%) on the new vegetable snack products developed from vegetable powder from imperfect vegetables. Largely consumers expressed their liking because of the crunchiness of extruded vegetable snack. Most of consumers expressed their interest to buy those products as it was a healthy alternative option for snack or to achieve a serve of vegetable per serving. The result of the survey confirmed a potential to use the broccoli or carrot powders as an ingredient for developing a healthy food. A more detailed report is in Appendix 6.3.

3.10Sensory Evaluation

New vegetable based powders and extrudates from broccoli and carrots were manufactured for sensory evaluation. These new vegetable based products include: 100% Australian broccoli and carrot powders, 100% broccoli and carrot extrudates and 20% broccoli and carrot snacks.

A total of 82 consumers participated in a consumer test of the vegetable powders and extrudates to gain insight into consumer acceptance of these new products. Each product was evaluated on its own for liking overall and several specific modalities (appearance, flavour and texture) using the 9-point hedonic scale, and were rated for specific sensory attributes using just-about-right scales. Consumers also assessed the suitability of the products for different applications. For each product category, the two flavour variants were assessed and a number of commercial benchmark snacks were also tested for comparison with the 20% vegetable extrudates. Summary of overall results for each product category are outlined below. A more detailed report is in Appendix 6.4.

Vegetable powders:

- *Overall liking* was higher for the broccoli powder than the carrot powder. Broccoli powder scored just above the neutral point, and carrot powder just below the neutral point for *liking*.
- *Overall*, both samples largely met the consumer ideal for *texture* attributes. Lower *liking* of the carrot sample was mainly related to its *flavour* profile, which was deemed *too intense, slightly too bitter* and not *salty enough*.
- Purchase intent was positive for the powders, with approximately 50% of consumers indicating that they *probably*, or *definitely would buy* them.

- Consumers indicated that they would use the 100% vegetable powders to add to dips, spreads, soups and pasta dishes and to make meals more interesting by adding new flavours.

100% vegetable extrudates:

- *Overall*, consumers *liked* the 100% carrot extrudates significantly more than they did the 100% broccoli extrudates, however, they both scored quite low on the 9-point hedonic scale (<5).
- Both samples did not meet the consumer ideal for *flavour* (too *intense* and suboptimal *sweetness*), and the broccoli also did not meet consumer ideal for *appearance* and *texture (*too *crunchy)*
- Results of purchase intent were mixed, with 40% of consumers each indicating that they *probably* or *definitely would*, and *probably* or *definitely would not* buy the vegetable extrudates.
- The majority of consumers found the broccoli (74%) and carrot (55%) extrudates to be *too small* as a snack but just right as a topping (59% and 45%, respectively). Consumers indicated that they would use the 100% vegetable extrudates as a healthy snack option (54%), or alternative to chips (44%) or other snacks (44%) and to make meals more interesting by adding new textures and flavours (48%)

20% vegetable snacks:

- The flavoured vegetable extrudates were *liked* more than the unflavoured extrudates. With the flavoured extrudates, the flavoured carrot was *liked* more than the flavoured broccoli.
- Flavoured carrot had a relatively high score on the 9-point hedonic scale (>7) showing high *overall liking* by consumers. It was equally preferred to the commercial benchmark Harvest Snap Peas and higher than the commercial benchmark Organix Carrot Stix. Flavoured broccoli, although slightly lower in *liking* (5.5), was still on par in liking with the commercial benchmark Organix Carrot Stix.
- Flavoured carrot had good sensory appeal in all modalities, where flavoured broccoli was too *intense* in *flavour*.
- As a snack, the *size* of the extrudates were found either *just right* or *slightly too small,* whereas as a topping there were *slightly too big*.
- Purchase intent was largely positive among consumers with 59% indicating that they *probably* or *definitely would buy* them.
- The most common uses that consumers had for the 20% extrudates were as a healthy snack option (79%) or as an alternative to chips (77%) and other snacks (71%).

This result of the sensory evaluation from consumers provides insights into the relative consumer acceptance of the vegetable extrudates and powder. The 20% flavoured extrudates had good consumer sensory acceptance and purchase intent, with the flavoured carrot sample scoring similarly or higher than the commercial benchmarks. Consumers have also indicated numerous ways in which they would use them at home, including, but not limited to, as a healthy snack alternative. As taste is of critical importance to consumer choice for snacks, overall results indicate good commercial potential for 20% flavoured extrudates.

The vegetable powders scored above the neutral point for their *overall liking* and also had a positive response to purchase intent. As these products are ingredients to add to other foods and not stand-alone foods (like snacks) the slightly lower liking ratings should not be seen as problematic.

Both vegetable powders and extrudates seem to have potential to further develop for commercialisation, in particular the broccoli powder and the flavoured 20% vegetable extrudates.

3.11 Bringing the extruder to the farm – On-farm demonstration

Three locations were selected with the help of Shayne Hyman, Clinton Muller, Carl Larsen and Deb Krause. First two on-farm demonstration were conducted in 2017 and reported in Milestone 3: (i) Bonacord, East Gippsland (20th September 2017) and (ii) Fresh Select, 610 Duncan Road, Werribee South (24th October 2017). The third on-farm extrusion demonstration was conducted at Taranto Farms, 57 the Crescent, Tyabb (28th March 2018).

In order to transport the extruder to the farm, a trailer was fitted with a timber frame (Figure 21). The extruder was then mounted on the timber frame (Figure 22) to avoid moving around during transportation. The extruder was wrapped in plastic to make it safe during transport and protect from rain (Figure 23), then connected onto the trailer mount behind a station wagon and transported to each site selected for demonstration (Figure 24). On arrival at the site the extruder was set-up and connected to power and water supply (Figure 25). The extruder was then set-up and tested before each of the demonstration (Figure 26).

A forum was carried out after each of the demonstration to provide an opportunity for participants and CSIRO to openly discuss the next steps and whether there is a real opportunity for commercialization around raw material supply, processing facility and market demands. The participants expressed that it was great to see the demonstration of the extrusion process which allowed them to get an idea of what the equipment looks like, noise levels, how it might fit into a packing line and a sense of the product it produces.

Product information flyers were made available to all participants, and prototype product samples were also available for tasting. Positive feedback was received during each of the event.

Figure 21 A trailer was fit with a timber frame

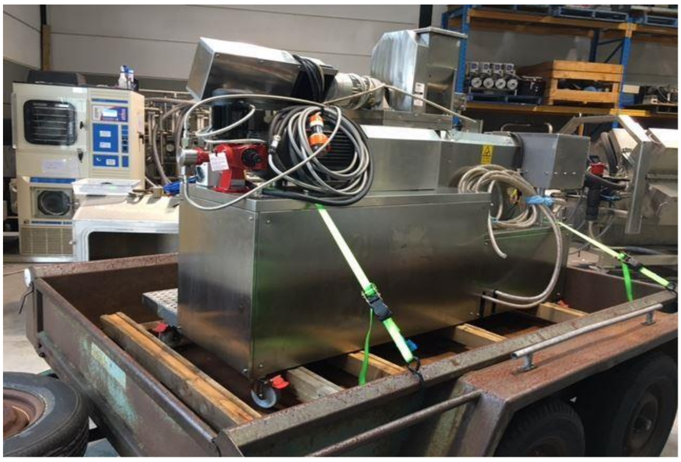

Figure 22 The extruder was seated on the timer frame to avoid moving around during transportation.

Figure 23 The extruder was rapped with plastics to make it weather tight during transportation

Figure 24 The extruder is ready to transport to site of demonstration

Figure 25 Extruder is set up on arrival at the site and connected to power and water supply.

Figure 26. The extruder was set up and ready to run at (left), and extruder being tested before the demonstration (right).

3.12 Pre-commercialisation activities

Product specifications and flyers were prepared for each product (see Appendix 6.1 and 6.2). These new products specifications were made available to all participants of the industry engagement workshops and the on-farm extrusion demonstrations.

A number of companies expressed interest in the commercialisation of the ingredients (powders and extrudates) or products using the broccoli and carrot powders.

We have identified that a pilot scale pre-commercialisation production facility be made available or accessible to assess market size and capacity required for a commercial scale manufacturing plant, in order to de-risk future capital investment in a commercial scale manufacturing plant consisting commercial dryer and extruder. CSIRO Food Innovation Centre at Werribee has a pilot scale processing equipment that could assist companies in pre-commercialisation activities and initial product launches.

The initial BMC prepared (Figure 28) remains current until new business model for commercialisation is finalised.

(Note: commercialisation activities and technology transfer is outside the scope of this project.)

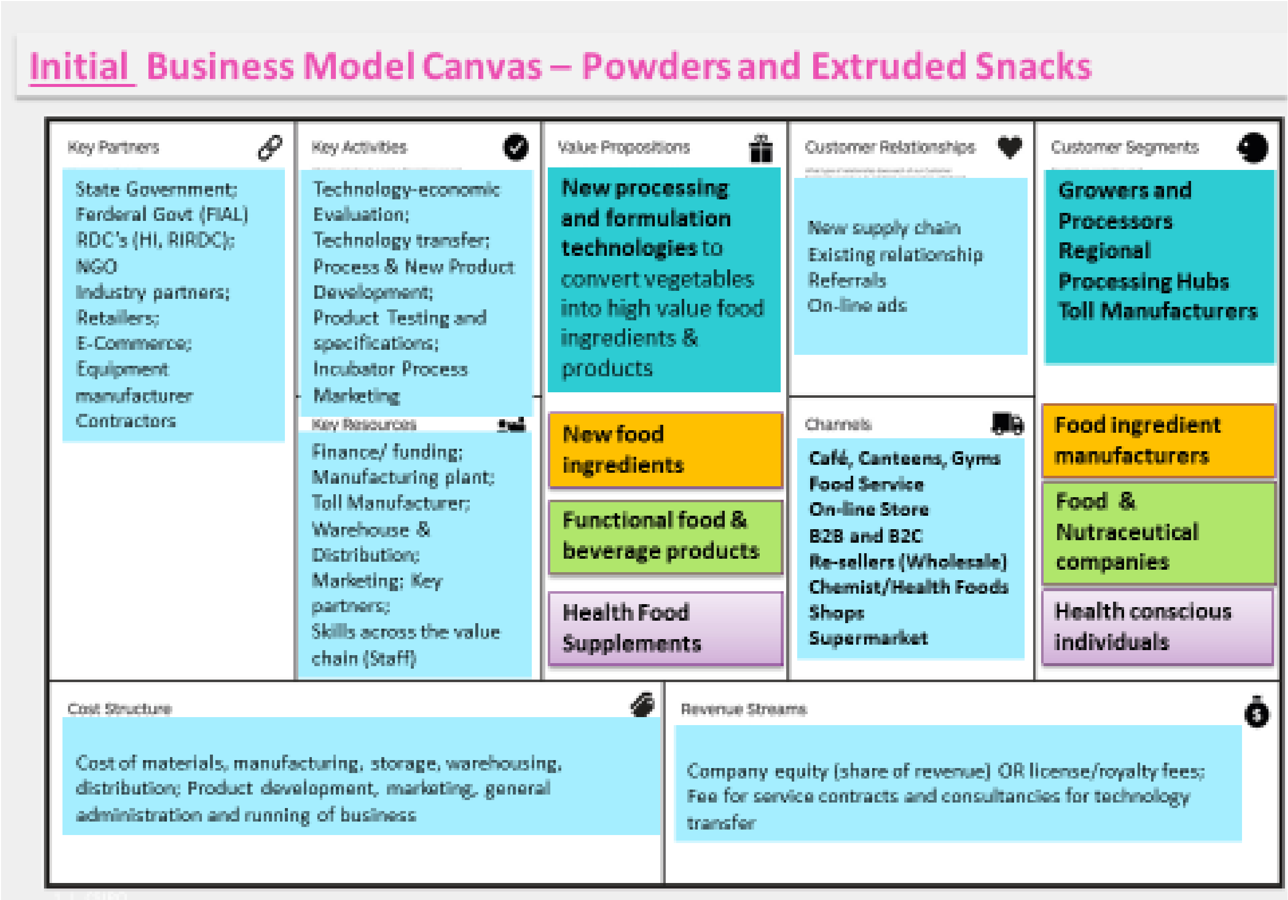

Figure 27. Business Model Canvas

4 Conclusions

Steam blanching and freeze drying was successfully used to stabilise and manufacture prototype powder ingredients from broccoli and carrots for completed activities during this reporting period. The use of wet broccoli and carrot pomace resulted in low level incorporations of ~3% in extruded formulations. However, incorporation of powder ingredients (whole vegetable powder and vegetable pomace powder) resulted in extruded prototype products with up to 100% of vegetable powder.

As a first attempt to produce prototype extruded products, the incorporation of both the wet broccoli and carrot pomace and the powder ingredients (whole vegetable powder and vegetable pomace powder) in extruded product formulations was considered a success. The physical characteristics of the extrudates were deemed acceptable, but further optimisation of the formulation and extrusion process conditions is required to achieve improved product characteristics while maintaining the retention of nutrients in the final product suitable for commercial product demonstration.

Three on farm extrusion demonstrations were carried out successfully. The growers felt it great to see the demonstration of the extrusion process and allowed the growers to get an idea of what the equipment looks like, noise levels, how it might fit into a packing line and a sense of the product it produces.

Seven companies expressed interest in the commercialisation of the ingredients (powders and extrudates) or products using the broccoli and carrot powders.

We have identified that a pilot scale pre-commercialisation production facility be available or accessible to assess market size and capacity required for a commercial scale manufacturing plant, in order to de-risk future capital investment in a commercial scale manufacturing plant consisting commercial dryer and extruder. CSIRO Food Innovation Centre at Werribee has a pilot scale extruder but will required a pilot scale dryer to be able to assist companies in pre-commercialisation activities and initial product launches.

5 References

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6 Appendices

APPENDIX 6.1: Broccoli products specifications

APPENDIX 6.1.1

100% Broccoli powder specifications

We have developed a process for transforming fresh broccoli into a shelf stable, nutritious, functional ingredient ready-to-go for commercialisation.

CSIRO's food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh broccoli into a shelf stable, safe, nutritious, functional ingredient.

Our 100% broccoli powders are made from whole broccoli, and produced using a combination of selected pre-treatment and drying process to retain the natural colour, flavour and nutrient composition of fresh broccoli.

Our 100% powders can be added to your standard meal preparations to increase your vegetable intake or can be used as an ingredient for different food applications such as smoothies, dips, sauces, spreads, soups, gravies, pasta, noodles, bakery products and extruded snacks.

Features

- 100% broccoli
- No added additives
- Excellent source of protein and fibre
- 1 serve of broccoli in 7.5g powder

Nutritional Composition

Composition	g/100 g
Energy (KJ)	1250
Protein (g/100g)	30.4
Total Fat (g/100g)	0.8
Ash (g/100g)	9.3
Carbohydrate (g/100g) *- Sugars (g/100g)*	19.0 *18.0*
Dietary Fibre (g/100g)	29.7

APPENDIX 6.1.2

100% Extruded broccoli specifications

Value added shelf stable, nutritious, high fibre extruded broccoli product made from 100% broccoli

CSIRO's food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh broccoli into a shelf stable, safe and nutritious ingredients and products.

Our 100% extruded broccoli is made from whole broccoli, and produced using a combination of selected pre-treatment, drying and extrusion process to retain the natural colour, flavour and nutrient composition of fresh broccoli.

Our 100% extruded broccoli can be used as a culinary ingredient, in soup premixes or added to your standard meal preparations to increase your vegetable intake.

Features

- 100% broccoli
- No added additives
- Excellent source of protein and fibre
- 1 serve of broccoli in 7.5g extruded product

Nutritional Composition

Composition	**Per 100 g**
Energy (KJ)	1230
Protein (g/100g)	29.9
Total Fat (g/100g)	3.5
Ash (g/100g)	7.4
Carbohydrate (g/100g) - *Sugars (g/100g)*	23.0 *12.0*
Dietary Fibre (g/100g)	24.8

APPENDIX 6.1.3

20% Broccoli snacks specifications

Shelf stable, nutritious ready to eat vegetable snacks

CSIRO's food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh broccoli into a shelf stable, safe, nutritious, functional ingredients and products.

Our extruded snacks contains at least 20% broccoli and produced using a combination of selected pre-treatment, drying and extrusion process to retain the natural colour, flavour and nutrient composition of fresh broccoli.

Our 20% broccoli extruded snacks is an ideal on the go healthy snack containing 1 serve of broccoli per 38 g serving.

Features

- Contains 20 % broccoli
- No added additives
- Excellent source of fibre
- 1 serve of broccoli in 38g snack

Nutritional Composition

Composition	**Per 100 g**
Energy (KJ)	1520
Protein (g/100g)	13.2
Total Fat (g/100g)	1.5
Ash (g/100g)	3.3
Carbohydrate (g/100g) - *Sugars (g/100g)*	70.0 4.1
Dietary Fibre (g/100g)	6.8

APPENDIX 6.2: Carrot products specifications

APPENDIX 6.2.1

100% Carrot powder specifications

A shelf stable, nutritious, functional ingredient made from 100% carrot

CSIRO's food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh carrot into a shelf stable, safe, nutritious, functional ingredient.

Our 100% carrot powders are made from whole carrot, and produced using a combination of selected pre-treatment and drying process to retain the natural colour, flavour and nutrient composition of fresh carrot.

Our 100% powders can be added to your standard meal preparations to increase your vegetable intake or can be used as an ingredient for a variety of food application such as smoothies, dips, sauces, spreads, soups, gravies, pasta, noodles, bakery products and extruded snacks.

Features

- 100% carrot
- No added additives
- Excellent source of fibre
- 1 serve of carrots 7.5g powder

Nutritional Composition

Composition	**g/100 g**
Energy (KJ)	1280
Protein (g/100g)	6.7
Total Fat (g/100g)	0.7
Ash (g/100g)	7.4
Carbohydrate (g/100g) - *Sugars (g/100g)*	51.0 *41.0*
Dietary Fibre (g/100g)	27.1

APPENDIX 6.2.2

100% Extruded carrot specifications

Value added shelf stable, nutritious, high fibre extruded carrot product made from 100% carrots

CSIRO’s food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh carrot into a shelf stable, safe, nutritious, ingredients and products.

Our 100% extruded carrot is made from whole carrot, and produced using a combination of selected pre-treatment, drying and extrusion process to retain the natural colour, flavour and nutrient composition of fresh carrot.

Our 100% extruded carrot can be used as a culinary ingredient, in soup premixes or added to your standard meal preparations to increase your vegetable intake.

Features

- 100% carrot
- No added additives
- Excellent source of fibre
- 1 serve of carrot in 7.5 gram extruded product

Nutritional Composition

Composition	**g/100 g**
Energy (KJ)	1260
Protein (g/100g)	4.3
Total Fat (g/100g)	1.3
Ash (g/100g)	6.5
Carbohydrate (g/100g) - *Sugars (g/100g)*	56.0 *47.0*
Dietary Fibre (g/100g)	23.7

APPENDIX 6.2.3

20% Carrot snacks specifications

Shelf stable, nutritious ready to eat vegetable snacks

CSIRO's food innovation centre experts in food science, food process engineering and ingredient and product development have developed a process for transforming fresh carrot into shelf stable, safe, nutritious, functional ingredients and products.

Our extruded snacks contains at least 20% carrots and produced using a combination of selected pre-treatment, drying and extrusion process to retain the natural colour, flavour and nutrient composition of fresh carrot.

Our 20% carrot extruded snack is an ideal on the go healthy snack containing 1 serve of carrot per 38 g serving.

Features

- Contains 20% carrot
- No added additives
- Good source of fibre
- 1 serve of carrots in 38g snack

Nutritional Composition

Composition	**g/100 g**
Energy (KJ)	1530
Protein (g/100g)	7.6
Total Fat (g/100g)	0.9
Ash (g/100g)	3.1
Carbohydrate (g/100g) *- Sugars (g/100g)*	78.0 *11.0*
Dietary Fibre (g/100g)	4.7

APPENDIX 6.3: Consumer survey Report

Report: Preliminary consumer survey on sensory acceptability of vegetable extruded snack

Prepared by Thu McCann

Background:

Broccoli and carrot powders produced from the unused vegetable respectively, classed as food loss or waste have showed a potential to be used as food ingredient. In order to explore the application of these powders, the broccoli and carrot powders were used to produce a vegetable extruded snack at a target of 20 g of vegetable powder in 100 g of unflavoured extruded snack. After flavouring, the flavoured vegetable extruded snack would contain 7.5 g of vegetable powder or 1 serve of vegetable in 1 serve of extruded snack (55 g). The consumer survey on these products was conducted to understand the acceptance of consumer on new products.

Sensory survey design:

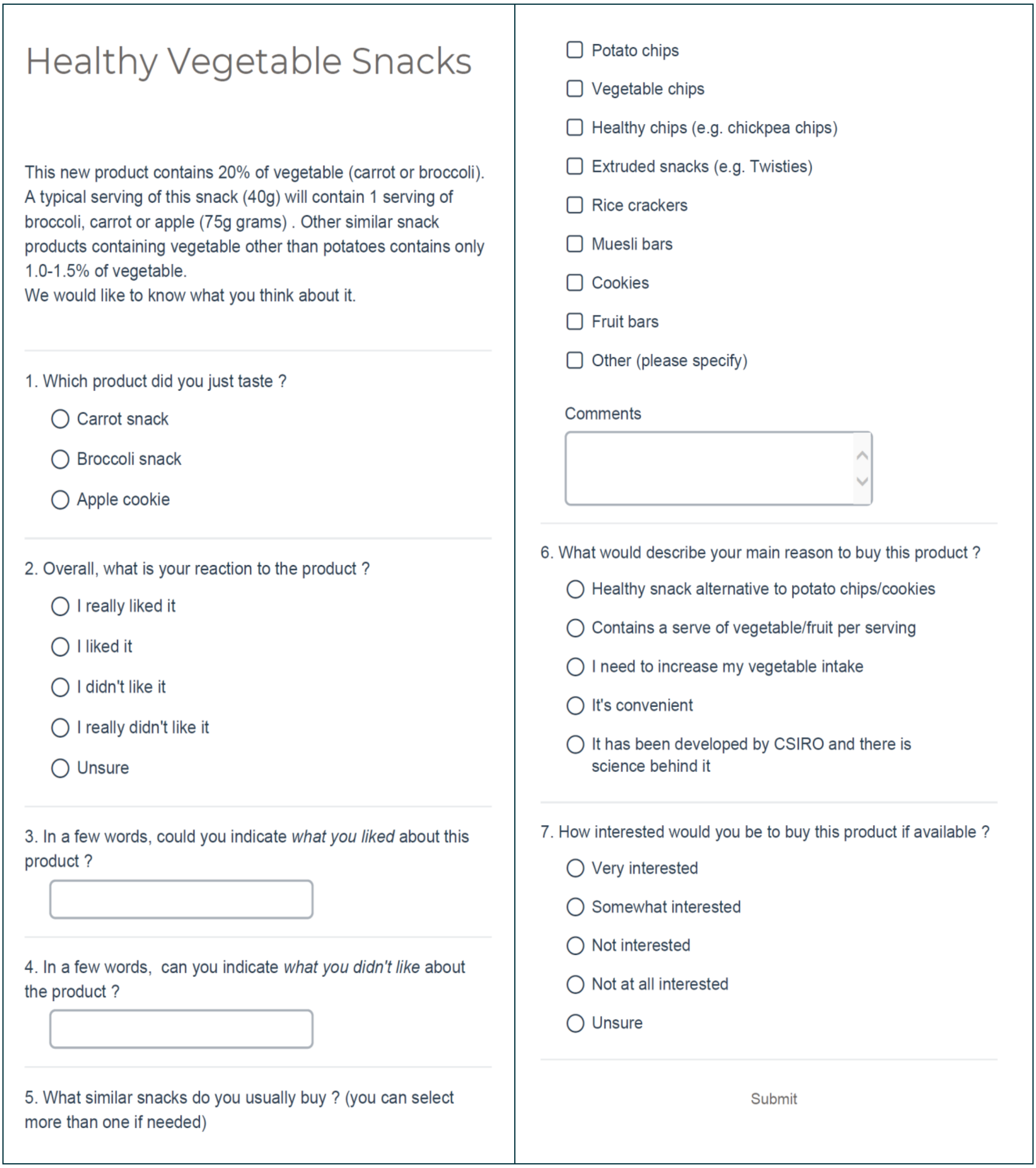
Broccoli extruded snack (20% broccoli powder and 80% rice flour) and carrot extruded snack (20% carrot powder and 80% rice flour) were flavoured using the recipe in Table 1:

Table 1: Flavouring formulation for vegetable extruded snack

Flavoured broccoli extruded snack		Flavoured carrot extruded snack	
Ingredient	Batch	Ingredient	Batch
20% broccoli extrudates	75 g	20% carrot extrudates	75 g
Canola Oil	30 g	Canola oil	25 g
Waters chilli and Garlic seasoning	5 g	Smoked paprika seasoning	9 g
Total	110 g	Total	109 g

These extruded snacks (2 g per pack) were packed in an individual bag for the survey. The survey was conducted at Horticulture Connect 2018, Brisbane and at CSIRO Agriculture and Food, Werribee. Total 68 answers were collected for each snack using the questionnaire detailed in Table 2. Data of survey was collected using the survey gizmo software.

Table 2: Sensory survey questionnaire



Healthy Vegetable Snacks

This new product contains 20% of vegetable (carrot or broccoli). A typical serving of this snack (40g) will contain 1 serving of broccoli, carrot or apple (75g grams) . Other similar snack products containing vegetable other than potatoes contains only 1.0-1.5% of vegetable.
We would like to know what you think about it.

1. Which product did you just taste ?
   - ○ Carrot snack
   - ○ Broccoli snack
   - ○ Apple cookie

2. Overall, what is your reaction to the product ?
   - ○ I really liked it
   - ○ I liked it
   - ○ I didn't like it
   - ○ I really didn't like it
   - ○ Unsure

3. In a few words, could you indicate *what you liked* about this product ?

4. In a few words, can you indicate *what you didn't like* about the product ?

5. What similar snacks do you usually buy ? (you can select more than one if needed)
   - ☐ Potato chips
   - ☐ Vegetable chips
   - ☐ Healthy chips (e.g. chickpea chips)
   - ☐ Extruded snacks (e.g. Twisties)
   - ☐ Rice crackers
   - ☐ Muesli bars
   - ☐ Cookies
   - ☐ Fruit bars
   - ☐ Other (please specify)

   Comments

6. What would describe your main reason to buy this product ?
   - ○ Healthy snack alternative to potato chips/cookies
   - ○ Contains a serve of vegetable/fruit per serving
   - ○ I need to increase my vegetable intake
   - ○ It's convenient
   - ○ It has been developed by CSIRO and there is science behind it

7. How interested would you be to buy this product if available ?
   - ○ Very interested
   - ○ Somewhat interested
   - ○ Not interested
   - ○ Not at all interested
   - ○ Unsure

Submit

Results

Flavoured vegetable extruded snack:

The number of liking and the express of purchasing interest was counted from the responses from the survey. The degree of liking was separated into 5 categories including ‘really liked’, ‘liked’, ‘didn’t like’, ‘really didn’t like’ and ‘unsure’. Likewise, the ‘interest to purchase’ was classed as ‘very’, ‘somewhat’, ‘not’, ‘not at all’ and unsure. The result of survey presented in Figure 1 as the percentage of each category, which was calculated as the number of each category per the total counts.

Result from Figure 1 showed that both flavoured broccoli and carrot extruded snack achieved 80 – 90% the liking and the 'interest to purchase' from consumers, only 10 – 17% did not like and was not interested to buy and around 3% consumer could not make a decision. The liking was mostly due to the crunchiness and flavour of extruded snack. The dislike was mostly caused by the appearance of the broccoli extruded snack whilst the saltiness was highlighted for the dislike with the carrot extruded snack. The 'interest to purchase' was mostly due to 'healthy snack' or for 'convenient'

Figure 1: Consumer survey result of flavoured vegetable extruded snack

Conclusion

The survey has demonstrated the acceptance of consumers (80 – 90%) on the new products developed from vegetable powder which came from the food lost across the value chain. Largely consumers expressed their liking because of the crunchiness of vegetable extruded snack. Most of consumers expressed their interest to buy those products as it was a healthy alternative option for snack or to achieve a serve of vegetable per serving. The result of the survey confirmed the potential to use the broccoli and carrot powders as an ingredient for developing a healthy food.

Acknowledgment

We would like to acknowledge Ms Maeva Broch for her advice on the questionnaire and constructing a survey website for this work.

APPENDIX 6.4: Consumer Sensory Evaluation Report

Report: Consumer sensory acceptance testing of vegetable powders and extrudates

Prepared by Jess Heffernan, Maeva Broch and Astrid Poelman

Executive Summary:

As part of a project for Hort Innovations, CSIRO has developed a range of Australian vegetable products derived from on-farm broccoli and carrot waste streams. These vegetable products include: 100% Australian vegetable powders, 100% Australian vegetable extrudates and 20% Australian vegetable extrudates.

A total of 82 consumers participated in a consumer test of the vegetable powders and extrudates to gain insight into consumer acceptance of the products. Each product was evaluated on its own for liking overall and several specific modalities (appearance, flavour and texture) using the 9-point hedonic scale, and were rated for specific sensory attributes using just-about-right scales. Consumers also assessed the suitability of the products for different applications. For each product category, the two flavour variants were assessed and a number of commercial benchmark snacks were also tested for comparison with the 20% vegetable extrudates.

The main conclusions of this research were:

- Vegetable powders:
  - *Overall liking* was higher for the broccoli powder than the carrot powder. Broccoli powder scored just above the neutral point, and carrot powder just below the neutral point for *liking*.
  - *Overall*, both samples largely met the consumer ideal for *texture* attributes. Lower *liking* of the carrot sample was mainly related to its *flavour* profile, which was deemed *too intense, slightly too bitter* and not *salty enough*.
  - Purchase intent was positive for the powders, with approximately 50% of consumers indicating that they *probably*, or *definitely would buy* them.
  - Consumers indicated that they would use the 100% vegetable powders to add to dips, spreads, soups and pasta dishes and to make meals more interesting by adding new flavours.
- 100% vegetable extrudates:
  - *Overall*, consumers *liked* the 100% carrot extrudates significantly more than they did the 100% broccoli extrudates, however, they both scored quite low on the 9-point hedonic scale (<5).
  - Both samples did not meet the consumer ideal for *flavour* (too *intense* and suboptimal *sweetness*), and the broccoli also did not meet consumer ideal for *appearance* and *texture (*too *crunchy)*

    - Results of purchase intent were mixed, with 40% of consumers each indicating that they *probably* or *definitely would*, and *probably* or *definitely would not* buy the vegetable extrudates.
    - The majority of consumers found the broccoli (74%) and carrot (55%) extrudates to be *too small* as a snack but just right as a topping (59% and 45%, respectively). Consumers indicated that they would use the 100% vegetable extrudates as a healthy snack option (54%), or alternative to chips (44%) or other snacks (44%) and to make meals more interesting by adding new textures and flavours (48%)
- 20% vegetable extrudates:
    - The flavoured vegetable extrudates were *liked* more than the unflavoured extrudates. With the flavoured extrudates, the flavoured carrot was *liked* more than the flavoured broccoli.
    - Flavoured carrot had a relatively high score on the 9-point hedonic scale (>7) showing high *overall liking* by consumers. It was equally preferred to the commercial benchmark Harvest Snap Peas and higher than the commercial benchmark Organix Carrot Stix. Flavoured broccoli, although slightly lower in *liking* (5.5), was still on par in liking with the commercial benchmark Organix Carrot Stix.
    - Flavoured carrot had good sensory appeal in all modalities, where flavoured broccoli was too *intense* in *flavour*.
    - As a snack, the *size* of the extrudates were found either *just right* or *slightly too small,* whereas as a topping there were *slightly too big*.
    - Purchase intent was largely positive among consumers with 59% indicating that they *probably* or *definitely would buy* them.
    - The most common uses that consumers had for the 20% extrudates were as a healthy snack option (79%) or as an alternative to chips (77%) and other snacks (71%).

This consumer research study provides insights into the relative consumer acceptance of the vegetable extrudates and powder. The 20% flavoured extrudates had good consumer sensory acceptance and purchase intent, with the flavoured carrot sample scoring similarly or higher than the commercial benchmarks. Consumers have also indicated numerous ways in which they would use them at home, including, but not limited to, as a healthy snack alternative. As taste is of critical importance to consumer choice for snacks, overall results indicate good commercial potential for 20% flavoured extrudates.

The vegetable powders scored above the neutral point for their *overall liking* and also had a positive response to purchase intent. As these products are ingredients to add to other foods and not stand-alone foods (like snacks) the slightly lower liking ratings should not be seen as problematic.

Both vegetable powders and extrudates seem to have potential to further develop for commercialisation, in particular the broccoli powder and the flavoured 20% vegetable extrudates.

Introduction

Food waste is a significant global issue. Identifying potential sources of food waste means that material that would otherwise go into landfill is able to be re-directed and reformulated to create healthy value-added food products. This project formed part of a larger project co-funded by Horticulture Innovation Australia (HIA), and as such, identifying sources and opportunities for minimising food wastage within the horticultural area, and more specifically, on-farm wastage, was chosen.

The overall aims of the larger project were to optimise the value from the edible waste in the vegetable supply chain, by creating healthy food ingredients and products from edible biomass left in the field, lost biomass after harvest or from side streams of food processing. This type of optimisation will increase the economic value derived from vegetable production and reduce waste disposed in landfill.

One activity within the larger overall project was to develop high-fibre Brassica-based and carrot-based ingredients which may be formulated into healthy consumer products. The results of this activity have seen the development of:

- 100% Australian vegetable powders (broccoli and carrot)
- Extruded snacks made from 100% Australian vegetable powders (broccoli and carrot)
- Extruded snacks made from 20% Australian vegetable powders (broccoli and carrot) and other ingredients, including seasonings

The vegetable powders are made from 100% Australian broccoli or carrot. Two tablespoons of the powder is equivalent to 75g fresh vegetable, or 1 serving of vegetable. The vegetable powders provide an easy way to add vegetables to any meal or beverage, thereby increasing vegetable consumption.

The extruded vegetable snacks are made from either 100% Australian broccoli or carrot, or 20% Australian broccoli or carrot with other ingredients added to form flavoured and unflavoured snacks. One serving of the snack (40g) is equivalent to 75g fresh vegetable, or 1 serve of vegetable. These snacks provide a healthier alternative to other common savoury snacks such a chips. They can also be added as a topping to meals, e.g.: in place of croutons in a soup or salad, thereby increasing vegetable consumption.

The aim of this specific component of the overall project was to determine consumer acceptability, purchase intent and suitability of applications of the Australian vegetable powders and extruded snacks, as developed in the larger project.

The specific objectives of this project component were:

1. To determine and compare consumer acceptance and sensory appeal of the vegetable powders and snacks
2. To compare consumer acceptance and sensory appeal of the vegetable snacks to similar market samples
3. To determine purchase intent of the vegetable powders and snacks
4. To determine the ways in which consumers would use the powders and snacks
5. To determine similar products that consumers currently buy

6. To collect background information on the consumer sample

Materials and Methods

Samples

The vegetable powders and snacks were produced using the method as found in the main report. Table 1, below, details the samples assessed in the consumer acceptance test.

Table 1: List of samples, ingredients and sample preparation used in the consumer acceptance test

SAMPLE	% VEGETABLE COMPONENT	OTHER INGREDIENTS	MARKET OR PROTOTYPE SAMPLE	SAMPLE PRESENTATION
Broccoli powder	100	-	Prototype	4g (also served as a paste for taste/texture evaluations – 1part powder : 4 parts water)
Carrot powder	100	-	Prototype	4g (also served as a paste for taste/texture evaluations – 1part powder : 4 parts water)
100% Broccoli extrusion	100	-	Prototype	1.3g – 1.4g
100% Carrot extrusion	100	-	Prototype	6 pieces
20% Broccoli snack (unflavoured)	20	Rice flour	Prototype	6 pieces
20% Broccoli snack (flavoured)	20	Rice flour, vegetable oil, salt, spices and spice extract, corn starch, maltodextrin, sugar, vegetable powders (onion, garlic), citric acid, natural flavour	Prototype	6 pieces
20% Carrot snack (unflavoured)	20	Rice flour	Prototype	6 pieces
20% Carrot snack (flavoured)	20	Rice flour, vegetable oil, salt, spices and spice extract, corn starch, maltodextrin, sugar, vegetable powders (onion, garlic), citric acid, natural flavour	Prototype	6 pieces
Baked pea crisps **(chili flavour)**	65	Vegetable oil (with antioxidant-Vit E), rice, original salt seasoning [sugar, salt, maltodextrin, yeast extract, vegetable oil, flavour enhancer (635). Anti-caking agent (551), food acid (330)], stabiliser (170)	Market (Harvest Snaps)	2 pieces
Carrot Stix **(flavoured)**	~80 (corn, carrot)	Corn, sunflower oil, carrot powder, potato powder, onion powder (contains rice flour), dried coriander leaf, Thiamin (Vit B1)	Market (Organix Goodies)	2 pieces

Consumers

A sample of 80 consumers (50% male and 50% female), between the ages of 18 and 65 was sought. Consumers were recruited via a third party recruitment agency and were selected based on the following screening criteria:

- Savoury snack consumers, eaten at least once in the past fortnight
- Likers of broccoli and carrot, eaten both in the past fortnight
- Health focused/conscious
- Non-rejecter of spicy flavours
- To be responsible for at least part of the grocery shopping
- 50% of the sample was also required to have purchased savoury snacks from the health food store/isle, in the past month

Consumer responses were collected centrally at CSIRO's sensory evaluation facility in Sydney, which has been designed in accordance with International Standards on Sensory Analysis (ISO 6658:1986). Consumers each took part in a single session of 1 hr duration. Nine sessions were conducted in total between 22nd and 24th August 2018 and a maximum of 10 consumers took part in each session.

Sample tasting and evaluation

Samples were served sequentially monadic, that is, one-at-a-time, within 3 blocks. The 3 blocks were based on the 3 categories of sample and all participants saw the blocks in the same order: 100% powders, 100% extrudates, 20% extrudates. Samples were randomised within blocks for each participant.

For the powder evaluations, consumers were first presented with 4g of the powder with which they rated *aroma* and *appearance liking*. To evaluate the taste attributes, participants were presented with 5g of 100% vegetable paste, made by mixing 1 part powder with 4 parts water. For the 100% carrot, and both 20% extrudates, 6 pieces were served. For the 100% broccoli extrudates, which were very small, 1.3 – 1.4g was served instead, which was the equivalent weight to 6 pieces of 100% carrot extrudates. Due to the size of the market samples, only 2 pieces were served. These sample amounts were chosen as they would allow two mouthfuls with which participants could rate the flavour and texture attributes.

Consumers were asked to rate their *overall acceptance* as well as acceptance of specific sensory attributes using a 9-point hedonic scale. They were also asked to assess key sensory attributes relevant to the particular product variant using 5-point just-about-right scales.

Purchase intent was also asked for each category and the size of the sample as a snack and as a topping was asked for the 100% and 20% extrudate samples.

Sample usage, motivation for use and similar products

In order to understand consumer usage of the samples and suitability of application, participants were asked to pick different ways they saw themselves using the samples at home and reasons for using the samples from a list. They were also allowed to provide their own responses to these questions. Participants were also asked about similar products they currently buy and were able to pick them from a list or provide their own response.

Data analysis

Data were analysed using SPSS statistical software package (version 23, IBM Corp.) and statistical significance was established at the five per cent confidence interval ($p \leq 0.05$).

Data were tabulated and graphed according to the question format. Hedonic data are presented as means; and intensity, purchase intent, sample size and sample usage questions are presented as percentages.

Hedonic data was statistically analysed with analysis of variance (ANOVA), using samples as the factor.

For the 20% extrudates, if an attribute was significant overall, post-hoc testing was conducted using the Bonferroni post-hoc test to determine which pairs of samples were different from each other. The statistically significant results are represented via letters (a, b, c...) next to the means. Samples with the same letter are not statistically significant to each other.

Results and Discussion

Description of consumer sample

A total of 82 consumers (average age was 39.3 ± 13.8 years) participated in the study. Of these, 51% were female and 49% were male. All participants met the screening criterion of having eaten savoury snacks in the past fortnight and 87% indicated that they had purchased savoury snacks from the supermarket health food aisle and/or, a health food store in the past month.

100% vegetable powders

Product acceptance

Table 2: *Overall acceptance* and *liking* of sensory attributes for 100% vegetable powders

Sample	Overall liking	Aroma liking	Appearance liking	Flavour liking	Texture liking
100% Broccoli Powder	5.69	5.88	6.57	5.42	5.81
100% Carrot Powder	4.37	4.91	6.33	4.38	5.94
F value	16.97	10.87	1.20	10.30	0.17
P value	<0.001	<0.001	0.27	<0.001	0.68

Overall, consumers *liked* the powdered broccoli sample significantly more than they did the powdered carrot sample.

Significant differences were also observed for *aroma liking* and *flavour liking*, with the broccoli sample being liked more than the carrot sample in both cases.

Texture and *appearance liking* did not differ significantly between the two samples.

Consumer opinion

Flavour intensity

Table 3: Frequency of consumer responses for opinion of *flavour intensity*

Flavour intensity	100% Broccoli Powder	100% Carrot Powder
Definitely not intense enough	1.2%	2.4%
Slightly not intense enough	12.2%	12.2%
Just right	52.4%	31.7%
Slightly too intense	24.4%	41.5%
Definitely too intense	8.5%	11.0%

Overall, the majority of consumers thought that the *flavour intensity* of the broccoli paste was *just right* (52%) and that the flavour intensity of the carrot paste was either *slightly* (42%) or *definitely* (11%) *too intense*.

Sweetness

Table 4: Frequency of consumer responses for opinion of *sweetness*

Sweetness	100% Broccoli Powder	100% Carrot Powder
Definitely not sweet enough	11.0%	4.9%
Slightly not sweet enough	26.8%	25.6%
Just right	58.5%	42.7%
Slightly too sweet	2.4%	23.2%
Definitely too sweet	0%	2.4%

Overall, the majority of consumers thought that the *sweetness* of the broccoli paste was *just right* (59%). Just under half of the consumers thought that the *sweetness* of the carrot paste was just right (43%). Approximately one quarter of consumers each thought that the *sweetness* of the carrot paste was either *slightly not sweet enough* (26%) or *slightly too sweet* (23%).

Bitterness

Table 5: Frequency of consumer responses for opinion of *bitterness*

Bitterness	100% Broccoli Powder	100% Carrot Powder
Definitely not bitter enough	2.4%	4.9%
Slightly not bitter enough	7.3%	7.3%
Just right	64.6%	42.7%
Slightly too bitter	2.4%	39.0%
Definitely too bitter	2.4%	4.9%

Overall, the majority of consumers thought that the *bitterness* of the broccoli paste was *just right* (64%). Approximately 40% of consumers each thought that that the *bitterness* of the carrot paste was either *just right* (43%) or *slightly too bitter* (39%).

Saltiness

Table 6: Frequency of consumer responses for opinion of *saltiness*

Saltiness	100% Broccoli Powder	100% Carrot Powder
Definitely not salty enough	11.0%	6.1%
Slightly not salty enough	43.9%	41.5%
Just right	39.0%	42.7%
Slightly too salty	3.7%	7.3%
Definitely too salty	1.2%	1.2%

Almost 40% of consumers each thought that the *saltiness* of the broccoli and carrot pastes were either *just right* (39% and 423%, respectively) or *slightly not salty enough* (44% and 42%, respectively).

Graininess

Table 7: Frequency of consumer responses for opinion of *graininess*

Graininess	100% Broccoli Powder	100% Carrot Powder
Definitely not grainy enough	4.9%	8.5%
Slightly not grainy enough	17.1%	20.7%
Just right	61.0%	58.5%
Slightly too grainy	15.9%	11.0%
Definitely too grainy	0%	0%

Overall, the majority of consumers thought that the *graininess* of both the broccoli and carrot pastes was *just right* (61% and 59%, respectively).

Consumer ideal

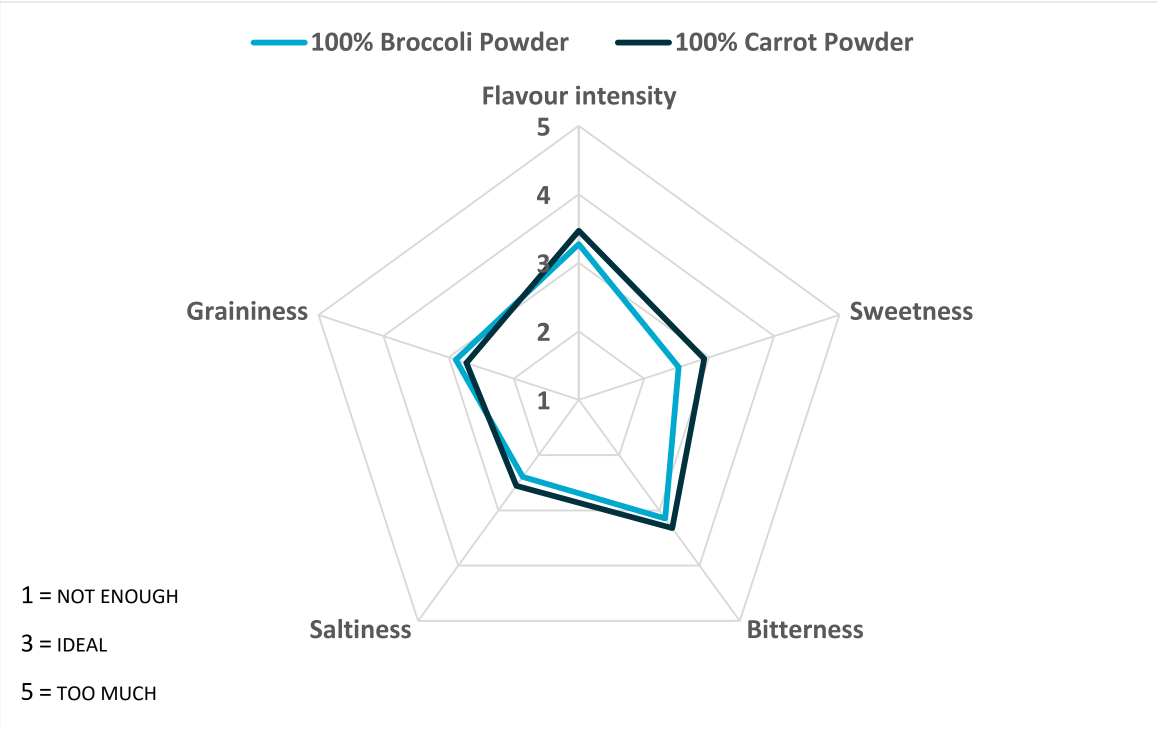


Figure 1: spider plot of the consumer ideal for each intensity attribute for 100% vegetable powders

Overall, both samples largely met the consumer ideal for *bitterness* and *graininess*. The 100% broccoli paste was perceived as being *slightly too intense* in *flavour* and *slightly not sweet* or *salty enough*. The 20% carrot paste also met the consumer ideal for *sweetness*, however, was perceived as being *slightly too intense* in *flavour* and *slightly not salty enough*.

Purchase intent

Table 8: Frequency of consumer responses for *purchase intent* of 100% vegetable powders

	% of consumers
Definitely wouldn't buy it	8.5%
Probably wouldn't buy it	8.5%
Not sure	35.4%
Probably would buy it	39.0%
Definitely would buy it	8.5%

When asked how likely they would be to purchase 100% vegetable powders, approximately one third of consumers indicated that they were *not sure*, however, almost 50% of consumers indicated that they *probably*, or *definitely would buy* 100% vegetable powders.

Suitability of application

Product usage

Table 9: Frequency of consumer responses for the different uses of 100% vegetable powders

Potential application	% of respondents
Added to dips or spreads	70.7%
Added to soups	69.5%
Added to pasta dishes	64.4%
Added to gravies or sauces	50.0%
Added to smoothies	41.5%
Used as a topping on savoury dishes	40.2%
Added to vegetable juices	39.0%
Used to enhance the presentation of a dish	28.0%
Incorporated into bakery products (bread, cakes)	25.6%
Added to tea/coffee	3.7%
Other	7.3%

Overall, consumers indicated that there were a number of applications that they would use 100% vegetable powders for. The most common uses were: added to dips or spreads (71%), added to soups (70%) and added to pasta dishes (64%). Consumers indicated that they were least likely to use the 100% vegetable powders in tea/coffee (4%).

When asked what other applications they would use the 100% vegetable powders in, consumers said:

- As a substitute for stock or herbs
- On bread, bagels etc.
- Added to meatballs or sauces
- To encourage “vegetable-shy” children to start eating vegetables
- Added to health shakes
- Used in rice or couscous

Motivation for use

Table 10: Frequency of consumer responses for the different reasons *why* they would use 100% vegetable powders

Reasons for powder use	% of respondents
To make meals more interesting by adding new flavours	65.9%
As a vegetable supplement	62.2%
As an alternative to other health food supplements (e.g.: spirulina)	46.3%
To increase my or my partners vegetable intake	45.1%
To increase my child’s vegetable intake	35.4%
Other	7.3%

The most common reasons why consumers would use 100% vegetable powders are to make meals more interesting by adding new flavours (66%) and as a vegetable supplement (62%).

When asked what other reasons people would use 100% vegetable powders for, they indicated:

- That they are an easy and tasty alternative
- They are shelf-stable, compared to fresh vegetables
- That they are pure healthy food, better than protein shakes

Similar products currently purchased

Table 11: Frequency of consumer responses for the products they currently purchase that share similarities with 100% vegetable powders

Similar products	% of respondents
Tea infusions (e.g.: with lemon or ginger)	69.5%
Herbal teas (e.g.: dandelion tea, raspberry leaf tea)	57.3%
Vegetable powders (e.g.: spirulina, Ginkgo, chlorophyll, wheat grass)	36.6%
Matcha tea	35.4%
Vegetable supplements in capsule form (e.g.: cranberry, turmeric, garlic)	32.9%
Coffee products (e.g.: green coffee)	13.4%
Other	8.5%

When asked what products consumers currently purchase that are similar to 100% vegetable powders, consumers most commonly indicated that tea infusions (70%) and herbal teas (57%) were purchased the most.

Other similar products currently purchased include:

- Vegetable stock, in powdered or cubed form
- Vitamin powders for children

100% vegetable extrudates

Product acceptance

Table 12: *Overall acceptance* and *liking* of sensory attributes for 100% vegetable extrusions

Sample	Overall liking	Aroma liking	Appearance liking	Flavour liking	Texture liking
100% Broccoli Extrudates	3.52	5.32	4.01	4.48	3.55
100% Carrot Extrudates	4.78	6.00	7.30	5.32	6.50
F value	15.31	5.23	176.34	6.53	89.16
P value	<0.001	0.02	<0.001	0.01	<0.001

Overall, consumers *liked* the 100% carrot extrudates significantly more than they did the 100% broccoli extrudates, however, they both scored below the neutral point on the 9-point hedonic scale (<5).

Consumers also liked the *aroma*, *appearance*, *flavour* and *texture* of the 100% carrot extrudates significantly more than they did the 100% broccoli extrudates.

Consumer opinion

Flavour intensity

Table 13: Frequency of consumer responses for opinion of *flavour intensity*

Flavour intensity	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not intense enough	4.9%	1.2%
Slightly not intense enough	7.3%	14.6%
Just right	30.5%	41.5%
Slightly too intense	41.5%	32.9%
Definitely too intense	15.9%	9.8%

One third of consumers found the *flavour intensity* of the broccoli extrudates *just right*, and 40% of consumers found the *flavour intensity* of the carrot extrudates just right.

Just over a third of consumers each found the broccoli and carrot extrudates to be *slightly too intense* (42% and 33%, respectively).

Sweetness

Table 14: Frequency of consumer responses for opinion of *sweetness*

Sweetness	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not sweet enough	14.6%	2.4%
Slightly not sweet enough	32.9%	11.0%
Just right	46.3%	37.8%
Slightly too sweet	4.9%	37.8%
Definitely too sweet	1.2%	11.0%

Approximately 40% of consumers each thought that the *sweetness* of the broccoli and carrot extrudates was *just right* (46% and 38%, respectively). Approximately 40% of consumers also thought that the broccoli extrudates were *slightly not sweet enough* (33%) and thought that the carrot extrudates were *slightly too sweet* (38%).

Bitterness

Table 15: Frequency of consumer responses for opinion of bitterness

Bitterness	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not bitter enough	1.2%	3.7%
Slightly not bitter enough	9.8%	19.5%
Just right	41.5%	50.0%
Slightly too bitter	37.8%	24.4%
Definitely too bitter	9.8%	2.4%

Approximately 50% of consumers thought that the *bitterness* of the 100% vegetable extrudates was *just right* (41.5% and 50.0% for broccoli and carrot respectively). Almost 40% of consumers also thought that the broccoli extrudates were *slightly too bitter* and almost one quarter thought that the carrot extrudes were *slightly too bitter*.

Saltiness

Table 16: Frequency of consumer responses for opinion of saltiness

Saltiness	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not salty enough	8.5%	14.6%
Slightly not salty enough	42.7%	35.4%
Just right	42.7%	45.1%
Slightly too salty	4.9%	4.9%
Definitely too salty	1.2%	0%

Almost half of the consumers thought that the *saltiness* of the broccoli and carrot extrudates was *just right* (42.7% and 45.1%, respectively). Over one third of consumers also thought that the extrudates were *slightly not salty enough* (42.7% and 35.4% for broccoli and carrot respectively).

Crunchiness

Table 17: Frequency of consumer responses for opinion of crunchiness

Crunchiness	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not crunchy enough	14.6%	4.9%
Slightly not crunchy enough	26.8%	15.9%
Just right	13.4%	79.3%
Slightly too crunchy	23.2%	0%
Definitely too crunchy	22.0%	0%

The *crunchiness* results for the 100% broccoli extrudates varied between consumers. Just over 40% of consumers each thought that the extrudates were *definitely* or *slightly not crunchy enough* (41.4%), or *definitely or slightly too crunchy* (45.2%). The remaining consumers found the crunchiness *just right* (13.4%). The majority of consumers thought that the crunchiness of the 100% carrot extrudates was just right (79.3%).

Toothpacking

Table 18: Frequency of consumer responses for opinion of toothpacking

Toothpacking	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not toothpacking enough	0%	1.2%
Slightly not toothpacking enough	4.9%	4.9%
Just right	22.0%	15.9%
Slightly too toothpacking	39.0%	40.2%
Definitely too toothpacking	34.1%	37.8%

The majority of consumers thought that both of the 100% extrudates were sl*ightly or definitely too toothpacking* (73.1% broccoli and 78% carrot). Less than one quarter of consumers found the toothpacking to be *just right* (22.0% broccoli and 15.9% carrot).

Consumer ideal

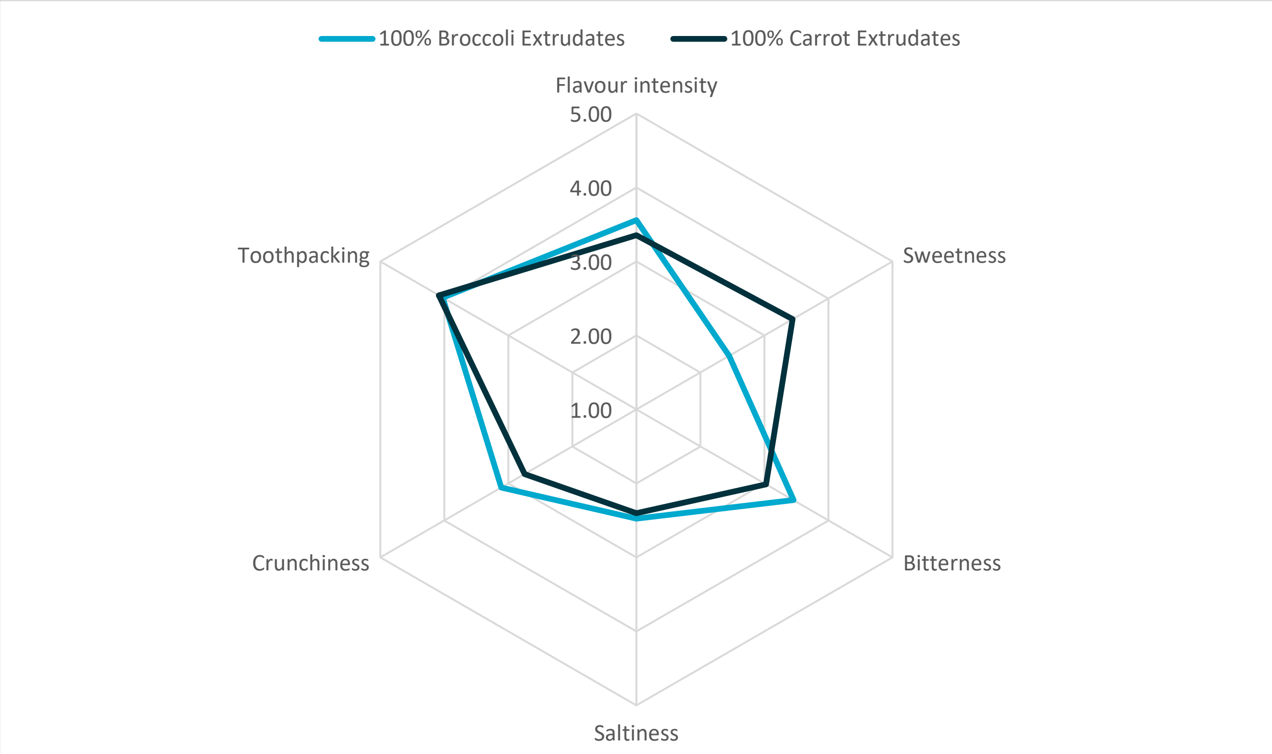


Figure 2: spider plot of the consumer ideal for each intensity attribute for 100% vegetable extrusions

Overall, both samples were above the consumer ideal for *flavour intensity* and *toothpacking*. For *sweetness*, the broccoli extrudates were *slightly below*, and the carrot extrudates were *slightly above* the consumer ideal. The 100% broccoli extrudates were above the consumer ideal for *bitterness*.

Size – snack

Table 19: Frequency of consumer response for size of pieces as a snack for 100% vegetable extrusions

Snack size	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not big enough	51.2%	17.1%
Slightly not big enough	23.2%	37.8%
Just right	15.9%	40.2%
Slightly too big	7.3%	1.2%
Definitely too big	2.4%	3.7%

The majority of consumers found the size of the broccoli extrudates *too small* with 74.4% indicating that they were either *slightly or definitely not big enough*. Some consumers also found the carrot extrudates *too small* (54.9%), however, 40.2% also found them to be *just right*.

Size – topping

Table 20: Frequency of consumer response for size of pieces as a topping for 100% vegetable extrusions

Topping size	100% Broccoli Extrudates	100% Carrot Extrudates
Definitely not big enough	4.9%	3.7%
Slightly not big enough	24.4%	14.6%
Just right	58.5%	45.1%
Slightly too big	7.3%	24.4%
Definitely too big	4.9%	12.2%

When asked about the size of the pieces as a topping, almost two thirds of consumers thought that the 100% broccoli extrudates were *just right* (58.5%), however, a quarter found them *slightly not big enough*. Almost half of the consumers thought that the carrot extrudates were *just right* (45.1%) and one quarter found them *slightly too big*.

6.1.1 Purchase intent

Table 21: Frequency of consumer responses for purchase intent of 100% vegetable extrusions

Purchase intent	% of respondents
Definitely wouldn't buy it	15.9%
Probably wouldn't buy it	24.4%
Not sure	19.5%
Probably would buy it	32.9%
Definitely would buy it	7.3%

Purchase intent for 100% vegetable extrudates was mixed, with 40% percent of consumers each said that they *probably* or *definitely would buy* 100% vegetable extrudates, and that they *probably* or *definitely would buy not them*. Only 20% were not sure.

6.1.2 Suitability of application

Uses

Table 22: Frequency of consumer responses for the different uses of 100% vegetable extrusions

Use	% of respondents
As a healthy snack option	53.7%
On its own, as an alternative to chips	43.9%
On its own, as an alternative to other snacks	43.9%
Added to salads	43.9%
To add texture to a dish	41.5%
On its own, as an alternative to nuts	40.2%
Added to pastas	30.5%
As a vegetable supplement	26.8%
For my children to eat at school as a source of vegetable	24.4%
Added to cereals	12.2%
Other	1.2%

Overall, consumers indicated that there were a number of applications that they would use 100% vegetable extrudates for. The most common uses included: as a healthy snack option (53.7%), an alternative to chips (43.9%) or other snacks (43.9) and to add to salads (43.9%). Consumers were least likely to add the extrudates to cereals (12.2%) or use as a vegetable supplement (26.8%).

The ‘other’ uses that consumers found for the 100% extrudates were to add them crushed in with drinks.

Motivation

Table 23: Frequency of consumer responses for the different reasons they would use 100% vegetable extrusions

Motivation	% respondents
As an alternative to chips	48.8%
To make meals more interesting by adding new textures and flavours	47.6%
As a vegetable supplement	42.7%
To add texture to a dish	40.2%
As an alternative to nuts	36.6%
To increase my child's vegetable intake	34.1%
To increase my or my partners vegetable intake	29.3%
For my children to eat at school as a source of vegetables	24.4%
Other	4.9%

The most common reasons that consumers would use the 100% vegetable extrudates are as an alternative to chips (48.8%), to make meals more interesting by adding new textures and flavours (47.6%) and as a vegetable supplement (42.7%).

The 'other' reasons consumers indicated that they would use the 100% extrudates are:

- To add to soups for flavour and texture
- As a lazy way to add more vegetables to a meal
- To mix with nuts

Similar products

Table 24: Frequency of consumer responses for the products they currently purchase that are similar to 100% vegetable extrusions

Product	% respondents
Natural snacks (e.g.: nuts, dried fruit)	80.5%
Crunchy toppings (e.g.: nuts, seeds) to use on/in savoury dishes (e.g.: soups, dips, pastas, salads)	68.3%
Healthy snacks for myself/my partner (e.g.: lentil chips, chickpea chips)	65.9%
Healthy snacks for my children	15.9%
Other	2.4%

When asked what products consumers currently purchase that are similar to 100% vegetable extrudates, consumers most commonly indicated natural snacks such as nuts and dried fruit (80.5%) and crunchy toppings like nuts and seeds added to savoury dishes (e.g.: soups, dips, pastas) (68.3%).

Other similar products that consumers currently purchase include:

- Nut and muesli bars
- Vegetable chips and sticks
- Rice crackers
- Sultanas and date balls
- Trail mix
- Popcorn

20% vegetable extrudates

Product acceptance

Table 25: overall acceptance and liking of sensory attributes for 20% vegetable extrusions

Sample	Overall liking		Aroma liking		Appearance liking		Flavour liking		Texture liking	
20% Broccoli unflavoured	3.52	c	4.28	d	4.10	c	3.66	e	5.79	d
20% Carrot unflavoured	5.17	b	5.28	c	6.87	ab	5.00	d	6.65	bc
20% Broccoli flavoured	5.49	b	6.24	b	4.61	c	5.52	cd	6.82	abc
20% Carrot flavoured	7.04	a	6.23	b	7.32	a	6.98	ab	7.39	ab
Organix Carrot stix	5.96	b	5.33	c	7.21	ab	6.16	bc	6.22	cd
Harvest Snaps peas	7.55	a	6.95	a	6.55	b	7.44	a	7.50	a
F value	46.93		32.85		59.36		45.50		11.13	
P value	<0.001		<0.001		<0.001		<0.001		<0.001	

Overall, consumers liked the Harvest Snap peas and 20% flavoured extrudates significantly more than the remaining samples. These two samples also scored highly on the 9-point hedonic scale (>7.0) showing high overall liking by consumers. The 20% unflavoured broccoli extrudates were liked significantly less than the remaining products tested. The 20% unflavoured carrot and flavoured broccoli samples were liked similarly.

For aroma liking, the Harvest Snap peas were liked significantly more than the other samples. Both 20% flavoured extrudates were liked similarly for aroma. The unflavoured broccoli extrudates were liked significantly less than the other samples for aroma liking.

The two market samples and the two carrot samples were liked similarly for their appearance, as were the two broccoli samples.

The Harvest Snap peas and 20% flavoured carrot extrudates were liked significantly more for their flavour than the remaining samples. The Organix carrot Stix and 20% flavoured broccoli extrudates were liked similarly for their flavour liking. The two unflavoured extrudates were liked the least for their flavour and also scored quite low on the 9-point hedonic scale (≤5.0).

The Harvest Snap peas were liked the most for their texture and were similar in liking to the two flavoured extrudates. The unflavoured broccoli extrudate was liked least, and significantly less, for its texture.

Consumer opinion

Flavour intensity

Table 26: Frequency of consumer responses for opinion of flavour intensity

Flavour intensity	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not intense enough	11.0%	31.7%	0.0%	1.2%	30.5%	0.0%
Slightly not intense enough	15.9%	36.6%	7.3%	39.0%	46.3%	3.7%
Just right	23.2%	23.2%	40.2%	50.0%	23.2%	79.3%
Slightly too intense	23.2%	7.3%	40.2%	8.5%	0.0%	13.4%
Definitely too intense	26.8%	1.2%	12.2%	1.2%	0.0%	3.7%

The majority of consumers thought that the flavour intensity of the 20% carrot flavoured extrudates (50.0%) and the Harvest Snap peas (79.3%) was just right. Consumer opinion of flavour intensity varied for the two unflavoured extrudates with the majority finding the unflavoured broccoli extrudates slightly/definitely too intense (50.0%) and the unflavoured carrot extrudates or slightly/definitely not intense enough (68.3%). Forty percent of consumers each thought that he flavour intensity of the flavoured broccoli extrudates was just right or slightly too intense.

Sweetness

Table 27: Frequency of consumer responses for opinion of sweetness

Sweetness	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not sweet enough	30.5%	6.1%	12.2%	0%	4.9%	2.4%
Slightly not sweet enough	30.5%	20.7%	23.2%	7.3%	11.0%	11.0%
Just right	35.4%	48.8%	61.0%	85.4%	53.7%	84.1%
Slightly too sweet	2.4%	22.0%	2.4%	4.9%	26.8%	1.2%
Definitely too sweet	1.2%	2.4%	1.2%	2.4%	3.7%	1.2%

Overall, the majority of consumers found the sweetness of the two flavoured extrudates and the two market samples to be just right. Almost 50% of consumers found the sweetness of the unflavoured carrot sample to be just right. Approximately 20% each also thought that they were slightly not sweet enough, or slightly too sweet. The majority of consumers found the unflavoured broccoli sample to be slightly or definitely not sweet enough (61%).

Bitterness

Table 28: Frequency of consumer responses for opinion of bitterness

Bitterness	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not bitter enough	4.9%	7.3%	0%	0%	3.7%	0%
Slightly not bitter enough	6.1%	25.6%	1.2%	12.2%	13.4%	3.7%
Just right	32.9%	58.5%	54.9%	81.7%	81.7%	89.0%
Slightly too bitter	35.4%	7.3%	28.0%	3.7%	1.2%	6.1%
Definitely too bitter	20.7%	1.2%	15.9%	2.4%	0%	1.2%

The majority of consumers thought that the bitterness of all samples was just right (>50%), with the exception of the unflavoured broccoli sample where the majority though that it was slightly or definitely too bitter (56.1%).

Saltiness

Table 29: Frequency of consumer responses for opinion of saltiness

Saltiness	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not salty enough	31.7%	30.5%	1.2%	4.9%	15.9%	0%
Slightly not salty enough	40.2%	41.5%	26.8%	26.8%	41.5%	9.8%
Just right	24.4%	26.8%	62.2%	57.3%	40.2%	75.6%
Slightly too salty	2.4%	0%	7.3%	7.3%	1.2%	11.0%
Definitely too salty	1.2%	1.2%	2.4%	3.7%	1.2%	3.7%

The majority of consumers thought that the saltiness of the two flavoured samples and the Harvest Snap peas was just right. The saltiness of the two unflavoured samples were perceived similarly with one quarter finding the saltiness just right and 72% finding them slightly or definitely not salty enough. The Organix carrot Stix were found to be slightly or definitely not salty enough b the majority of consumers.

Spiciness

Table 30: Frequency of consumer responses for opinion of spiciness

Spiciness	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not spicy enough	46.3%	46.3%	6.1%	14.6%	35.4%	0%
Slightly not spicy enough	35.4%	34.1%	22.0%	46.3%	43.9%	8.5%
Just right	14.6%	18.3%	53.7%	39.0%	19.5%	67.1%
Slightly too spicy	2.4%	1.2%	13.4%	0%	1.2%	19.5%
Definitely too spicy	1.2%	0%	4.9%	0%	0%	4.9%

It is worthwhile noting that only two of the samples had spicy flavourings added to them (the 20% carrot flavoured and the Harvest Snap peas). Of these two samples, the majority of consumers thought that the spiciness was slightly or definitely not enough (60.9%, flavoured carrot) and just right (67.1%, Harvest Snap peas). For the remaining samples, the majority of consumers found the spiciness to be just right (53.7%, flavoured broccoli) or slightly or definitely not spicy enough (unflavoured broccoli and carrot and Organix Stix).

Crunchiness

Table 31: Frequency of consumer responses for opinion of crunchiness

Crunchiness	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not crunchy enough	2.4%	1.2%	0%	1.2%	13.4%	0%
Slightly not crunchy enough	22.0%	17.1%	9.8%	8.5%	34.1%	12.2%
Just right	73.2%	79.3%	89.0%	85.4%	50.0%	85.4%
Slightly too crunchy	2.4%	2.4%	1.2%	3.7%	2.4%	1.2%
Definitely too crunchy	0%	0%	0%	1.2%	0%	1.2%

The majority of consumers thought that the crunchiness of all of the samples was just right (≥50%). A small percentage of consumer also thought that the crunchiness of the samples was slightly not crunchy enough.

Toothpacking

Table 32: Frequency of consumer responses for opinion of toothpacking

Toothpacking	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not toothpacking enough	1.2%	0%	0%	0%	1.2%	0%
Slightly not toothpacking enough	6.1%	3.7%	2.4%	3.7%	7.3%	1.2%
Just right	36.6%	52.4%	63.4%	72.0%	74.4%	85.4%
Slightly too toothpacking	48.8%	35.4%	28.0%	23.2%	15.9%	13.4%
Definitely too toothpacking	7.3%	8.5%	6.1%	1.2%	1.2%	0%

The majority of consumers found the toothpacking of the samples (described to them as the amount the product sticks to the molars) to be just right (>52%) with the exception of the unflavoured broccoli sample where only 36.6% of consumers found the tooth packing to be just right. A number of consumers also found the samples to be slightly too toothpacking, with a third to half find the unflavoured samples, a quarter finding the flavoured samples and approximately 15% finding the market samples to be slightly too toothpacking.

Consumer ideal

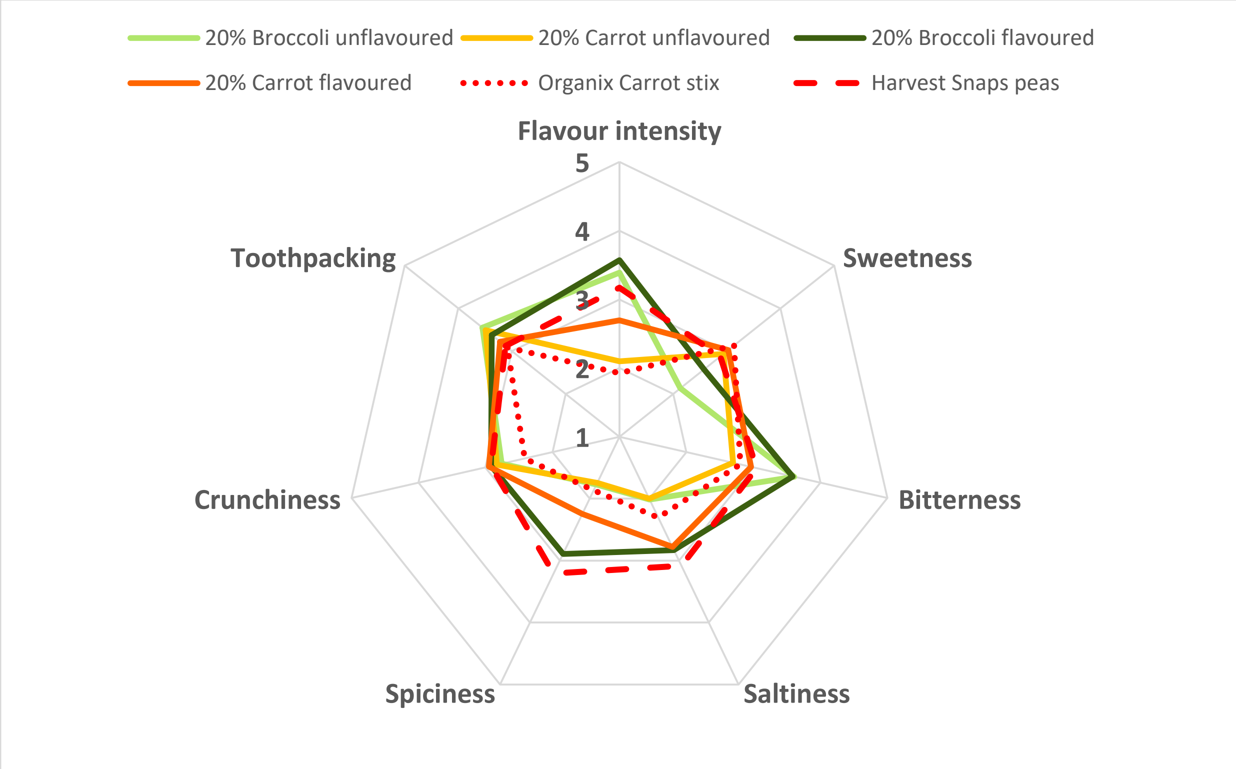


Figure 3: spider plot of the consumer ideal for each intensity attribute for 20% vegetable extrusions

The Harvest Snap peas and flavoured carrot samples largely met the consumer ideal for all attributes, with the exception of spiciness, where the flavoured carrot sample was slightly below the consumer ideal. The two broccoli samples were slightly above the consumer ideal for flavour intensity and bitterness. The unflavoured carrot an Organix Carrot Stix were below the consumer ideal for flavour intensity, bitterness, saltiness and spiciness. Most samples met the consumer ideal for crunchiness and toothpacking, with the exception of the Organix Carrot Stix which was slightly below the consumer ideal.

Size of pieces – as a snack

Table 33: Frequency of consumer response for size of pieces as a snack for 20% vegetable extrusions

	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not big enough	12.2%	11.0%	7.3%	17.1%	14.6%	15.9%
Slightly not big enough	22.0%	28.0%	25.6%	25.6%	6.1%	3.7%
Just right	59.8%	58.5%	61.0%	57.3%	69.5%	72.0%
Slightly too big	4.9%	2.4%	3.7%	0%	9.8%	7.3%
Definitely too big	1.2%	0%	2.4%	0%	0%	1.2%

The size of the pieces as a snack for all samples was found to be just right by the majority of consumers (>55%). Approximately one quarter of consumers also found the size of the pieces for all samples to be slightly or definitely not big enough as a snack.

Size of pieces – as a topping

Table 34: Frequency of consumer response for size of pieces as a topping for 20% vegetable extrusions

	20% Broccoli unflavoured	20% Carrot unflavoured	20% Broccoli flavoured	20% Carrot flavoured	Organix Carrot stix	Harvest Snaps peas
Definitely not big enough	7.3%	7.3%	2.4%	8.5%	6.1%	11.0%
Slightly not big enough	9.8%	11.0%	11.0%	11.0%	8.5%	4.9%
Just right	25.6%	40.2%	37.8%	41.5%	20.7%	15.9%
Slightly too big	42.7%	34.1%	35.4%	35.4%	31.7%	31.7%
Definitely too big	14.6%	7.3%	13.4%	3.7%	32.9%	36.6%

Consumer response to the size of the individual pieces as a topping varied. Approximately 40% of consumers found the size of the unflavoured carrot, flavoured broccoli and flavoured carrot to be just right as a topping. A further 30% found them to be slightly too big. The majority of consumers (>50%) found the unflavoured broccoli, Organix Stix and Harvest Snap peas to be slightly or definitely too big for use as a topping.

Purchase intent

Table 35: Frequency of consumer responses for purchase intent of 20% vegetable extrusions

Purchase intent	% of respondents
Definitely wouldn't buy it	6.1%
Probably wouldn't buy it	15.9%
Not sure	19.5%
Probably would buy it	36.6%
Definitely would buy it	22.0%

The majority of consumers probably or definitely would buy 20% vegetable extrudates (58.6%), however, 20% were not sure and 16% probably wouldn't buy them.

Suitability of application

Usage

Table 36: Frequency of consumer responses for the different uses of 20% vegetable extrusions

Use	% of respondents
As a healthy snack option	79.3%
On its own, as an alternative to chips	76.8%
On its own, as an alternative to other snacks	70.7%
On its own, as an alternative to nuts	52.4%
Added to salads	34.1%
As a vegetable supplement	31.7%
For my children to eat at school as a source of vegetable	30.5%
To add texture to a dish	30.5%
Added to pastas	12.2%
Added to cereals	2.4%
Other	0%

The most common uses that consumers had for the 20% extrudates were as a healthy snack option (79.3%), as an alternative to chips (76.8%) and as an alternative to other snacks (70.7%). Consumers were least likely to use the 20% extrudates to add to cereals (2.4%) or pastas (12.2%).

Motivation

Table 37: Frequency of consumer responses for the different reasons they would use 20% vegetable extrusions

Motivation	% respondents
As an alternative to chips	78.0%
As an alternative to nuts	45.1%
To make meals more interesting by adding new textures and flavours	40.2%
As a vegetable supplement	36.6%
To increase my or my partners vegetable intake	36.6%
To increase my child's vegetable intake	31.7%
To add texture to a dish	30.5%
For my children to eat at school as a source of vegetables	26.8%
Other	1.2%

Consumers listed as an alternative to chips (78.0%) and nuts (45.1%) as the most common reasons to use 20% vegetable extrudates. The least common reasons were for kids to eat at school as a source of vegetables.

Similar products

Table 38: Frequency of consumer responses for the products they currently purchase that are similar to 20% vegetable extrusions

Similar prods	%
Natural snacks (e.g.: nuts, dried fruit)	84.1%
Healthy snacks for myself/my partner (e.g.: lentil chips, chickpea chips)	68.3%
Crunchy toppings (e.g.: nuts, seeds) to use on/in savoury dishes (e.g.: soups, dips, pastas, salads)	65.9%
Healthy snacks for my children	14.6%
Other	1.2%

When asked what products consumers are currently purchasing that are similar to 20% vegetable extrudates, the most common were natural snacks such as nuts and dried fruit (84.1%). Specific products currently purchased include:

- Popcorn
- Crackers
- Vegetable sticks and chips
- Date balls, sultanas, fruit balls
- Nut/muesli bars
- Rice crackers

Conclusion, discussion and recommendations

The main conclusions of this research were:

- Vegetable powders:
    - *Overall liking* was higher for the broccoli powder than the carrot powder. Broccoli powder scored just above the neutral point, and carrot powder just below the neutral point for *liking*.
    - *Overall*, both samples largely met the consumer ideal for *texture* attributes. Lower *liking* of the carrot sample was mainly related to its *flavour* profile, which was deemed *too intense, slightly too bitter* and not *salty enough*.
    - Purchase intent was positive for the powders, with approximately 50% of consumers indicating that they *probably*, or *definitely would buy* them.
    - Consumers indicated that they would use the 100% vegetable powders to add to dips, spreads, soups and pasta dishes and to make meals more interesting by adding new flavours.
- 100% vegetable extrudates:
    - *Overall*, consumers *liked* the 100% carrot extrudates significantly more than they did the 100% broccoli extrudates, however, they both scored quite low on the 9-point hedonic scale (<5).
    - Both samples did not meet the consumer ideal for *flavour* (too *intense* and suboptimal *sweetness*), and the broccoli also did not meet consumer ideal for *appearance* and *texture (*too *crunchy)*
    - Results of purchase intent were mixed, with 40% of consumers each indicating that they *probably* or *definitely would*, and *probably* or *definitely would not* buy the vegetable extrudates.
    - The majority of consumers found the broccoli (74%) and carrot (55%) extrudates to be *too small* as a snack but just right as a topping (59% and 45%, respectively). Consumers indicated that they would use the 100% vegetable extrudates as a healthy snack option (54%), or alternative to chips (44%) or other snacks (44%) and to make meals more interesting by adding new textures and flavours (48%)
- 20% vegetable extrudates:
    - The flavoured vegetable extrudates were *liked* more than the unflavoured extrudates. With the flavoured extrudates, the flavoured carrot was *liked* more than the flavoured broccoli
    - Flavoured carrot had a relatively high score on the 9-point hedonic scale (>7) showing high *overall liking* by consumers. It was equally preferred to the commercial benchmark Harvest Snap Peas and higher than the commercial benchmark Organix Carrot Stix. Flavoured broccoli, although slightly lower in *liking* (5.5), was still on par in liking with the commercial benchmark Organix Carrot Stix.

- Flavoured carrot had good sensory appeal in all modalities, where flavoured broccoli was too *intense* in *flavour*.
- As a snack, the *size* of the extrudates were found either *just right* or *slightly too small,* whereas as a topping there were *slightly too big*.
- Purchase intent was largely positive among consumers with 59% indicating that they *probably* or *definitely would buy* them.
- The most common uses that consumers had for the 20% extrudates were as a healthy snack option (79%) or as an alternative to chips (77%) and other snacks (71%).

This consumer research study provides insights into the relative consumer acceptance of the vegetable extrudates and powder. Results show that the 20% flavoured extrudates had good consumer sensory acceptance and purchase intent, with the flavoured carrot sample scoring similarly or higher than the commercial benchmarks. Consumers have also indicated numerous ways in which they would use them at home, including, but not limited to, as a healthy snack alternative. As taste is of critical importance to consumer choice for snacks, overall results indicate good commercial potential for 20% flavoured extrudates.

The vegetable powders scored above the neutral point for their *overall liking* and also had a positive response to purchase intent. As these products are ingredients to add to other foods and not stand-alone foods (like snacks) the slightly lower liking ratings should not be seen as problematic.

Consumer perception of sensory attributes and feedback relative to ideal should be interpreted with care, and not taken at face value for further product development. For example, consumers have indicated in some cases that a product is *too intense in flavour* but also *not salty enough*. Increasing saltiness through addition of sodium chloride would increase flavour intensity further due to the flavour enhancing effect of salt, however, excess use of such ingredients is discouraged.

Recommendations:

- Both vegetable powders and extrudates seem to have potential to further develop for commercialisation
- Within the vegetable powders, the broccoli powder seems to have higher potential than the carrot powder
- Within the vegetable extrudates, it is recommended to further focus on extrudates with a lower vegetable content (20% rather than 100%) and with flavouring.
-

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Creating Value from Edible Vegetable Waste

Project VG 15076

Final Report

Appendix 3: Activity 3

Fermentation for the production of functional foods and ingredients

Client

Horticulture Innovation Australia Limited

Level 8, 1 Chifley Square

Sydney, NSW, 2000

[Insert ISBN or ISSN and cataloguing-in-publication (CiP) information if required]

[CSIRO Agriculture & Food]

Citation

Terefe NS, McAuley CM, Weerakkody R, Maeva Broch, David Beale, and Augustin MA (2018). Creating value from edible vegetable waste: Fermentation for the production of functional foods and ingredients. Final report. CSIRO, Australia.

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Contents

Executive Summary

Fruit and vegetable waste make up a large proportion of the food loss in the supply chain. The majority of this loss in the affluent Western nations is due to cosmetic market specifications with only limited amount lost during processing (FAO, 2011). Carrot and broccoli are among the vegetables with the highest quantitative loss in Australia. The objective of this project activity was to develop lactic acid bacteria fermentation processes for the stabilisation and conversion of broccoli and carrot biomass to safe, stable and functional food products. Pureed vegetables, as opposed to shredded vegetables as in traditional vegetable fermentation, were selected for the fermentation processes development so as to obtain versatile products that can be converted into powder or directly used as ingredients in beverages, smoothies, dips, sauces, baby food and formulated foods for older adults.

The project involved (i) the development of laboratory scale processes for the production of fermented carrot and broccoli puree, (ii) physicochemical, nutritional and microbiological characterisation of the products, iii) microbial challenge studies to determine the robustness of the fermentation process to mitigate microbiological risks from incidental contamination at the various stages in the process, (iv) scale up of the fermentation processes to pilot scale, (v) development of Hazard Analysis and Critical Control Points (HACCP) and food safety plans for production of food grade products and (vi) sensory assessment of the products by a trained sensory panel.

With respect to carrot puree fermentation, the laboratory scale process development involved evaluation of five commercially available vegetable starter cultures viz. Lyofast, Caldwell's, Wilderness family naturals, Mad Millie and Cutting Edge starter cultures and comparison with a culture developed by CSIRO for carrot fermentation. The best performing starter cultures for carrot in terms of microbial quality and fermentation rate were Lyofast, Mad Millie and the CSIRO culture. At equivalent dosage, the CSIRO culture enabled the shortest fermentation time of 8 hrs to a target pH of 4.2. Fermentation of carrot puree by these cultures resulted in visually appealing products with bright orange colour and enhanced nutritional attributes and free from pathogenic microorganisms. In addition fermentation by Mad Millie culture resulted in 85% increase in Oxygen Radical Absorbance Capacity (ORAC) values, a measure of antioxidant capacity, and 66% increase in total polyphenol content (TPC) whereas fermentation by the CSIRO and Lyofast cultures resulted in 29% and 47% increase in TPC respectively. Furthermore, following fermentation by the Mad Millie culture, about 15% and 12% increase in fibre and protein contents were observed whereas fermentation by the CSIRO culture resulted in 37% and 12% increase in fibre and protein contents of carrot puree samples. The results showed the potential of lactic acid fermentation for enhancing the nutritional and functional properties of carrot. The laboratory scale fermentation process for carrot puree was relatively consistent with no significant batch to batch variation and non-uniformity observed within the samples.

Similar commercial starter cultures as in the case of carrot were evaluated for laboratory scale fermentation process development of broccoli puree and compared with a culture developed by

CSIRO for the fermentation of broccoli puree. As in the case of the carrot puree, the shortest fermentation time was achieved with the CSIRO culture followed by the Wilderness Family Naturals starter culture. The worst performer for broccoli was the Lyofast culture with the other commercial cultures performing in a similar way. In the case of broccoli, there was a significant batch to batch variation even when similar fermentation conditions (mixing, starter type, inoculum size) were maintained which indicates significant variability in the raw material. The microbial quality of the fermented broccoli purees was excellent with no spoilage and pathogenic organisms detected irrespective of the starter culture. Fermentation by the CSIRO culture resulted in a 50% increase in TPC and 20% increase in antioxidant capacity, as reflected by ORAC values. Fermentation by the Wilderness Family Naturals culture resulted in about 50% increase in TPC and 50% reduction in ORAC values, which was somehow unexpected since ORAC and TPC are usually correlated as measures of total antioxidant capacity, albeit based on different measuring principles. This may in part be attributed to the production of metabolites with radical scavenging activity which do not contribute to the measured value of TPC. In order to understand batch to batch variation, preliminary investigation comparing different batches of broccoli and carrot were conducted using targeted and untargeted LC-MS metabolite profiling. The result indicated much more batch to batch variability in the metabolite profile of raw broccoli compared to carrot with consequences on the rate of fermentation. It is recommended that further investigation be conducted using similar methodologies to understand the effect of factors such as postharvest storage and variety on broccoli fermentation process as a basis for developing consistent process and product quality attributes during larger scale production.

The laboratory scale fermentation process for both carrot and broccoli puree resulted in products with no detectable level of pathogenic microorganisms. However, in order to assess the robustness of the fermentation process to control incidental contamination by pathogenic microorganisms, challenge studies were conducted with four pathogens that can pose potential risk in the fermented products so as to determine if the fermentation process was able to inhibit the growth of these organisms. The pathogens assessed were five-strain cocktails each of *Escherichia coli*, *Salmonella*, *Listeria monocytogenes* and *Bacillus cereus*. With respect to carrot, preliminary experiments with *E. coli* strains as challenge organisms indicated that the process in its current state was not able to eliminate risks that may arise from contamination with such organisms. Thus, a pre-processing heating step was introduced into the process and a HACCP plan was developed for food grade production of fermented carrot which included preheating of carrot to a core temperature of 80 °C as a basis for process scale up and food grade production. With broccoli, challenge studies were conducted with the four challenge organisms. The challenge study showed that the broccoli fermentation process under the current protocol was sufficiently robust to mitigate risks emanating from pathogenic organisms including *E. coli*, *Salmonella*, *Listeria* and *B. cereus* that can potentially contaminate the raw material. Based on the challenge study, a HACCP plan was developed for food grade production of fermented broccoli puree which included a lower target pH of 3.8 to control potential risks from contamination by *Listeria monocytogenes*.

The laboratory scale carrot and broccoli puree fermentation processes were successfully scaled up to ~20 kg using commercially available starter cultures *viz*. Caldwell's and Lyofast for broccoli and carrot respectively. The fermentation processes in both cases required longer periods owing to the lower target pH (pH 3.8) to minimize food safety risks and perhaps due to changes in the raw material properties and the fermentation conditions i.e. the inability to exclude air and control temperature at the desired condition during pilot scale processing. As in the case of the laboratory scale processes, the pilot scale fermentation processes resulted in products safe for consumption with no detectable level of pathogenic microorganisms, although the yeast count in the products was high in three of the five batches with potential impact on shelf-life stability. This was mainly due to the higher initial load in the raw purees which needs to be addressed in future process development activities. Further process optimisation using an equipment fit for the purpose (i.e. a fermentation tank with an air tight lid and the instrumentation that enables temperature and agitation rate control) and with starters more suited to the respective substrates (e.g. the CSIRO cultures for broccoli and carrot) will be required prior to commercial scale development of these processes. Studies are also required in order to establish suitable storage conditions, shelf-lives of the products and whether post-fermentation pasteurisation is required for shelf-life extension. It should be recognised that the HACCP plans developed in this study are specific to the raw materials sourced and processed exactly as described in the study using the same starter cultures, at the same dosage and the same fermentation condition. Any deviation from that requires a separate microbial challenge study and HACCP plan developed accordingly. In addition, , the heat treatment condition for carrot needs to be optimised by conducting challenge studies on a process that incorporates surface decontamination using a short hot water blanching since most of the potential contaminants are on the surface of the vegetable.

Sensory assessment of the fermented carrot and broccoli purees was conducted using a trained panel with and without the addition of yoghurt. The results indicate that the products can be used as ingredients in several food products including beverages, smoothies, dips and sauces as envisaged with no objectionable flavour noted by the panellists. The result also showed that the pre-processing of the purees and their final texture needs to be tuned to the intended product applications.

1 General introduction

Fermentation is an ancient food preservation technology as old as human civilisation, with the earliest records dating back to 6000 BC (Caplice & Fitzgerald, 1999). At its inception, its primary purpose was preservation of perishable produce such as milk, meat, fruits and vegetables. Some suggest that ancient humans owe their survival partly to food preservation technologies such as fermentation (Steinkraus, 1991). With time, the role of fermentation changed from its primary purpose of preservation into a technology for creating foods and beverages with desirable sensorial attributes leading to a wide range of fermented products worldwide. A large proportion of the population in developing countries and the Fareast still depend on fermented foods for their nourishment. In the developed west on the other hand, the importance of fermented foods had declined with the advent of modern food preservation technologies with the exception of products such as yogurt, cheese, fermented sausages and bread which survived unto the modern era (Terefe, 2016).

There is a resurgence of interest in fermented foods in recent times, the main driver being the purported health benefits of fermented foods (Hugenholtz, 2013). Most of the health claims around fermented foods are based on folklore and anecdotal evidences. However, there are emerging scientific data from animal model and human studies which support some of these health claims (Marco et al., 2016; Kim et al., 2011; Ruijschop et al., 2008). There is a general consensus that the health status of our gut and the composition of our gut microbiome have substantial impact on our health and wellbeing (Valdes et al., 2018). As such, some of the health benefits derived from fermented foods could be related to the probiotic organisms present in such products (Marco et al., 2016). In addition to being a vehicle for probiotic organisms, the reported beneficial effects of fermented foods could be related to microbial production of bioactive compounds and the enhancement in bioactivity and bioavailability of plant derived bioactive compounds such as polyphenols and carotenoids during fermentation. Fermentation also enriches foods with nutrients such as protein, vitamins and minerals, improve the bioavailability and bioaccessbility of nutrients such as proteins and minerals in complex matrices such legumes and degrade anti-nutritional factors and toxins improving the nutritional status and wellbeing of populations dependent on such foods (Terefe et al., 2016).

Fruit and vegetable waste make up a large proportion of the food loss in the supply chain. The majority of this loss in the affluent Western nations is due to cosmetic market specifications with only limited amount lost during processing (FAO, 2011). Carrot and broccoli are among the vegetables with the highest quantitative loss in Australia. According to a research by Horticulture Australia, less than 50% of broccoli produce makes it to the premium market and more than 31% is wasted. The same is the case with carrot with over 38% loss due to out of specification (23%), damage and cracks (10%) and during processing (5%)(Roger, 2013). Interestingly, based on data from 2012, only 6% of the population aged two and above meets the WHO recommended daily intake of vegetables in Australia (ABS, 2012). Thus, one way of reducing wastage is encouraging consumption of vegetables. Fermentation as a technology that may help in this effort by providing products with differentiated sensory profile and potential health benefits both for domestic and export markets. Moreover, fermentation as a preservation technology prolongs the postharvest life of vegetables reducing loss. It also enables the utilisation of second grade produce that does not meet the premium market specification as well as the 'traditionally inedible' parts of the vegetables that are left in the field or used as animal feed.

The fermentation process that is commonly used for the preservation of vegetables is lactic acid fermentation, which utilises the growth and metabolic activity of lactic acid bacteria for preservation and transformation of food materials. The metabolites produced by lactic acid bacteria (LAB) such as organic acids, carbon dioxide, hydrogen peroxide and antimicrobial peptides such as bacteriocins create an environment which supress pathogenic and spoilage organisms, thereby enhancing the safety and stability of food products (Di Cagno, 2013). Apart from enhancing the safety of food products, lactic acid fermentation imparts characteristic flavour and texture and nutritional and health promoting attributes to food substrates (Terefe, 2016). Commonly consumed foods such as yogurt, fermented sausages and fermented vegetables such as sauerkraut and kimchi are products of lactic acid bacteria fermentation. The objective of this project activity was to develop lactic acid bacteria fermentation processes for the stabilisation and conversion of broccoli and carrot biomass to safe, stable and functional food products. Pureed vegetables, as opposed to shredded vegetables as in traditional vegetable fermentation, were selected for the fermentation processes development so as to obtain versatile products that can be converted into powder or directly used as ingredients in beverages, smoothies, dips, sauces, baby food and formulated foods for the elderly.

The project involved the (i) development of laboratory scale processes for the production of fermented carrot and broccoli puree, (ii) physicochemical, nutritional and microbiological characterisation of the products, (iii) microbial challenge studies to determine the robustness of the fermentation process to mitigate microbiological risks from incidental contamination at the various stages in the process, (iv) scale up of the fermentation processes to pilot scale, development of HACCP and food safety plans for production of food grade products and (v) sensory assessment of the products by a trained sensory panel.

2 Laboratory scale fermentation process development

2.1 Introduction

The objective of this work was to develop laboratory scale lactic acid fermentation processes for the stabilisation and conversion of second grade carrot and broccoli to microbiologically safe and stable and nutritionally enriched and functional ingredients for potential applications in beverages, smoothies, dips, sauces, baby food and foods for the elderly. Preliminary investigations at the initial phase of the project (reported in milestone 2) were used as the basis for these process development activities.

2.2 Materials and Methods

2.2.1 Materials

Market fresh carrot (regular variety) and broccoli were purchased from local Coles supermarket. All chemicals and reagents were analytical grade or better and were purchased from major chemical suppliers such as Sigma and Oxoid as detailed in the description of the various methods. Five commercials starter cultures sourced from different suppliers (Table 1) were evaluated for use as starters in the carrot and broccoli fermentation processes. The performance of these cultures was compared with consortia of lactic acid bacteria (LAB) isolated from Australian carrot (hereafter referred to as Carrot LAB) and broccoli (hereafter referred to as Broccoli LAB) developed by CSIRO within an internally funded project for carrot and broccoli fermentation respectively. Broccoli LAB was a consortia of seven lactic acid bacteria isolates (Five *Lactobacillus plantarum* and two *Leuconostsoc mesenteroides*). Carrot LAB consisted of four LAB isolates from carrot (one *L. plantarum*, two *Leu. mesenteroides*) and one LAB isolate from broccoli (*L. plantarum*). The commercial starters were used in the trials at the dosage recommended by the manufactures as well as increased or decreased doses, where possible, to have comparable starter culture concentrations to the CSIRO cultures. The commercial starters were used in the experiments after conditioning (hydration) in a water bath maintained at 30 °C for 15 min since all the starters were in dry format.

Table 1 Commercial vegetable starter cultures obtained from international manufacturers

CULTURE	MANUFACTURER	CULTURE ORIGIN	CULTURE COMPOSITION	RECOMMENDED DOSAGE
Caldwell's Starter Culture	Caldwell Bio Fermentation Canada	Canada	*Lactobacillus plantarum, Leuconostoc mesenteroides, Pediococcus acidilactici*	2 g sachet makes 2 kg vegetables. Use 0.1 g for 100 g vegetables (~10^6 CFU/g).
Cutting Edge Starter Culture	Cutting Edge Cultures	USA	*Lactobacillus plantarum, Leuconostoc mesenteroides, Pediococcus acidilactici*	2 g sachet makes 5 lb vegetables. Use 0.1 g for 100 g vegetables (~10^6 CFU/g).
Lyofast	Sacco	Italy	*Lactobacillus rhamnosus, Lactobacillus plantarum*	1 sachet (~0.68 g) makes 100 kg vegetables. Therefore ~ 0.0068 g culture for 100 g vegetables (~10^9 CFU/g).
Mad Millie Fermented Vegetable Culture	Mad Millie	UK	*Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis*	2 g sachet makes 2 kg vegetables. Use 0.1 g for 100 g vegetables (~10^7 CFU/g).
Wilderness Family Naturals Cultured Vegetable Starter	Wilderness Family Naturals	Germany	*Lactococcus lactis* subsp., *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis*, *Leuconostoc* subsp.	3 g sachet makes 4 quarts. Use 0.1 g for 100 g vegetables (~10^7 CFU/g).

2.2.2 Carrot fermentation experiments

Preliminary experiments were conducted to establish sample preparation steps, water to carrot ratio for puree production, the type of carrot (regular versus juicing) and the fermentation temperatures. Based on the preliminary experiments, the following processing steps *viz.* sanitisation to reduce initial microbial load, size reduction and pureeing were selected as sample preparation steps prior to inoculation with the starter cultures, mixing and incubation at the selected temperature to effect fermentation. Sanitization was performed by immersing carrot with the green bottom tip removed in Milton Antibacterial solution (chlorinated solution) for 30 min. Following sanitisation, the carrot samples were sliced using a sanitised knife and chopping board and pureed using a kitchen scale Magic bullet homogeniser (Nutribullet pro 1200 series, LLC, USA) with a 2:1 carrot to water ratio. The carrots were not peeled so as to reduce loss and retain the skin which is rich in phytonutrients. The resulting puree was dispensed into 100 mL glass Schott bottles and used without further heat treatment so as to retain the natural microflora for fermentation while maintaining the stability of heat labile nutrients and phytonutrients.

In order to evaluate the performance of the commercial starter cultures, carrot fermentation experiments were conducted using the commercial starters at comparable dose to that of CSIRO carrot LAB i.e. 10^7 CFU/g, a dosage that was experimentally determined to be optimal for carrot fermentation and the commonly used dosage in the literature. Accordingly, the dosage of Caldwell's and cutting edge starter cultures was increased by 10 times above the recommended dosage in order to get 10^7 CFU/g. In all cases, the powdered cultures were suspended in 1 mL of sterile deionised water. The rehydrated cultures were conditioned in a 30 °C water bath prior to use and 1 mL of rehydrated culture was used to inoculate ~100 g carrot puree sample. All sample bottles, for both the CSIRO LAB and commercial cultures, were stirred for 1 min after culture addition to ensure uniform distribution of culture within the sample. Samples were incubated in a thermostated water bath maintained at 30 °C until the desired target pH was attained in the product. The carrot puree fermentation trials with the commercial starters are summarised in Table 2. The first trial was conducted in order to select the best commercial starters in terms of the fermentation rate and microbial quality of the fermented product. The last two trials were conducted with selected starter cultures for full characterisation of the fermented products with respect to physicochemical, nutritional and microbiological quality attributes.

The progress of the fermentation process was followed using a pH data logger (MM-PIT-4U, EAI instruments, UK), which continually monitored the pH of the samples during fermentation. The fermentation process was completed when the pH of the samples dropped below 4.4, which is considered as the threshold pH for the growth of pathogenic microorganisms.

Table 2 Summary of carrot fermentation experiments

	BATCH		
	CC1	CC2	CC3
NUMBER OF REPLICATES			
CULTURE	INOCULUM IN 100 ML OF CARROT		
CSIRO LAB	10^7 cfu/mL	10^7 cfu/mL	10^7 cfu/mL
Caldwell's Starter Culture	10^7 cfu/mL	ND	ND
Cutting Edge Starter Culture	10^7 cfu/mL	ND	ND
Lyofast	10^8 cfu/mL	10^8 cfu/mL	ND
Mad Millie Fermented Vegetable Culture	10^7 cfu/mL	10^7 cfu/mL	10^7 cfu/mL
Wilderness Family Naturals Cultured Vegetable Starter	10^7 cfu/mL	ND	ND

ND: not done

2.2.3 Broccoli fermentation experiments

Broccoli fermentation experiments were conducted as described for carrot above. Broccoli florets were washed and cut into smaller pieces and were homogenised using a Magic bullet processor with a 3:2 broccoli to water ratio. Samples were aliquoted into 100 mL glass Schott bottles. The 10^{10} cfu/mL cultures of the seven LAB strains were pooled together at the same volumetric proportion and 1mL of the pooled culture was added to the broccoli puree to obtain ~10^8 cfu/mL in each 100 mL Schott bottle.

The commercial cultures were prepared as for the carrot puree experiments, except that in the initial experiment, the starter cultures were not conditioned at 30 °C for 15 min after rehydration. The initial experiment used the recommended dose of each commercial starter culture (Table 3). Subsequent experiments used a dose containing a bacterial concentration comparable to the concentration of the CSIRO LAB as much as practicable. In the case of the higher dose of Wilderness Family Naturals, 2 mL of water was used for each dose to enable hydration. For all of the commercial cultures except Wilderness Family Naturals, 1 mL of rehydrated culture was added to each 100 mL broccoli puree sample. At the higher dose, 2 mL of rehydrated Wilderness Family Naturals culture was added to each sample. For the experiments with 2 mL of Wilderness Family Naturals culture, an additional 1 mL of water was added to the other samples to maintain an equivalent addition of water.

The rate of fermentation was monitored using a pH data logger. Non-uniform fermentation was observed. However, the problem was not as pronounced as in our preliminary investigation perhaps due to the initial thorough mixing. Thus, the pH of the samples during fermentation was measured periodically after mixing the sample until the pH dropped below 4.4. The first two experiments were conducted to determine the fermentation rate using the various commercial starters and select the best commercial starter for fermentation of broccoli puree for first generation products and the last two experiments were conducted for characterising the physicochemical, nutritional and microbial quality of the fermented products.

Table 3 Summary of broccoli fermentation experiments

	BATCH			
	CC1	CC2	CC3	CC4
NUMBER OF REPLICATES	2	2	9	10
CULTURE	INOCULUM IN 100 ML OF BROCCOLI			
CSIRO LAB	10^8 cfu/mL	10^8 cfu/mL	10^8 cfu/mL	10^8 cfu/mL
Caldwell's Starter Culture	10^6 cfu/mL	10^7 cfu/mL	ND	ND
Cutting Edge Starter Culture	10^6 cfu/mL	10^7 cfu/mL	ND	ND
Lyofast	10^9 cfu/mL	ND	ND	ND
Mad Millie Fermented Vegetable Culture	10^7 cfu/mL	10^8 cfu/mL	ND	ND
Wilderness Family Naturals Cultured Vegetable Starter	10^7 cfu/mL	10^8 cfu/mL	10^8 cfu/mL	10^8 cfu/mL

2.2.4 Microbial Analysis

Samples were taken from the raw puree and fermented samples. Samples were diluted as required using Maximum Recovery Diluent (MRD; CM0733, Oxoid, Thermo Fisher Scientific, Scoresby, Victoria, Australia) (Standards Australia, 2004; AS 5013.11.1). Primary dilution samples were prepared by pipetting 1 mL of sample into 9 mL of MRD. The samples were homogenized with a vortex mixer at room temperature. Microbial analysis of the raw puree was conducted in accordance with Di Cagno et al. (2008) with some modification, i.e. mesophilic lactic acid bacteria by plating on MRS agar (MRS; CM0361, Oxoid); total Enterobacteriaceae on 3M™ Petrifilm™ Enterobacteriaceae Count Plates (Thermo Fisher Scientific); *Escherichia coli* and coliforms on 3M™ Petrifilm™ *E. coli*/Coliform Count Plates (Thermo Fisher Scientific); and yeast and mould on Dichloran Rose-Bengal Chloramphenicol Agar (DRBC; CM0727, Oxoid).

All of the raw carrot samples as well as the raw broccoli from batches CC3 and CC4 were tested at Werribee. The samples were spread plated (0.1 mL) (Standards Australia, 1991; AS 1766.1.4) onto MRS agar and incubated at 30 °C for 48-72 h. All colonies on the incubated plates were counted as LAB. Samples were pour plated (1.0 mL) onto both Petrifilm™ Count Plates. Enterobacteriaceae Petrifilm™ were incubated at 30 °C for 24 h. *E. coli*/coliform Petrifilm™ were incubated at 37 °C for 48 h. The Petrifilm™ Count Plates were interpreted according to manufacturer's instructions. The samples were spread plated (0.1 mL) onto DRBC and incubated at 25 °C for 5 d. All colonies on the plates were counted as yeast and mould.

Fermented carrot samples from batches CC1 and CC3 and fermented broccoli samples from batch CC4 were tested at Werribee as for the raw puree samples. Fermented carrot samples from batch CC2 were tested for LAB and total Enterobacteriaceae at Werribee and for *E. coli*, coliforms, *Listeria*, *Salmonella*, *Clostridium perfringens, Bacillus cereus,* coagulase positive Staphylococci (*S. aureus* and other species), yeast and mould at a commercial testing laboratory (DTS Food Assurance, Kensington, Victoria, Australia). The fermented broccoli samples from batch CC3 were tested as above, except that Enterobacteriaceae were also tested at DTS Food Assurance.

2.2.5 Physicochemical and nutritional Analysis

Nutritional analysis

Pooled fermented carrot and broccoli puree samples (from 8 and 9 replicates for carrot and broccoli respectively) were frozen immediately after the fermentation was completed and they were freeze dried. The freeze dried samples were sent to National measurement institute (NMI) for proximate analysis of macronutrients. Reference non-fermented samples were also freeze dried and analysed in the same way.

pH, titratable acidity and colour

The pH of the samples was determined as described above using a pH data logger. The titratable acidity of the samples was measured using an automatic titrator (TIM854, Radiometer analytical, France) in accordance with the OECD method. The total volume of NaOH solution required for titration to the titration end point of pH 8.1 was recorded and converted into gram equivalent of lactic acid per gram of sample in accordance with the following equation (eqn 1).

$$\text{Titratable acidity (g/kg)} = \frac{\text{Titre} \times \text{acid factor} \times 1000}{\text{sample weight (10 gm)}} \quad (1)$$

Where the titre is the volume of 0.1M NaOH in mL required for titration to the end point and the acid factor for lactic acid is 0.009.The colour of the puree samples was measured using Minolta colorimeter (CR-300, Japan), with the colour represented in L*-a*-b* space coordinates and the total colour change (ΔE) during fermentation was calculated as follows (Eqn 2).

$$\Delta E = \sqrt{(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2} \quad (2)$$

Where L_o, a_o and b_o are the average colour coordinates for the unprocessed puree samples.

Oxygen radical absorbance (ORAC) antioxidant capacity, total polyphenol content and β-carotene content analyses

The oxygen radical absorbance (ORAC) assay was conducted in accordance with the method of Huang et al. (2002). The total polyphenol content of the samples was analysed in accordance with Folin-Ciocalteu colorimetric method (Singleton & Rossi, 1965) with modifications. Briefly, 50 mg of freeze dried broccoli or carrot powder was suspended in 10 mL of acidified (1 % HCl) methanol/water (70:30, v/v) solution and extracted in ultrasonic bath (IDK technology Pty Ltd, VIC, Australia) for 8 min. The suspensions were kept for 16 h at 4 °C and filtered with 0.2 µM filter and stored at 4 °C until analysis. 1 mL of 0.2 N Folin-Ciocalteu reagent, 800 µL of sodium carbonate solution (7.5% p/v) and 180 µL Milli-Q grade water were added to the extract (20 µL). After 1 h of incubation in the dark at 37 °C, the absorbance was measured at 765 nm in triplicates with a UV-VIS spectrophotometer (UV-1700 Pharma Spec, SHIMADZU). Gallic acid was as a standard and TPC was expressed as the mg gallic acid equivalent (GAE) per 100 g of fresh weight (mg GAE/100 g FW). The β-carotene content of the samples was analysed using the methods of Biswas et al. (2011) with some modification. Accordingly, 0.1 gm of freeze dried powder was dispersed in 5 mL chilled acetone and kept overnight at 4 °C in the dark before centrifugation at 1370xg for 10 min at 4 °C. The extraction with 5 mL was repeated 3 times with vigorous shaking for 10 min followed by centrifugation. The supernatants from each centrifugation step were pooled together and filtered with Whatman no 42 filter paper and its absorbance was measured at 449 nm using a UV-VIS spectrophotometer. The β-carotene content in the sample was calculated based on a calibration curve developed with known quantity of β-carotene standard dissolved in acetone. The total protein, carbohydrate, fat and fibre content of the fermented samples were analysed at the National measurement institute (NMI) using standard methods.

2.2.6 Data Analysis

Data analysis was conducted using Microsoft excel and Design expert software (version 7.1.3., Stat-Ease Inc., MN, USA).

2.3 Results and Discussion

2.3.1 Comparison of fermentation rate using the various starters

Carrot

The fermentation profile of carrot puree using the various starters are presented in Figure 1. Fast fermentation rate was observed when CSIRO LAB, Lyofast and Mad Millie were used as starters. The fermentation time to reach pH 4.2 are summarised in Table 4, where the shortest time of 7 hrs was achieved with Lyofast, followed by CSIRO (8.7 hrs) and Mad Millie (9 hrs). The fast fermentation rate with Lyofast could be partly attributed to the higher dosage. On the other hand, all the other commercial starters performed poorly resulting in fermentation time between 20 to 25 hrs. The relatively poor performance of the commercial cultures could be partly attributed to the fact that they were in freeze dried matrix compared to that of CSIRO LAB cultures which were kept frozen with glycerol as a cryostabiliser. It has to be noted that the CSIRO LAB were isolated from carrot and broccoli and are well suited to carrot fermentation, which may also have contributed to their excellent performance in carrot fermentation. Further fermentation experiments were conducted with the best commercial starters (Lyofast and Mad Millie) and CSIRO LAB as starters for determining the consistency of the fermentation process and get samples for detailed product characterisation. The fermentation profile from the second carrot experiment is presented in Figure 2 and the fermentation times to attain pH 4.2 are summarised in Table 4. The fermentation time was fairly consistent. Overall, shorter fermentation time was observed compared to our preliminary investigation (milestone 2 report) probably due to the thorough initial mixing of the samples after inoculation in these experiments.

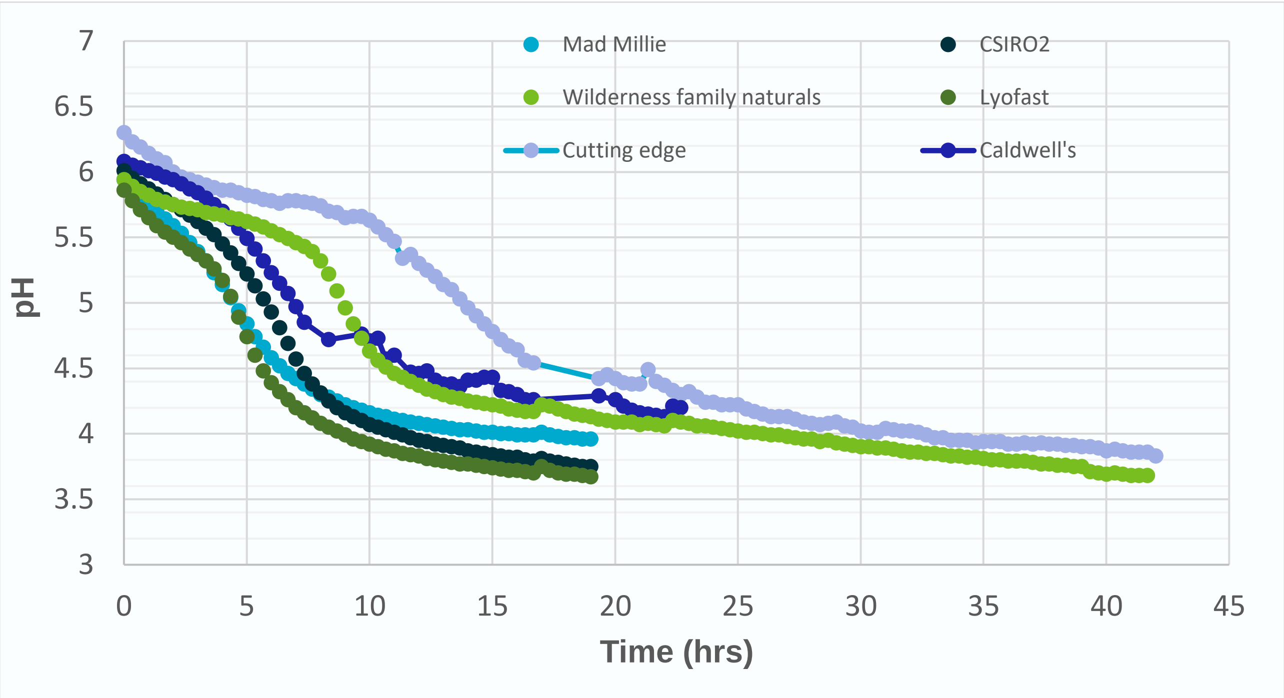

Figure 1 The rate of pH decrease during carrot puree fermentation (2:1 carrot to water ratio) with CSIRO LAB and commercial starters during fermentation at 30 °C

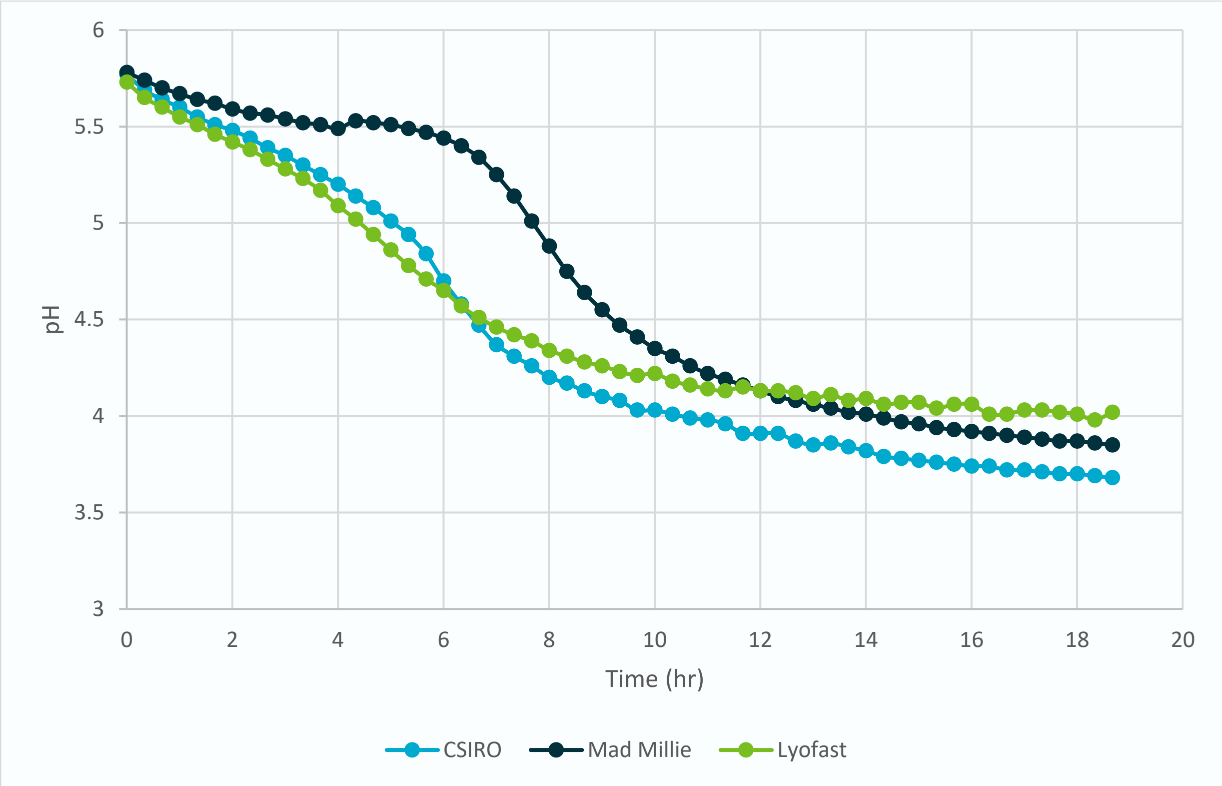

Figure 2 The rate of pH decrease during carrot puree (2:1 carrot to water ratio) fermentation at 30 °C using different starters.

Table 4 Fermentation time required for carrot puree to attain pH 4.2 during fermentation at 30 °C using different starter cultures at dosage of 10^7 CFU/ml with the exception of lyofast (10^8 CFU/ml)

	BATCH	
	CC1	CC2
CULTURE	Fermentation Time (hrs)	
CSIRO LAB	8.7	8
Caldwell's Starter Culture	22.7	ND
Cutting Edge Starter Culture	25	ND
Lyofast	7	10
Mad Millie Fermented Vegetable Culture	9.3	11
Wilderness Family Naturals Cultured Vegetable Starter	23	ND

Broccoli

The rates of broccoli puree fermentation with commercial starters were compared with that of CSIRO LAB at the recommended inoculum concentration of the manufactures as well as comparable inoculum size with that of CSIRO LAB. Examples of broccoli puree fermentation profiles using the different starter cultures are presented in Figure 3. As can be seen, the curves are not smooth due to the inhomogeneous nature of the fermentation process. However, significant improvement in process uniformity was achieved due to the initial through mixing especially when the CSIRO culture was used as a starter. The fermentation profiles of the first batch, where the initial mixing was not as good as in subsequent experiments, had significant non-uniformity which was worse than that observed with the other batches (data not presented). The fermentation times to achieve pH 4.4 in the product are summarised in Table 5. A significant improvement in fermentation time was observed compared to the fermentation times in our preliminary study and there was a substantial decrease in fermentation time with initial thorough mixing of the ferment (compare batch 1 with batch 2).

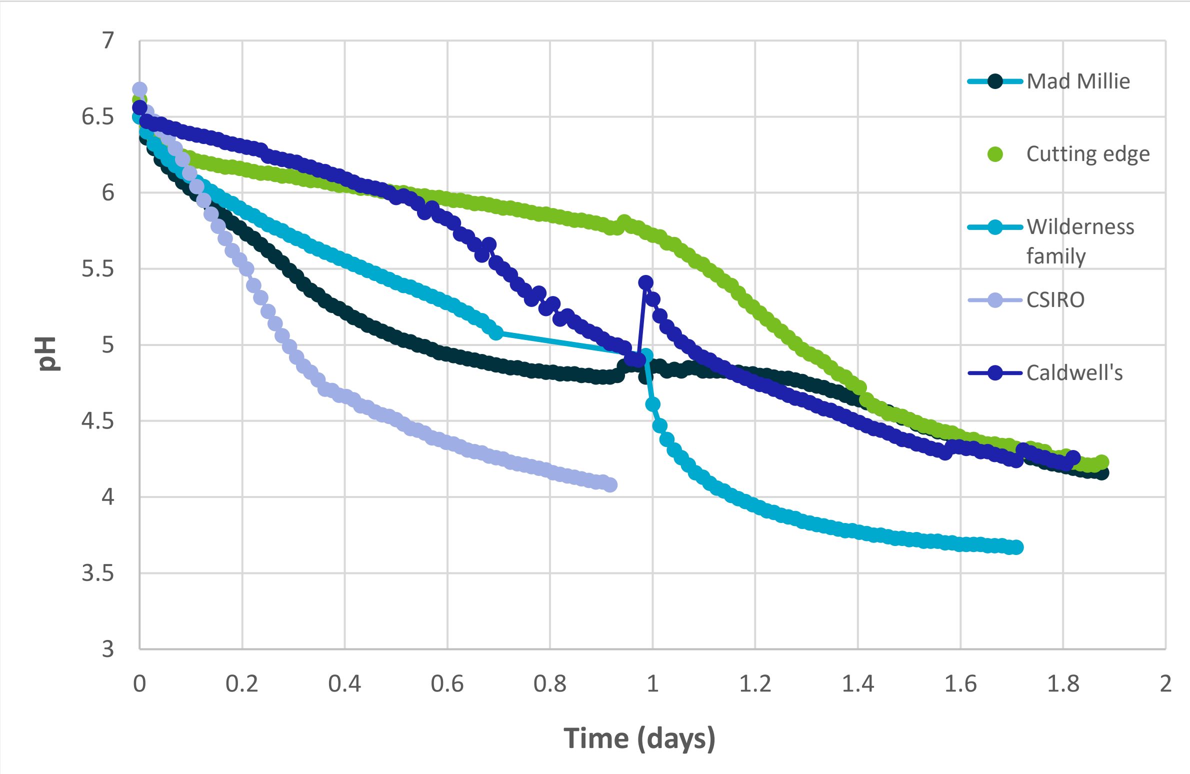

Figure 3 pH change profiles during broccoli puree (3:2 broccoli to water ratio) fermentation at 30 °C using different starter cultures

In all cases, the fastest fermentation was achieved with the CSIRO culture, with half the fermentation time compared to the best commercial cultures. The fermentation time decreased substantially in the second trial for all the starters. For instance, the fermentation time using the CSIRO starter decreased from 3.7 days to 0.5 days. Similar substantial decrease was observed with the commercial starters, which can be partially attributed to an increase in inoculum dosage. However, the initial thorough mixing as well as the properties of the raw material may have contributed to the observed decrease since there was no increase in dosage with respect to the CSIRO culture. This is confirmed in the third trial where the fermentation time increased to 1.9 days for the CSIRO culture although all other processing parameters except the raw material remained constant. Thus, further investigation is required to understand the effect of postharvest storage and variety on the fermentation process so as to achieve consistent processing condition and product quality during process scale up. Lyofast was excluded from the second trial since it showed a very poor performance although its dosage was even higher than that of the CSIRO starter. Further experiments focused on the Wilderness Family Naturals culture and CSIRO LAB since they were the best performers.

Table 5 Fermentation time required for broccoli puree to attain pH 4.4 during fermentation at 30 °C using different starter cultures

	BATCH					
	CC1		CC2		CC3	
Culture	**Dosage**	**Days**	**Dosage**	**Days**	**Dosage**	**Days**
CSIRO LAB	10^8 cfu/mL	3.7	10^8 cfu/mL	0.5	10^8 cfu/mL	1.9
Caldwell's Starter Culture	10^6 cfu/mL	6.6	10^7 cfu/mL	1.4	ND	ND
Cutting Edge Starter Culture	10^6 cfu/mL	10	10^7 cfu/mL	1.5	ND	ND
Lyofast	10^9 cfu/mL	6.5	ND	ND	ND	ND
Mad Millie Fermented Vegetable Culture	10^7 cfu/mL	6.3	10^8 cfu/mL	1.5	ND	ND
Wilderness Family Naturals Cultured Vegetable Starter	10^7 cfu/mL	7	10^8 cfu/mL	1.0	10^8 cfu/mL	2.9

2.3.2 Microbial quality of fermented carrot puree samples

The microbial quality of the carrot puree samples were assessed prior to and after fermentation using the different starters in experiment 1. Data are summarised in Table 6. Fermentation of carrot puree by all the starter cultures resulted in acceptable microbial quality. However, the yeast and mould count in samples fermented by Cutting Edge starter indicating potential for reduced storage stability. The enterobacteriaceae count in the samples fermented by the Wilderness Family Naturals starter culture was also relatively high, although the sample was still in the acceptable range from a food safety perspective. None of the indictor organisms were detected in samples fermented by the other starter cultures. Further experiments were conducted only with the Lyofast and Mad Millie starter cultures which were the most promising in terms of fermentation kinetics and product microbial quality. Samples fermented by these cultures and the CSIRO LAB were further analysed for indicator organisms of microbial quality as well as pathogenic organisms. Data are presented in Table 7. All the starter cultures resulted in fermented carrot puree products with excellent microbial quality safe for consumption with no detection of pathogenic organisms in the samples. Nevertheless, some yeast was detected in all the samples fermented by Lyofast and one of the samples fermented by Mad Millie culture, which can potentially affect the storage stability of those products. No spoilage organism were detected in samples fermented by CSIRO culture. Further microbial challenge experiments will be conducted to evaluate the ability of the fermentation process using the different cultures to inhibit and inactivate pathogenic organisms intentionally introduced into the raw material so as to assess the robustness of the fermentation process to control incidental contamination of the raw material.

2.3.3 Microbial quality of fermented broccoli samples

Our preliminary investigation, reported previously in milestone 2, showed that fermentation by lactic acid bacteria results in a broccoli product with excellent microbial quality with none of the indicator organisms i.e. *enterobacteriaceae*, yeast and mould detected in fermented broccoli puree samples. Thus, only the batches with selected starter cultures were subjected to detailed microbial analysis. Data are presented in Table 8. As can be seen, pathogenic and spoilage microorganisms were not detected in the broccoli puree samples fermented both by the CSIRO and Wilderness Family Naturals starter cultures.

Table 6 Microbial count (CFU/g) of Batch 1 carrot puree (2:1 carrot to water ratio, regular variety) samples prior to and after fermentation at 30 °C

Sample	LAB	Yeast & Mould (PDA)	Yeast & Mould (DRBC)	Enterobacteriaceae	Coliform	*E. coli*
Raw	2E+02	<100	1.5E+03	3E+02	3E+02	2.5E01
CSIRO LAB	1.1E+09	<100	<100	<100	<10	<10
Caldwell	9.6E+08	<100	<100	<10	<10	<10
Cutting edge	1.6E+08	1.6E+03	9.5E+02	<100	NT	<10
Lyofast	1.2E+09	<100	<100	<100	<10	<10
Mad millie	2.2E+08	<100	<100	<100	<10	<10
Wilderness family	4.6E+08	<100	<100	1.9E+02	NT	<10

Table 7 Microbial count of Batch 2 carrot puree samples fermented by CSIRO and selected commercial starters at 30 °C (Note: MPN – most probable number)

Microorganism	Fermented samples		
	CSIRO LAB	Lyofast	Mad Millie
Coliform	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
E. coli	< 3 MPN/g	< 3 MPN/g	< 3 MPN/g
Yeasts	<100 CFU/g	1.2 x10^3 CFU/g	200 CFU/g
Moulds	<100 CFU/g	<100 CFU/g	<100 CFU/g
B. cereus	<100 CFU/g	<100 CFU/g	<100 CFU/g
Coagulase +ve *Staphylococci* (S. Aureus and other spp.	<100 CFU/g	<100 CFU/g	<100 CFU/g
Clostridium perfringens	<10 CFU/g	<10 CFU/g	<10 CFU/g
Salmonella	Not detected/25 g	Not detected/25 g	Not detected/25 g
Listeria	Absent/25 g	Absent/25 g	Absent/25 g

Table 8 Microbial count (CFU/g) of broccoli puree (3:2 broccoli to water ratio) after fermentation using selected starter cultures at 30 °C

Microorganism	Fermented samples	
	CSIRO LAB	Wilderness family
Coliform	< 3 MPN/g	< 3 MPN/g
E. coli	< 3 MPN/g	< 3 MPN/g
Yeasts	<100 CFU/g	<100 CFU/g
Moulds	<100 CFU/g	<100 CFU/g
B. cereus	<100 CFU/g	<100 CFU/g
Coagulase +ve *Staphylococci* (*S. Aureus* and other spp.	<100 CFU/g	<100 CFU/g
Clostridium perfringens	<10 CFU/g	<10 CFU/g
Salmonella	Not detected/25 g	Not detected/25 g
Listeria	Absent/25 g	Absent/25 g

2.3.4 Physiochemical quality of fermented carrot samples

Colour

There was a significant change in the colour coordinates of carrot puree samples during fermentation using the different starters resulting in a relatively high value of total colour difference (ΔE) indicative of a noticeable colour change (Figure 4). The highest total colour difference was observed during fermentation by the Mad Millie culture. Nevertheless, these change resulted in visibly brighter orange colour in the fermented carrot puree products which will have a positive impact on the acceptability of the product by consumers.

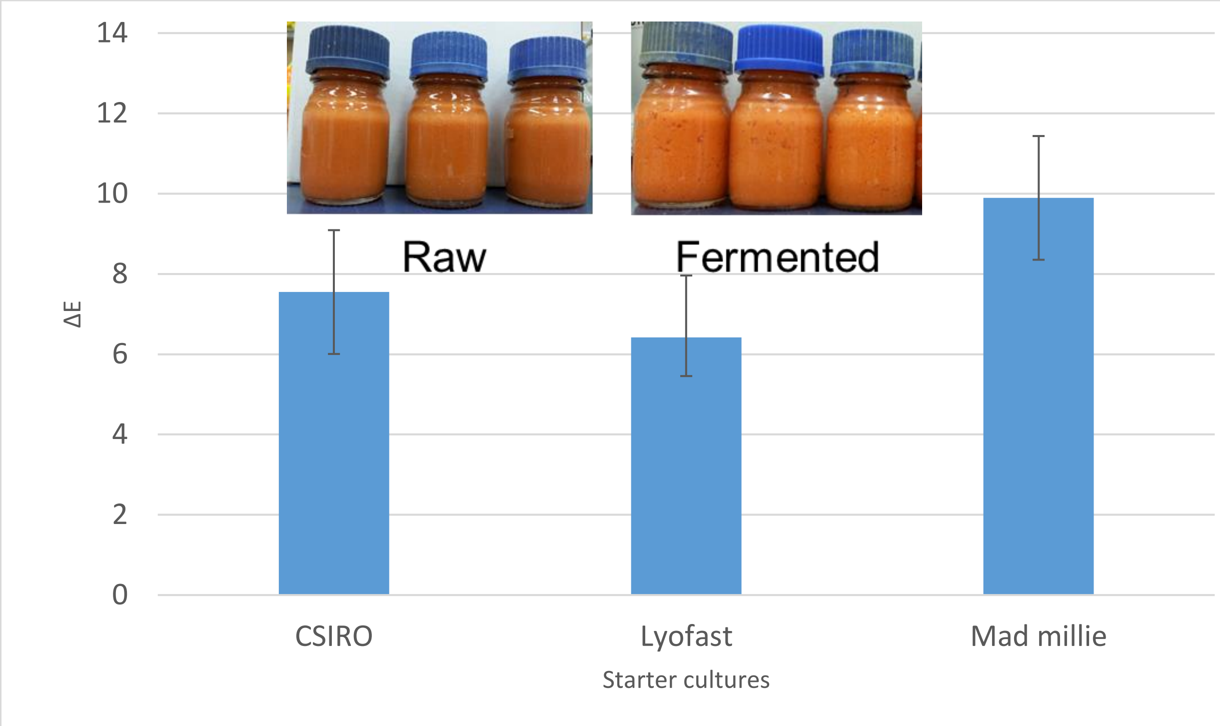

Figure 4 Total colour change in carrot puree samples after fermentation by selected starter cultures at 30 °C. Picture of only Mad millie fermented sample presented since there was no visual difference among the three ferments.

Titratable acidity

As would be expected, fermentation of carrot puree by the different starter cultures resulted in a substantial increase in the acidity of the carrot puree samples (Fig 5). The highest acidity was observed in the samples fermented by the CSIRO starter and the value was about 20% higher than that observed in our preliminary investigation (reported in milestone 2) where all the carrot isolates were pooled together and used as starter in the fermentation of carrot puree. This may have contributed to the better microbial quality of the fermented carrot puree in the current investigation. In all cases, the final pH of the samples was around 4.0.

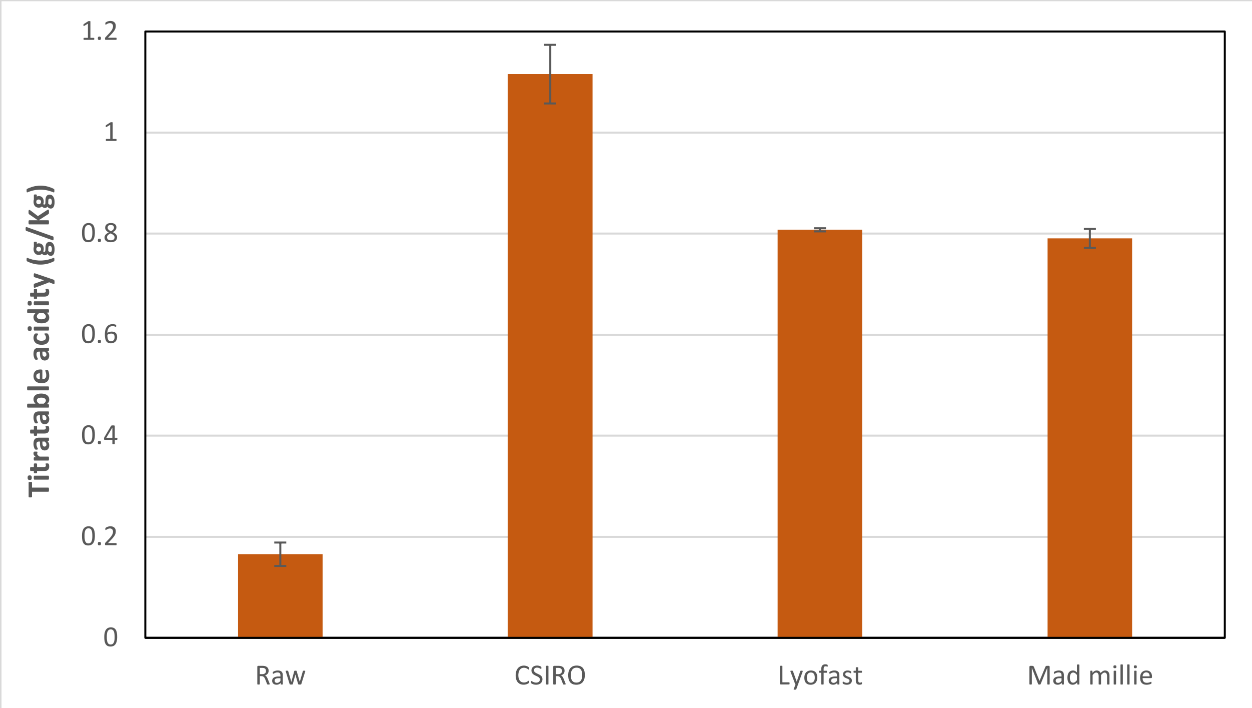

Figure 5 The titratable acidity of fermented carrot puree samples

2.3.5 Physiochemical quality of fermented Broccoli puree samples

Colour

Substantial and visible change in colour of broccoli puree was observed after fermentation with the two starter cultures (Figure 5). There was a significant decrease in greenness (-a) and a slight decrease in lightness L of all the samples. Overall, the samples looked yellow-brownish after fermentation, which could be due to acid and enzymatic hydrolysis of chlorophyll. The colour change was significantly higher ($p<0.05$) in the samples fermented by the wilderness family culture perhaps due to the longer fermentation time.

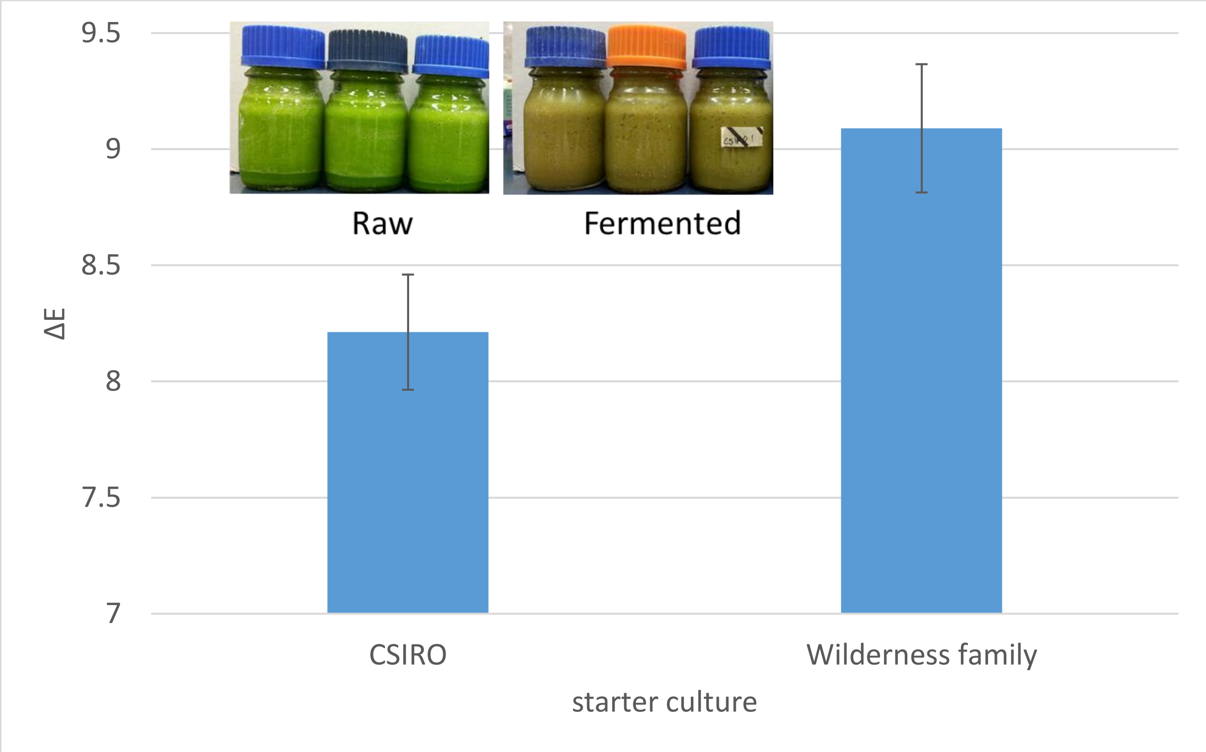

Figure 6 The total colour change in broccoli puree samples after fermentation. Picture presented only for CSIRO LAB fermented samples since there was no visually discernible difference between the two ferments.

Titratable acidity

There was a significant increase in the acidity of broccoli puree samples after fermentation using both starters (Figure 7). The observed increase in acidity was similar in with both starters and slightly less than what was observed in carrot samples fermented by CSIRO LAB, which could be due to the small proportion of *Leu mesenteroides* in the CSIRO broccoli culture.

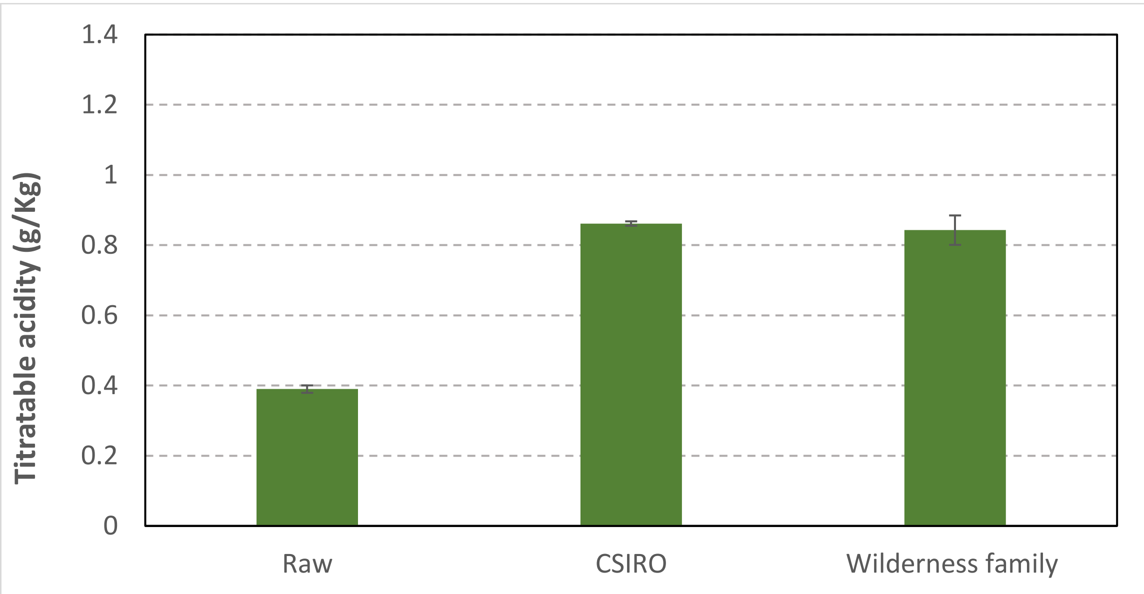

Figure 7 The change in titratable acidity of broccoli puree samples after fermentation

2.3.6 Nutritional quality of fermented carrot samples

Macronutrient profile

The macronutrient profiles of carrot samples prior to and after fermentation using the CSIRO carrot starter and the commercial Mad Millie starter are presented in Table 1. As would be expected, fermentation resulted in a measureable decrease of the carbohydrate content of the samples (excluding fibre), which could be due to the consumption of simple sugars by the fermenting organisms. In addition, substantial increase (~37%) in total fibre content was observed specially in samples fermented by the CSIRO carrot starter. This could be due to the conversion of some of the simple sugars in carrot to exopolysaccharides. The CSIRO culture consists of two *L. mesenteroides* strains which are known to produce exopolysaccharides. There were also slight increases in the total protein and ash content of the samples after fermentation (Table 1). Overall, fermentation improved the nutritional quality of carrot puree samples.

Table 9 Macronutrient profile of carrot fermented using CSIRO carrot and Mad Millie starters (gm/100 gm dry weight)

Sample	Carbohydrate	Protein	Fat	Total fibre	Ash
Raw	57.3	6.7	2.05	27.2	6.7
CSIRO	45.4	7.5	1.9	37.4	7.8
Mad Millie	52.1	7.5	1.9	31.4	7.0

ORAC antioxidant capacity

The data on the ORAC antioxidant capacity of the carrot puree samples prior to an after fermentation with the selected starter cultures are presented in Figure 8. Fermentation by the Lyofast cultures did not have significant effect on the ORAC antioxidant capacity of carrot puree samples. Fermentation by Mad Millie starter culture and the CSIRO culture on the other hand resulted in 85% and 26% increase respectively in the ORAC antioxidant capacity of the puree samples. The basis for this difference is likely to be differences in the metabolite profile obtained with different cultures. A targeted profiling of the antioxidant compounds in carrot may provide a better understanding of the basis for the differences in the effects of the three fermentation processes.

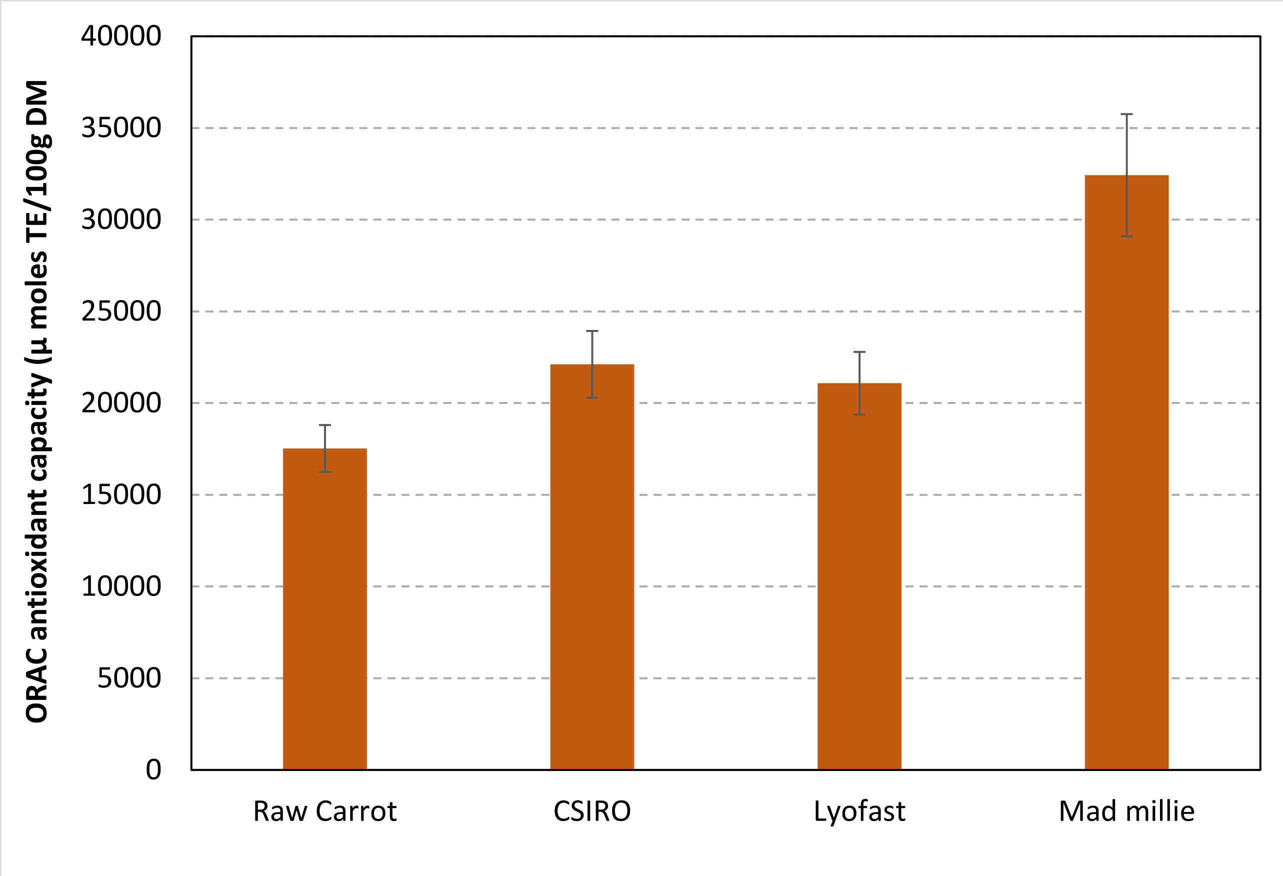

Figure 8 The changes in ORAC antioxidant capacity of carrot puree samples after fermentation by selected starter cultures at 30 °C.

Total polyphenol content

Fermentation by the different starters resulted in a significant increase of the total polyphenol contents (TPC) of carrot puree samples (Figure 9). The highest increase of 66% was observed after fermentation by the Mad Millie culture followed by that of CSIRO and Lyofast which resulted in about 29% and 47% increase in TPC of carrot samples. The TPC trend more or less correlated with that of ORAC antioxidant capacity.

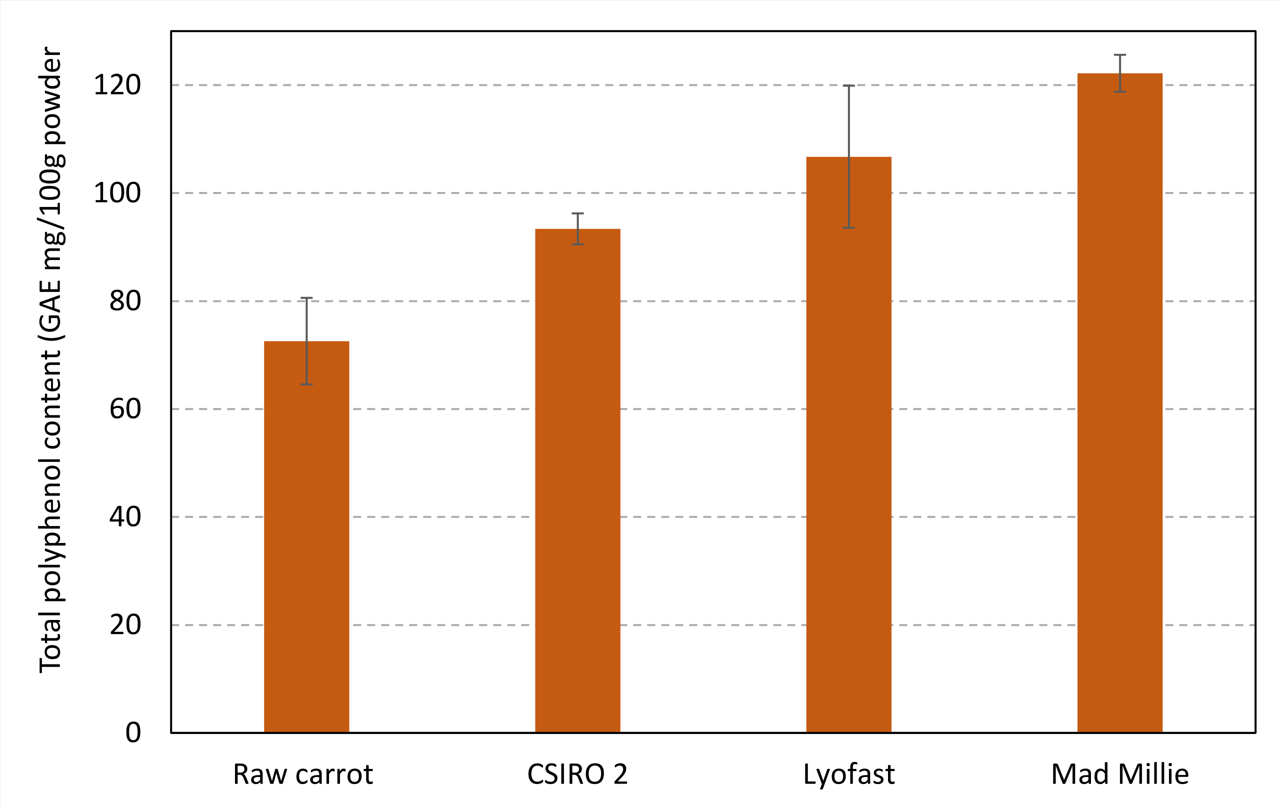

Figure 9 The changes in total polyphenol contents (TPC) of carrot puree samples after fermentation with selected starters at 30 °C.

β- carotene content

The β-carotene contents of carrot puree samples were analysed prior to and after fermentation with the selected starter cultures. Data are presented in Figure 10. In contrast to TPC and ORAC antioxidant capacity, fermentation by the Mad Millie culture caused only a slight increase in the β-carotene content of carrot puree sample. Fermentation by the CSIRO culture and Lyofast on the other hand resulted in ~40% increase in β-carotene content. Interestingly, the highest total colour change (towards a more orange colour) was also observed in the samples fermented by the Mad Millie culture. It seems that the visual colour of fermented carrot puree is not correlated with the β-carotene content.

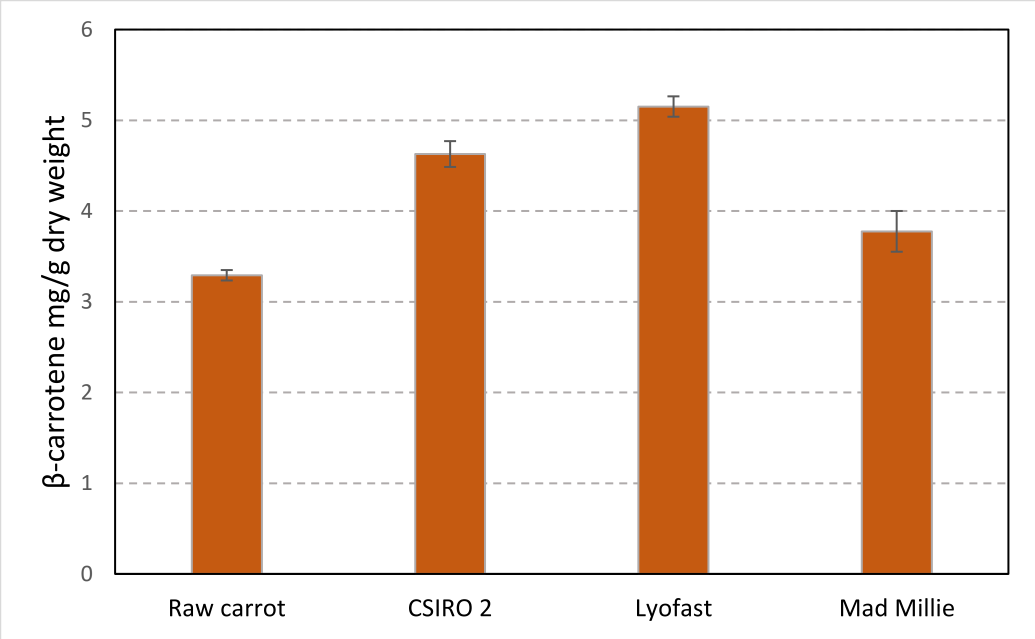

Figure 10 The changes in the β-carotene content of carrot puree samples after fermentation by selected starter cultures at 30 °C.

2.3.7 Nutritional Quality of fermented broccoli puree samples

Macronutrient profile

Fermentation by the CSIRO starter resulted in an increase of the protein and fibre content of broccoli puree whereas the total carbohydrate content (excluding fibre) decreased by about 50% (Table 2). The increase in fibre content can be attributed to the conversion of the simple sugars into exopolysaccharides by the fermenting organisms. The increase in protein content could be due to microbial production of peptides and amino acids during fermentation. There was no significant change in the macronutrient profile of broccoli after fermentation by the WFN starter culture. Considering that sugars are metabolised during fermentation, the observed no decrease in carbohydrate content is rather odd. However, all the commercial starter cultures were freeze dried with a carbohydrate matrix which may have provided sufficient nutrient for the growth of the organisms in broccoli puree. Overall, the CSIRO fermented broccoli puree exhibited better nutritional profile compared to the WFN and the raw samples.

Table 10. Changes in macronutrient profile of broccoli after fermentation (g/100 gm dry weight)

Sample	Carbohydrate	Protein	Fat	Total fibre	Ash
Raw	21.9	35.5	3.2	30	9.4
CSIRO	10.6	39.3	4.3	36	9.6
Wilderness family naturals (WFN)	21.9	36	2.9	30.4	8.8

ORAC antioxidant capacity

In agreement with our results in Milestone 2, fermentation by the CSIRO culture resulted in an increase in the ORAC antioxidant capacity of broccoli puree samples (Figure 11). However, there was only 18% increase compared to the 70% increase observed in our earlier investigation (milestone 2 report). In contrast to the CSIRO culture, fermentation by the Wilderness Family Naturals culture resulted in a 50% reduction in ORAC antioxidant capacity. Further studies are required in order to confirm the result of this trial and understand the basis for it if indeed the result is confirmed.

Total polyphenol content

Fermentation by both starter cultures resulted a significant increase in the total polyphenol content of broccoli puree samples (Figure 12). Fermentation by both starters resulted in about 50% increase in TPC. The result did not correlate well with the change in the ORAC antioxidant capacity as would normally be expected. The reason is not clear and need further investigation.

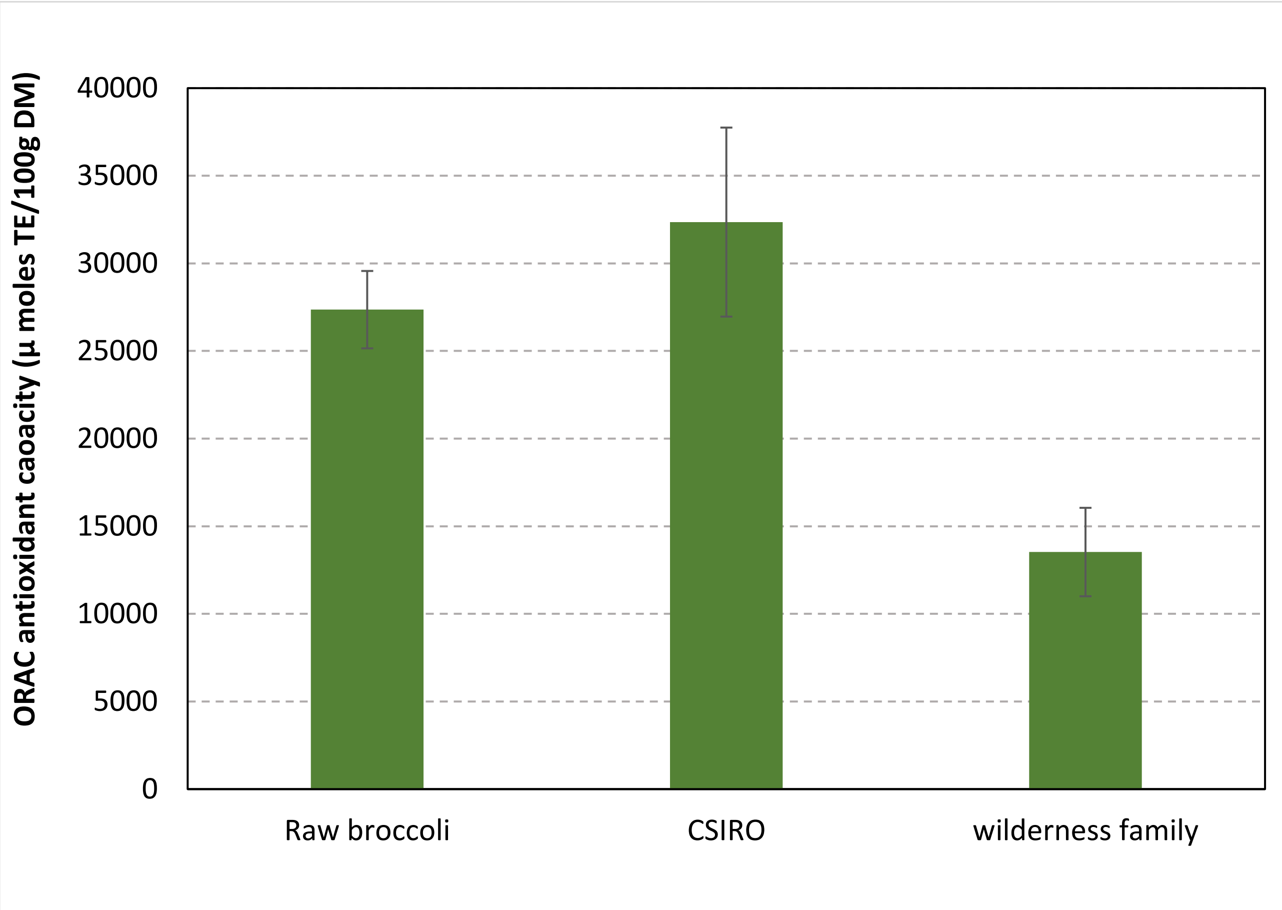

Figure 11 The changes in the ORAC antioxidant capacity of broccoli puree after fermentation with selected starters at 30 °C.

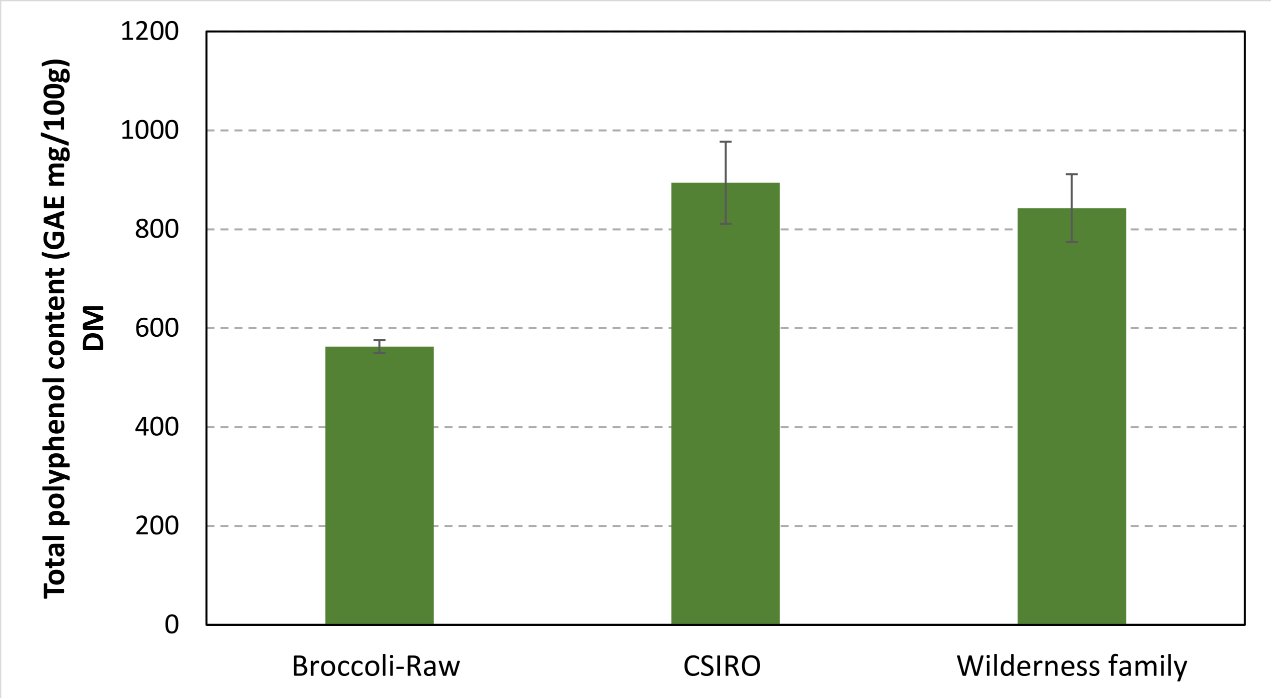

Figure 12 The changes in the total polyphenol content of broccoli puree samples after fermentation by selected starter cultures at 30 °C.

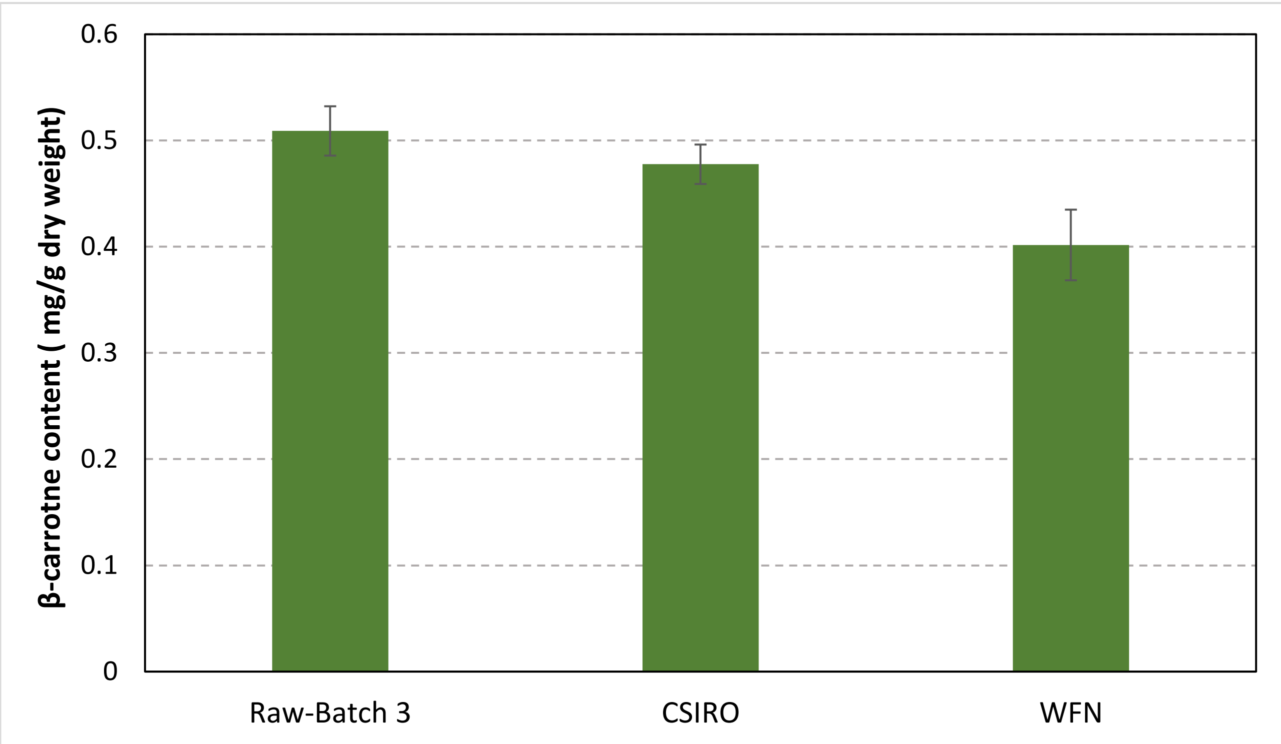

Figure 13 The changes in the β-carotene content of broccoli puree samples after fermentation by selected starter cultures at 30 °C (WFN: Wilderness Family Naturals).

β-carotene content

Fermentation resulted in a slight decrease in the β-carotene content of broccoli puree samples (Figure 13) which is in contrast to what was observed with the carrot samples. This could be related to the difference in matrix composition as well as the metabolic capacity of the starter cultures. The observed decrease was statistically significant only for samples fermented by the Wilderness Family culture.

2.4 Conclusion and Recommendation

Following preliminary experiments on carrot and broccoli puree fermentation, five commercial vegetable fermentation starter cultures namely Lyofast, Cutting edge, Wilderness Family naturals, Caldwell's and Mad Millie were evaluated for the fermentation of both products and compared with cultures developed by CSIRO in a separate project. With respect to carrot puree fermentation, the best performing starter cultures in terms of microbial quality and fermentation rate were Lyofast, Mad Millie and the CSIRO culture. At equivalent dosage, the CSIRO culture enabled the shortest fermentation time of 8 hrs to the target pH of 4.2, a significant improvement from the preliminary investigations reported in milestone 2 (a reduction in fermentation time by half), which was achieved by thorough initial mixing of the ferment. Fermentation of carrot puree by these cultures resulted in visually appealing bright orange products free from pathogenic organisms with enhanced nutritional attributes. Fermentation by Mad Millie culture resulted in 85% increase in ORAC antioxidant capacity and 66% increase in total polyphenol content (TPC) while maintaining the β-carotene content. Fermentation by the CSIRO culture resulted in 40% increase in β-carotene content and about 27% increase in ORAC and TPC of carrot puree indicating the potential of fermentation for enhancing the functional properties of food products.

As in the case of the carrot puree, the shortest fermentation time in the case of broccoli puree was achieved with the CSIRO culture, which to a target pH of 4.4 ranged from 0.5 to 1.9 days in the samples with thorough initial mixing, a significant improvement from the preliminary investigation (reported in milestone 2) where the shortest fermentation time was six days. Among the commercial starters, the best fermentation rate was achieved with the Wilderness Family starter culture, which resulted in fermentation times ranging from 1 to 2.9 days. There was clearly a significant batch to batch variation even when similar fermentation conditions (mixing, starter type, inoculum size) were maintained which indicates significant variability in the raw material. Thus, further investigation is required to understand the effect of postharvest storage and variety on the fermentation process so as to achieve consistent processing condition and product quality during process scale up. The microbial quality of the fermented broccoli purees was excellent with no spoilage and pathogenic organisms detected in all samples fermented by both the CSIRO and wilderness family starters. Fermentation by the CSIRO culture resulted in a 50% increase in TPC and 20% increase in ORAC antioxidant capacity. Fermentation by the wilderness family culture resulted in about 50% increase in TPC and 50% reduction in ORAC antioxidant capacity, which was somehow unexpected since ORAC and TPC are usually correlated.

The work conducted in this section enabled the selection of two potentially viable commercial starter cultures (Lyofast and Mad Millie) and one commercial starter culture (Wilderness family) for first generation fermented carrot and broccoli products respectively. Further microbial challenge experiments will be conducted to evaluate the ability of the fermentation processes using the different starter cultures to inhibit and inactivate pathogenic organisms intentionally introduced into the raw material so as to assess the robustness of the fermentation process to control incidental contamination of the raw material prior to pilot scale trials.

3 Targeted and untargeted LC-MS based metabolomics for characterisation of raw and fermented products

3.1 Introduction

Our investigations during laboratory scale fermentation process development showed significant batch to batch variability with respect to fermentation time and effects of fermentation on antioxidant capacity particularly in the case of broccoli. The objective of this study was to gain a better understanding of the underlying causes for batch to batch variation through targeted and untargeted liquid chromatography coupled with mass spectroscopy (LC-MS) analysis. Such approaches enable global understanding of the basis for variations that arise from raw material variability, post-harvest handling and storage conditions and processing.

3.2 Materials and Methods

3.2.1 Fermented sample preparation

Fermented carrot and broccoli puree samples were prepared as described in chapter 2. Samples from two batches of raw and fermented broccoli were freeze-dried for metabolomics characterisation.

3.2.2 LC-MS targeted and untargeted metabolomics analysis

Freeze dried samples were used for metabolomics analysis. The samples (100 mg) were extracted using 1 ml of ice-cold methanol and Milli-Q water (50:50, v:v), which comprised 100 mg/ml of caffeine as an internal standard. The samples were then vortexed for 2 minutes prior to being sonicated (40 Hz) for 30 minutes. Samples were then centrifuged at 20,000 rpm at 4°C for 30 minutes, and the supernatant transferred to clean silanised LC-MS vials. Samples were analysed by injecting 1.4 µl into an Agilent 6410 LC-QQQ HPLC (Agilent Technologies, Santa Clara, California, USA). The analyses were performed using a reversed-phase Agilent Zorbax Eclipse Plus C18, Rapid Resolution HD, 2.1 x 50 mm, 1.8 um (Agilent Technologies, Santa Clara, California, USA), with a column temperature of 30 °C and a flow rate of 0.3 ml/min. The mobile phase was operated isocratically for 1 min 95:5 (A:B) then switched to 1:99 (A:B) for a further 12 min before returning back to 95:5 (A:B) for an additional 2 min; providing a total run time of 15 min. Mobile phase ‘A’ consisted of 100% H2O and 0.1% formic acid, and mobile phase ‘B’ contained 75% acetonitrile, 25%

isopropanol and 0.1% formic acid. The MS was collecting data in the mass range 50–1000 m/z. Qualitative identification of the compounds was performed according to the Metabolomics Standard Initiative (MSI) Chemical Analysis Workgroup using several online LC–MS metabolite databases, including Massbank and METLIN. Overall, the instrumental conditions were similar for both positive electrospray (+ESI) and negative electrospray (−ESI) modes. Scan time was 500, the source temperature was maintained at 350°C, the gas flow was 12 L/min and the nebuliser pressure was 35 psi. Polyphenolic standards were used for the targeted quantitative analyses of selected polyphenols.

3.2.3 Data Analysis

Data analysis was conducted using Microsoft excel, SIMCA and Metaboanalyst softwares.

3.3 Results and Discussion

3.3.1 Batch to batch variations in the metabolite profile of raw carrot samples

We compared the metabolite profile of two non-fermented carrot puree samples through untargeted metabolite analysis. There was a small difference in the metabolite profile with 5 metabolites showing significant fold change between the two batches. However, principal component analysis (PCA) and partial list square discriminant analysis (PLS-DA) did not clearly differentiate the two carrot batch samples. Figure 14 shows the PLS-DA score plot comparing the two batches. The small difference between the two batches appears to be due an outlier sample in batch 2 which may have been handled in a slightly different way. Sample handling and especially the duration between pureeing and freezing determines the extent of endogenous enzyme mediated reactions in the carrot samples.

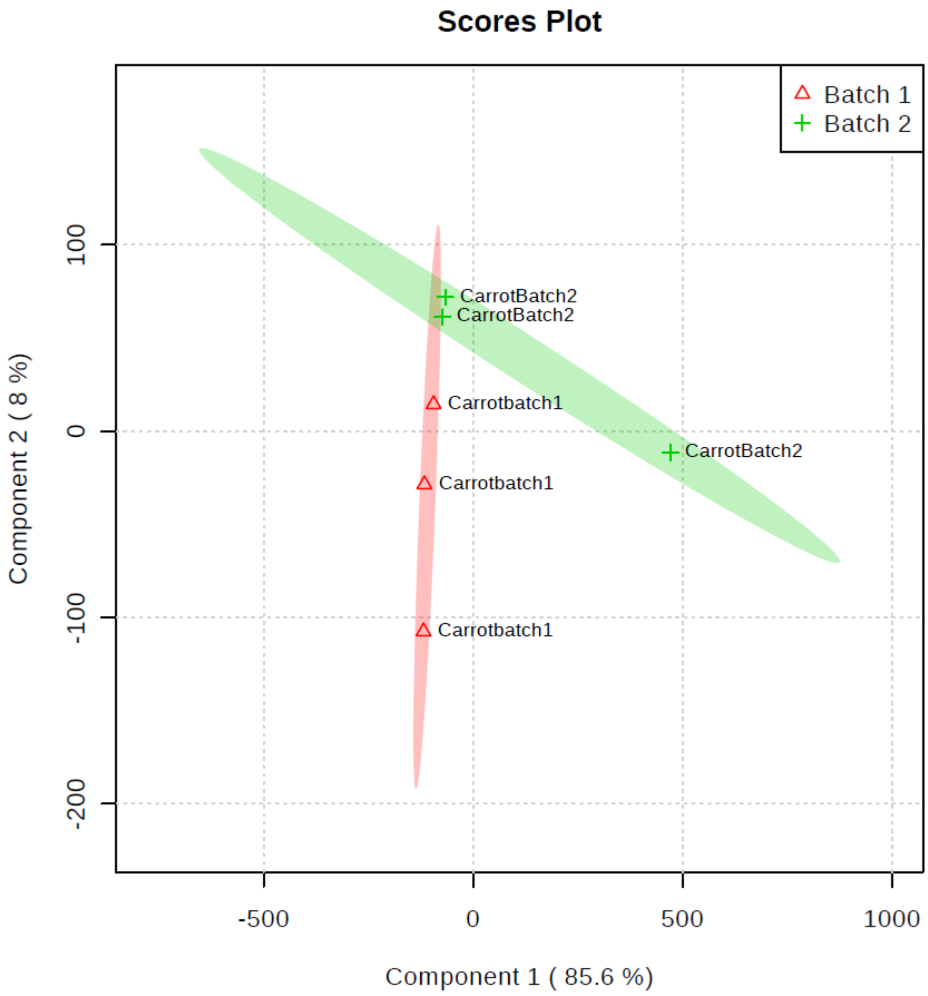

Figure 14 PLS-DA score plot comparing the metabolite profile of different carrot batches based on untargeted LC-MS analysis

3.3.2 Changes in the metabolite profile of carrot during fermentation

There was substantial change in the metabolite profile of carrot during fermentation using the different starter cultures. Samples that were fermented by the Mad Millie culture were the closest to the raw sample in metabolite profile whereas the samples fermented by the CSIRO carrot culture were the farthest (Figure 15). The main feature compounds that are responsible for the differences between the samples are only putatively identified. As such, further studies are required to elucidate the basis for the differences between carrot puree samples fermented by the different starters.

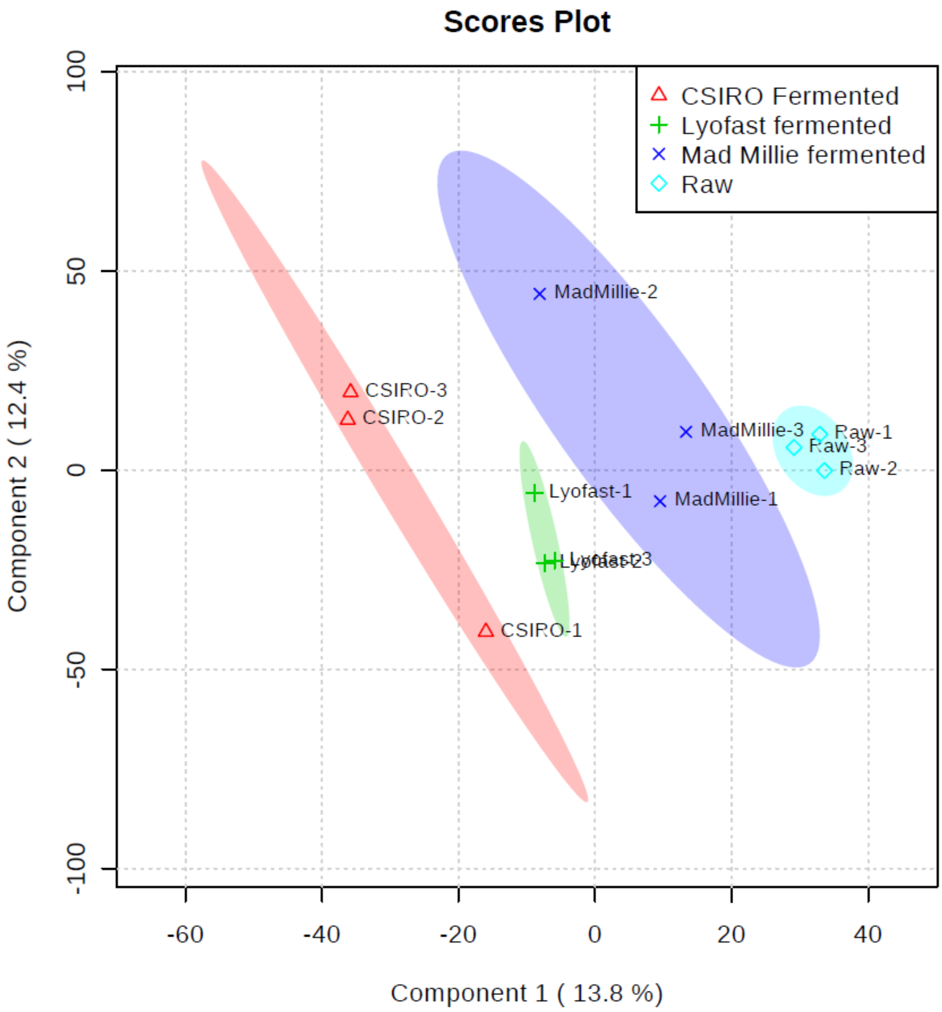

Figure 15 PLS-DA score plot showing the effect of fermentation by various starters on metabolite profile of carrot puree based on untargeted LC-MS metabolomics.

We also made pairwise comparison between raw and fermented samples. In all cases, fermentation caused significant and distinct starter culture dependent changes in the metabolite profile of carrot puree samples. A PLS-DA score plot comparing the metabolite profile of the raw samples with samples fermented by CSIRO culture is presented in Figure 16.

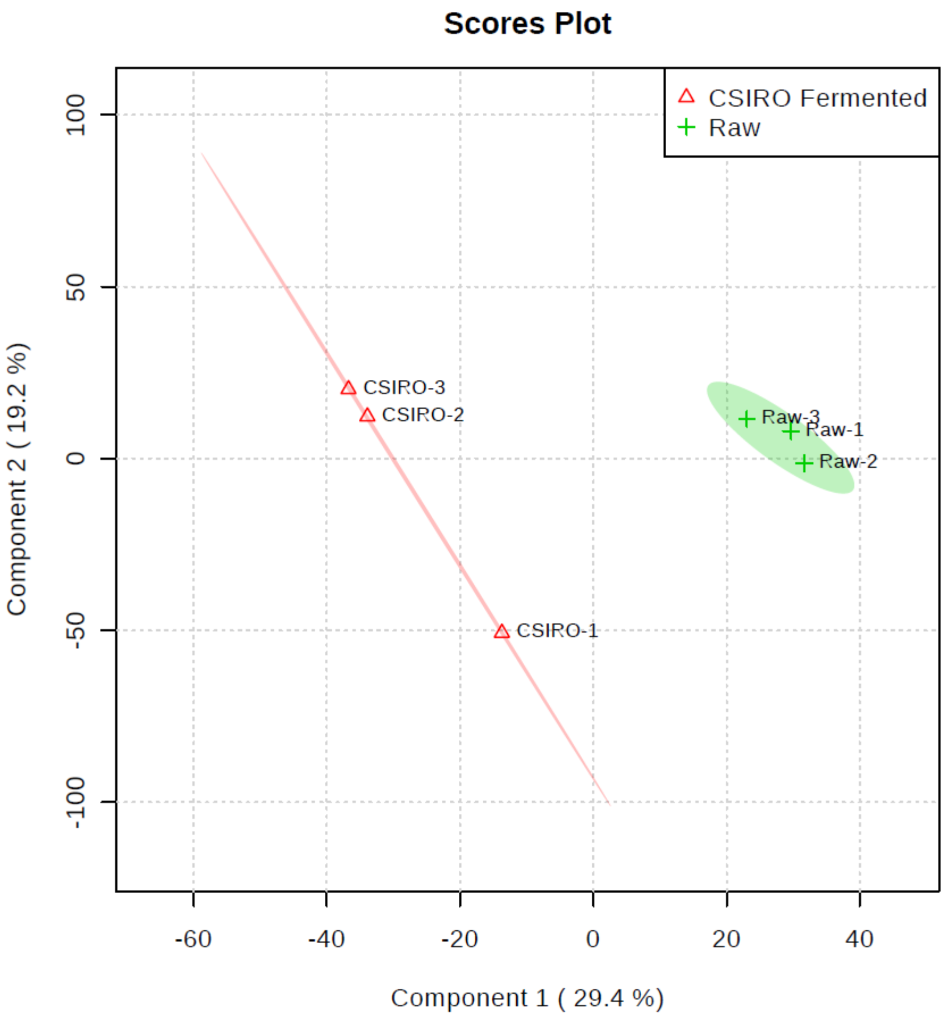

Figure 16 PLS-DA score plot showing the effect of fermentation by the CSIRO starter on the metabolite profile of carrot based on untargeted LC-MS metabolomics analysis.

The putatively identified feature compounds that differentiated the raw samples from CSIRO fermented samples included alcohols, aldehydes and ketones related to flavour, polyols such as mannitol and sorbitol derived from the conversion of sugars by the enzymes produced by the fermenting organisms and the amino acid L-phenylalanine (Figure 17). Some of these compounds including L-phenylalanine, E-2-pentenol and 1-pentan-3-one were also significantly increased in the Lyofast fermented samples in addition to the amino acid L-glutamine, which was specific to Lyofast. There was some similarities between the feature metabolites of Lyofast and Mad Millie samples, although there was a distinct and significant increase in L-proline only in Mad Millie samples. Further studies with targeted analysis will be required in order to fully understand the relevance of the differences in the metabolite profiles of the different samples to the sensory and nutritional quality of fermented carrot products.

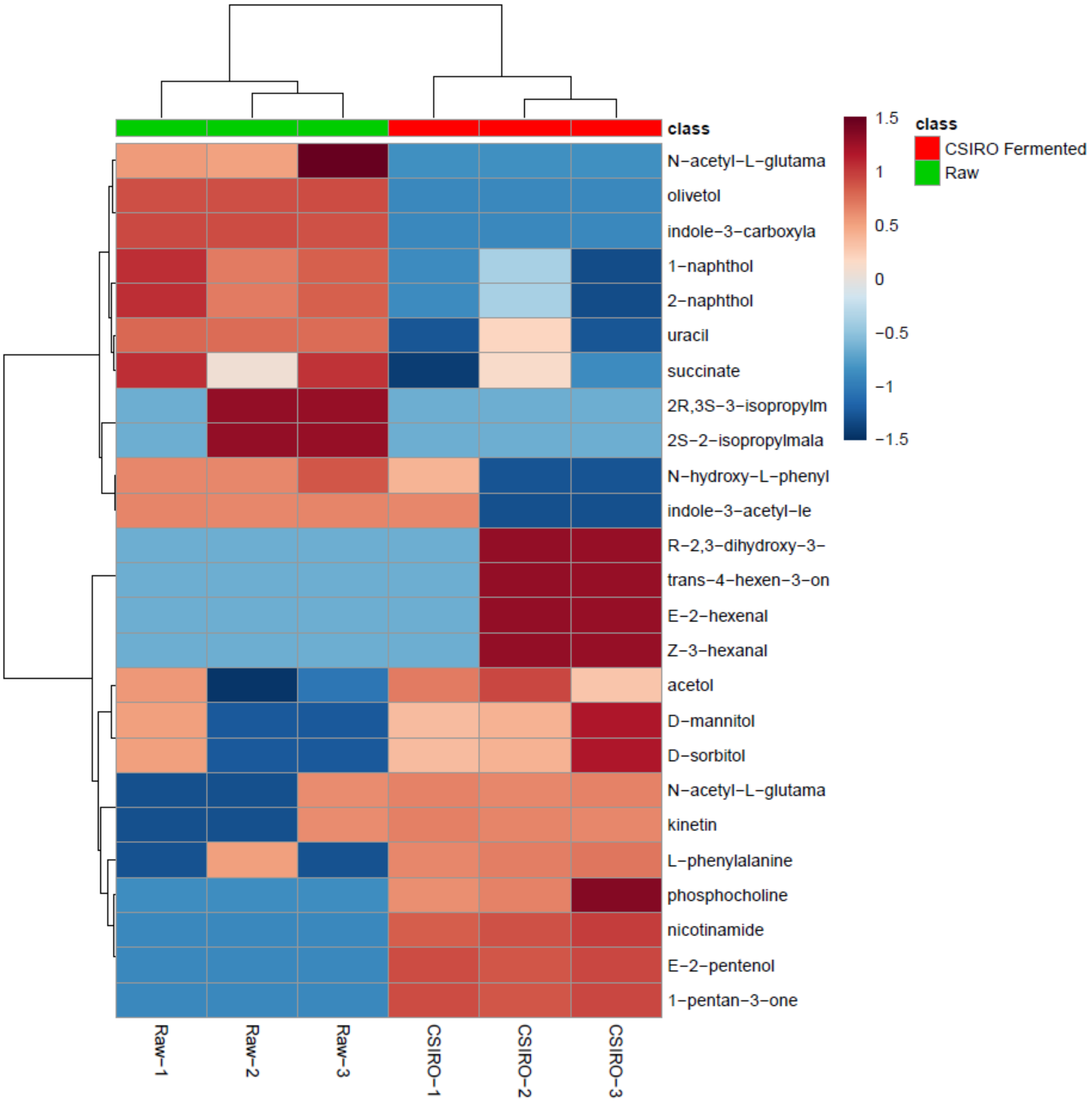

Figure 17 Heat map showing the top 25 putatively identified metabolites with significant fold changes after fermentation using the CSIRO culture based on untargeted LC-MS analysis. (From top to bottom N-acetyl-L-glutamate, olivetol, Indol-3-carboxylate, 1-naphtol, 2-napthol, uracil, succinate, 2R,3S-3-isopropylmalate, 2s_2-isopropylmalate, N-hydroxy-L-pheylalanine, indole-3-acetyl-leucine, R-2,3-dihydroxy-3-methylpentanoate, trans-4-hexen-3-one, E-2-hexenal, z-3-hexanal, acetol, D-mannitol, D-sorbitol, N-acetyl-L-glutamate 5-semialdehyde, kinetin, L-phenylalanine, phosphocholine, nicotinamide, E-2-pentol, 1-pentan-3-one)

3.3.3 Batch to batch variation in raw broccoli samples

The metabolite profile of two batches were compared based on untargeted LC-MS analysis. A significant difference was observed between the metabolite profile of the two broccoli batches (Figure 18), which could be due to varietal differences or differences in postharvest handling and storage conditions (time, temperature). Both batches of broccoli were market fresh produce purchased from Coles supermarket at different times (on 18 September and 10 October 2017 respectively). The difference in metabolite profile could be the reason for the different fermentation times of these samples (3.8 days and 0.5 days respectively for a pH drop to 4.4) (Chapter 2).

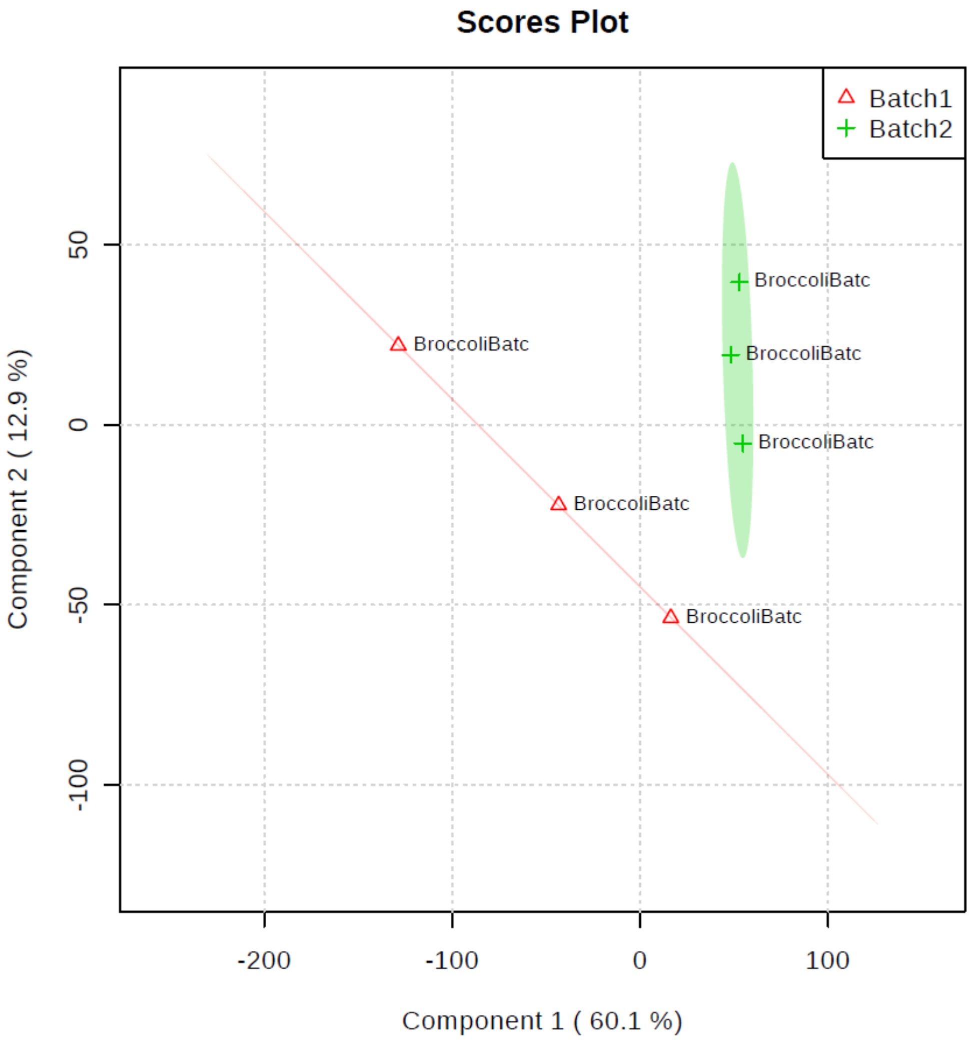

Figure 18 PLS-DA score plot showing batch to batch variation in raw broccoli samples based on untargeted LC-MS analysis

The main putatively identified metabolites that were significantly higher in batch 1 were N-dimethylethanolamine and salicylate. Additional investigation is required in order to confirm the identity of these compounds and understand their roles in the fermentation process.

3.3.4 Changes in the metabolite profile of broccoli puree after fermentation

Significant changes in the metabolite profile of broccoli was observed after fermentation (Figure 19). Some of the metabolites that increased significantly after fermentation with both starters include polyols such as mannitol and sorbitol, and amino acids such as L-tryptophan. On the other hand the concentration of polyphenols such as quercetin, coumarin and benzyl benzoate decreased significantly after fermentation perhaps due to conversion by microbial enzymes to other phenolic catabolites which commonly occurs during lactic acid fermentation.

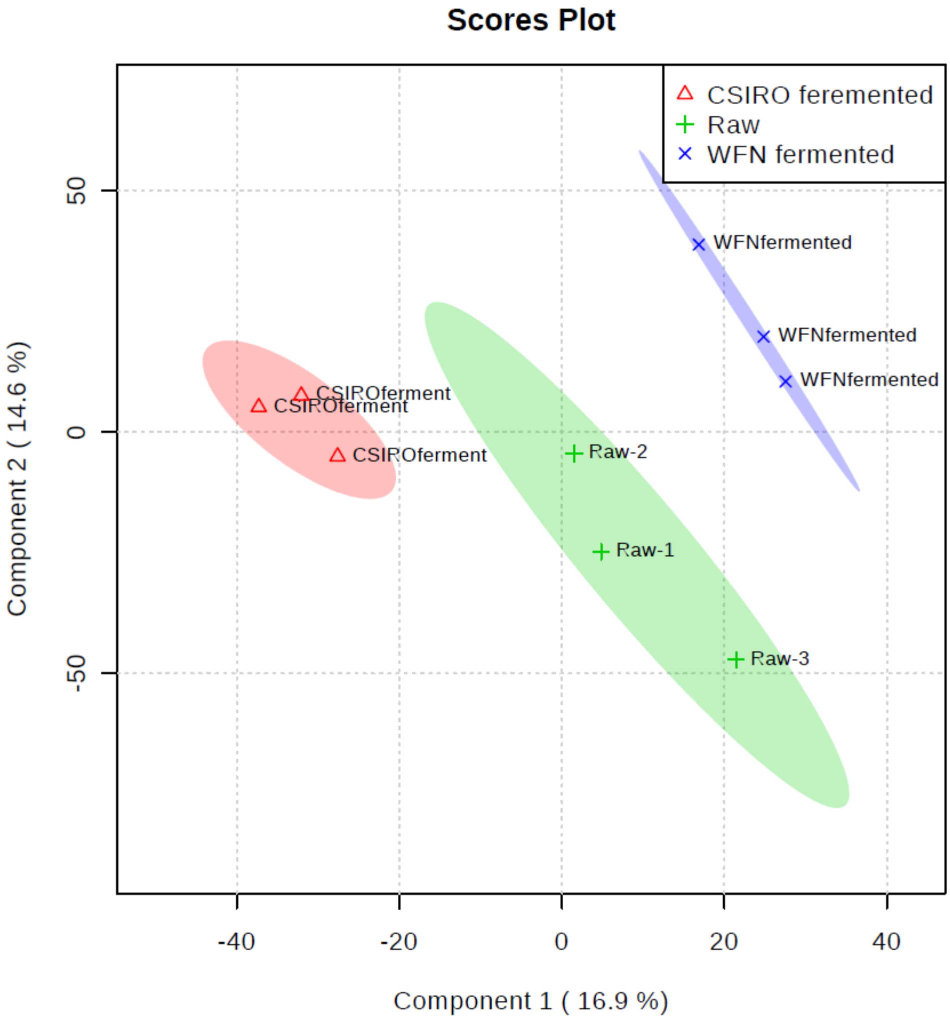

Figure 19 PLS-DA score plots showing the effects of fermentation on the metabolite profile of broccoli based on untargeted LC-MS analysis

The metabolite profile of the raw samples was also compared individually with those fermented by the CSIRO culture and the Wilderness Family Natural (WFN) culture. Significant and distinct changes dependent on the starter culture were observed during fermentation. The PLS-DA score plot comparing the metabolite profile of raw broccoli puree with that of fermented broccoli by the CSIRO culture is presented in Figure 20. Based on putative identification, the top metabolites that increased with fermentation using the CSIRO culture include sorbitol, mannitol, some aldehydes and ketones whereas salicylate and benzyl benzoate showed significant decrease (Data not presented). The metabolite profile of the WFN fermented product on the other hand showed a significant increase in L-tryptophan and ketones such as 1-pentane-3-one as the CSIRO culture fermented broccoli. Salicylate and quercetin are some of the top compounds that showed significant fold decrease after fermentation with the WFN culture (Figure 21).

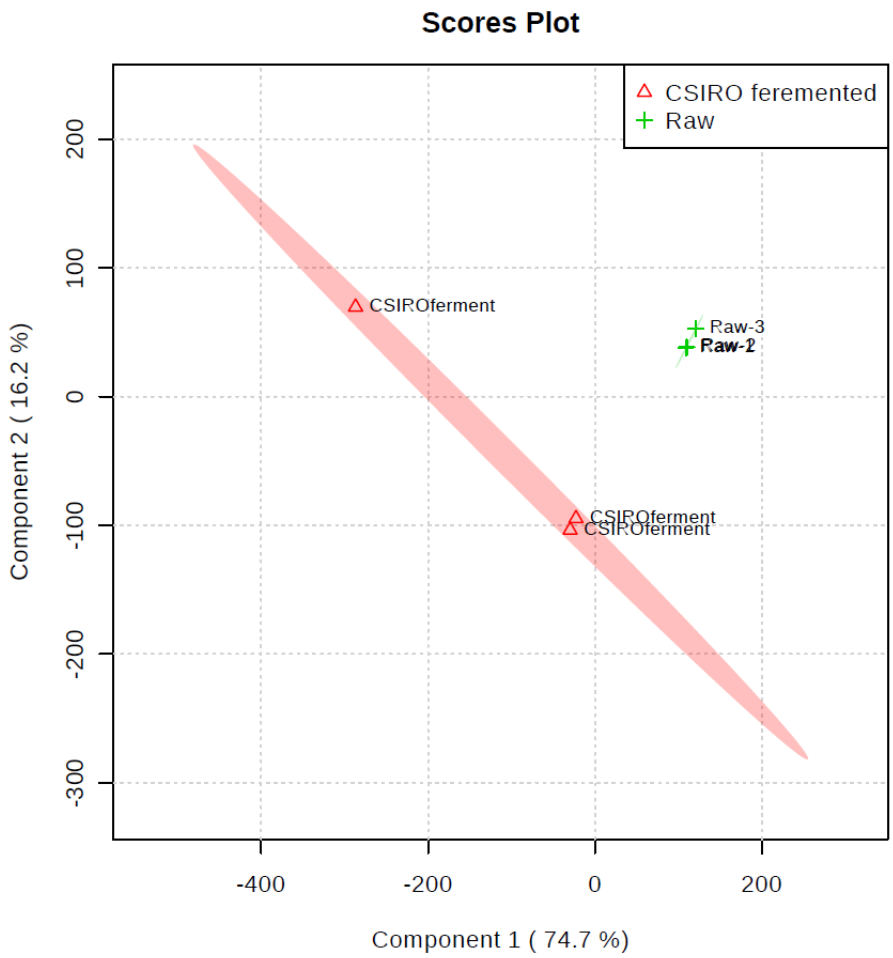

Figure 20 PLS-DA score plot showing the changes in the metabolite profile of broccoli puree after fermentation with the CSIRO culture based on untargeted LC-MS analysis

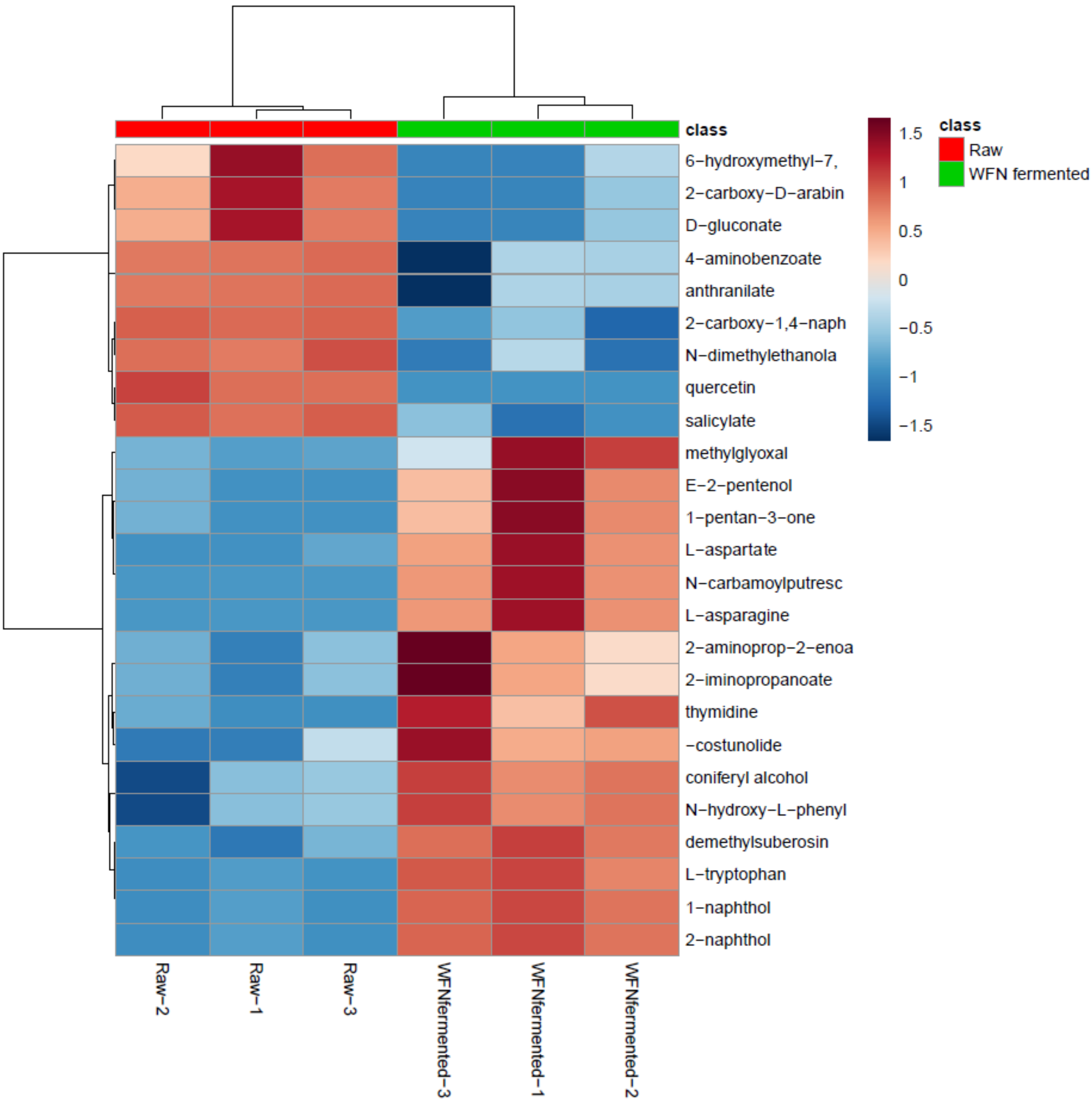

Figure 21 Heat map showing the top putatively identified metabolites that changed significantly during fermentation of broccoli puree with the WFN culture. **(From top to bottom 6-(hydroxymethyl)-7,8-dihydropterin, 2-carboxy-D-arabinitol, D-gluconate, 4-aminobenzoate, anthranilate, 2-carboxy-1,4-naphthoquinol, N-dimethylethanolamine, quercetin, salicylate, methylglyoxal,E-2-pentenol, 1-pentan-3-one, L-aspartate, N-carbamoylputrescine, L-aspargine, 2-aminoprop-2-enoate, 2-iminopropanoate, thymidine, (+)-costunolide, coniferyl alcohol, N-hydroxy-L-phenylalanine, demethylsuberosin, L-tryptophan, 1-naphtol, 2-naphtol)**

3.4 Targeted LC-MS analysis of polyphenols

In this work, the variations in 20 polyphenolic compounds were evaluated so as to understand batch to batch variations of these compounds and their changes during fermentation of broccoli and carrot.

3.4.1 Batch to batch variation in the polyphenolic profile of carrot

There was a significant difference between the polyphenolic profile of the two carrot batches investigated (Figure 22). However, the difference was substantial only in the case of caffeic acid where 10 times higher concentration was observed in batch two compared to batch one (Figure 23).

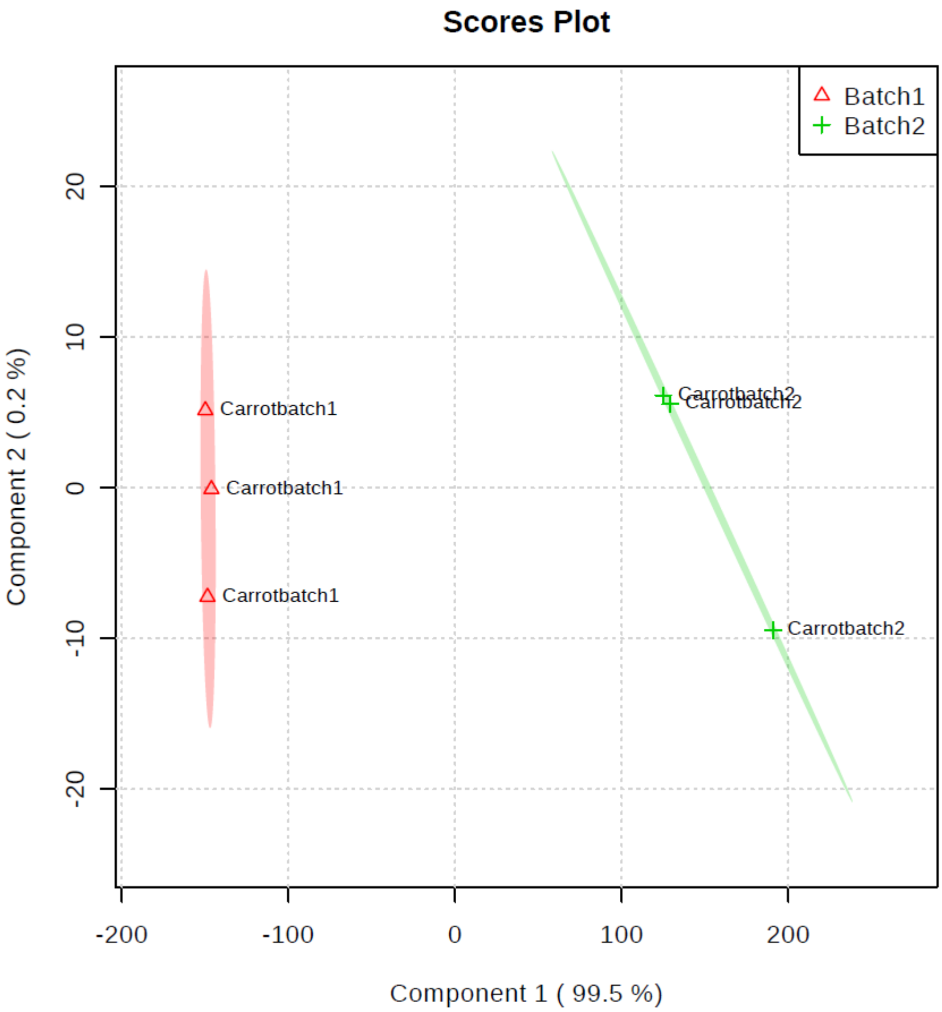

Figure 22 PLS-DA score plot showing batch to batch variation in polyphenolic profile of carrot based on targeted polyphenolic analysis

3.4.2 Changes in polyphenolic profile of carrot puree during fermentation

There was a significant change in the polyphenolic profile of carrot puree during fermentation. However, there was an overlap between the CSIRO and Mad Millie fermented samples indicating similar polyphenolic profile with regard to the polyphenols analysed (Figure 25). The concentration of most of the investigated polyphenols decreased during fermentation except the concentration of caffeic acid and p-coumaric acid, which increased slightly after fermentation with Mad Millie culture (Figure 24). The higher content of caffeic acid and p-coumaric acid in the Mad Millie fermented sample may partially explain the higher ORAC antioxidant capacity and total polyphenol content of these samples compared to the raw samples as well as the other fermented samples (Chapter 2). The decrease in the concentration of most of the investigated polyphenols during fermentation could be attributed to conversion by microbial esterases and decarboxylases into other polyphenolic catabolites during fermentation. It has to be noted that the study focused on only 20 polyphenolic compounds, which does not give us a complete picture of changes in the polyphenolic profile of carrot during fermentation with the various starter cultures.

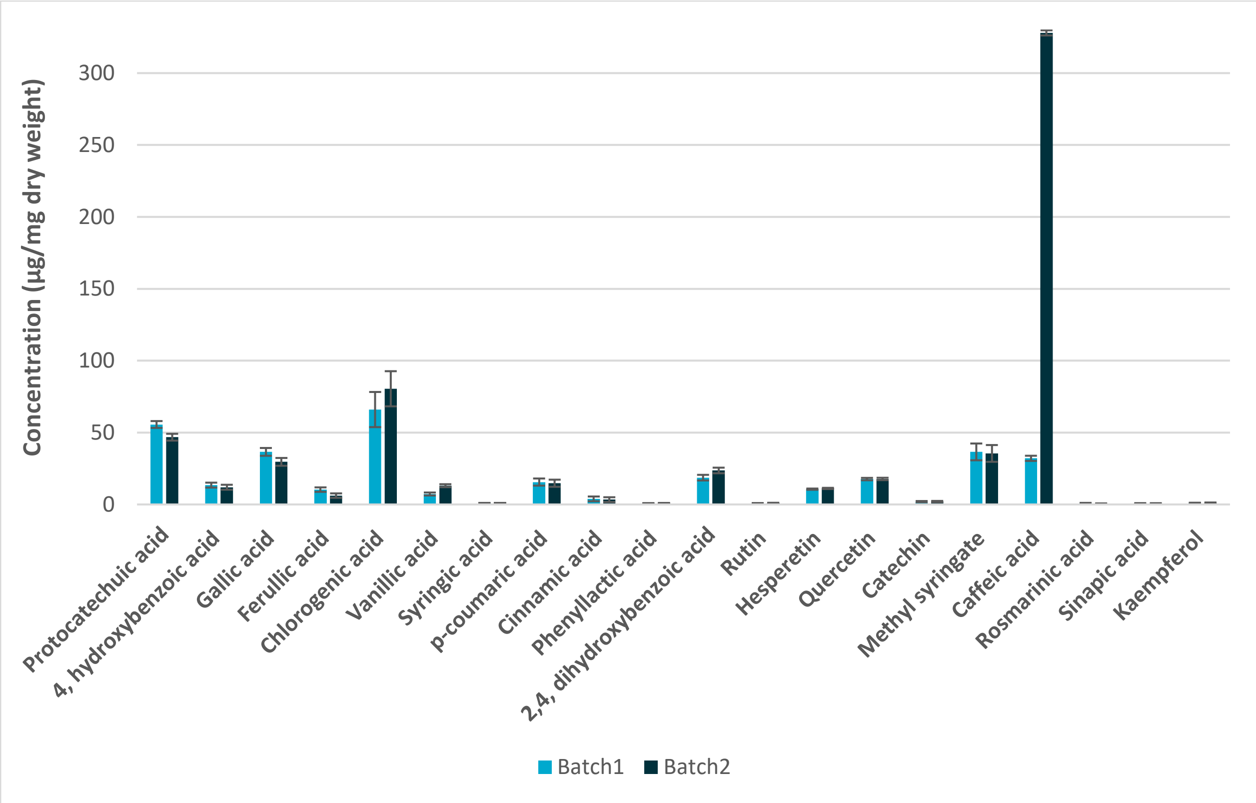

Figure 23 Comparison of the polyphenolic profile of two carrot batches based on targeted LC-MS analysis

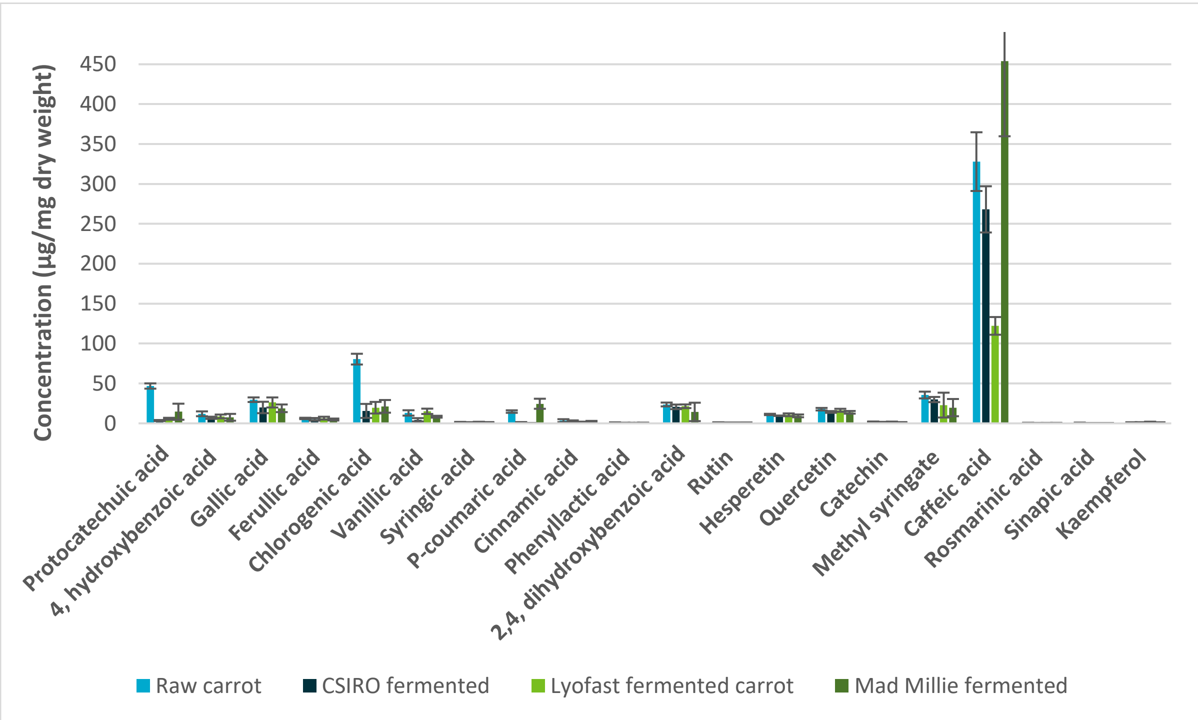

Figure 24 Changes in polyphenolic profile of carrot puree samples during fermentation using the various starter cultures.

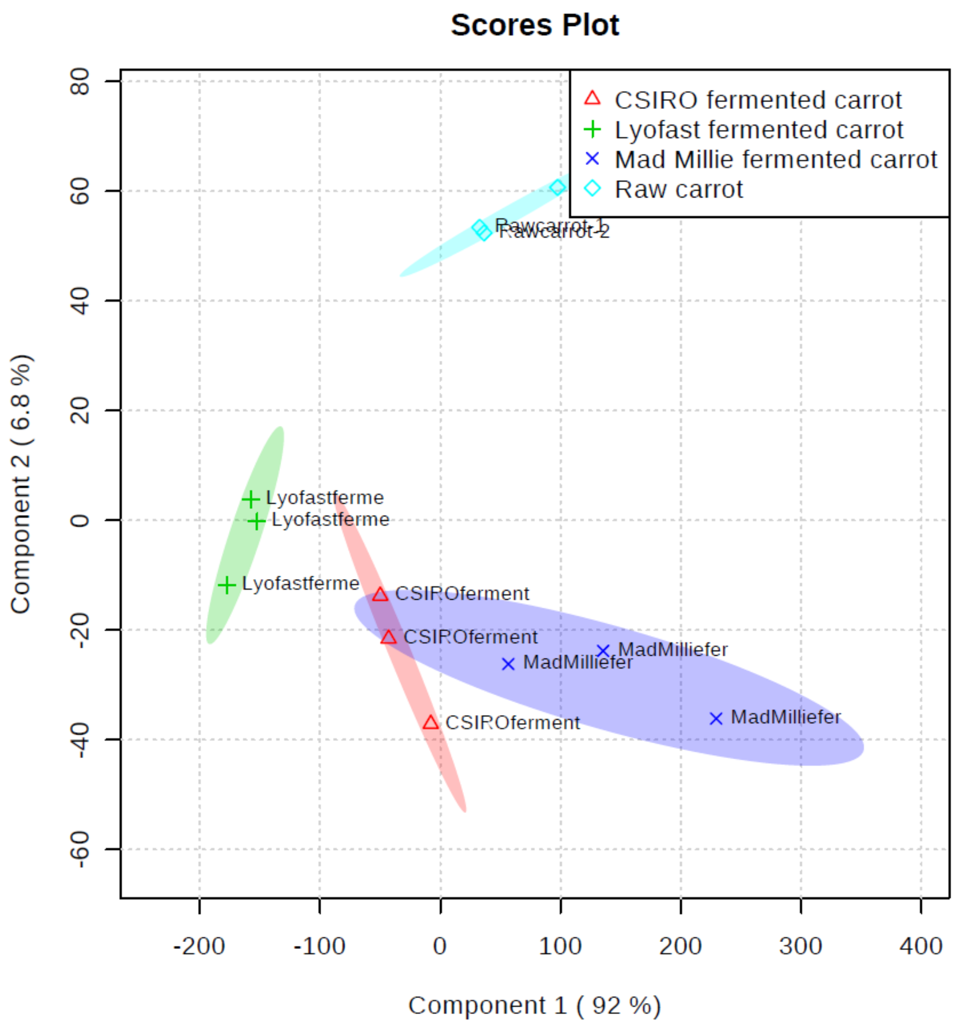

Figure 25 PLS-DA score plot showing the effects of fermentation with various starters on the polyphenolic profile of carrot puree based on targeted analysis of 20 polyphenols

3.4.3 Batch to batch variation in the polyphenolic profile of broccoli samples

We compared the polyphenolic profile of the two broccoli batches with respect to the 20 polyphenols investigated. There was a significant difference between the two batches (Figure 26). The second batch of broccoli had the same or higher concentration of most of the polyphenols. Among the polyphenols investigated, 4, hydroxybenzoic acid, quercetin, hesperetin and p-coumaric acid were significantly higher in batch 2 samples (Figure 27). The concentration of chlorogenic acid and vanillic acid were higher in batch 1 samples, although the difference was not statistically significant (P>0.05). Whether that contributed to the substantially longer fermentation time of this batch (3.8 days versus 0.5 days) is a matter for further investigation.

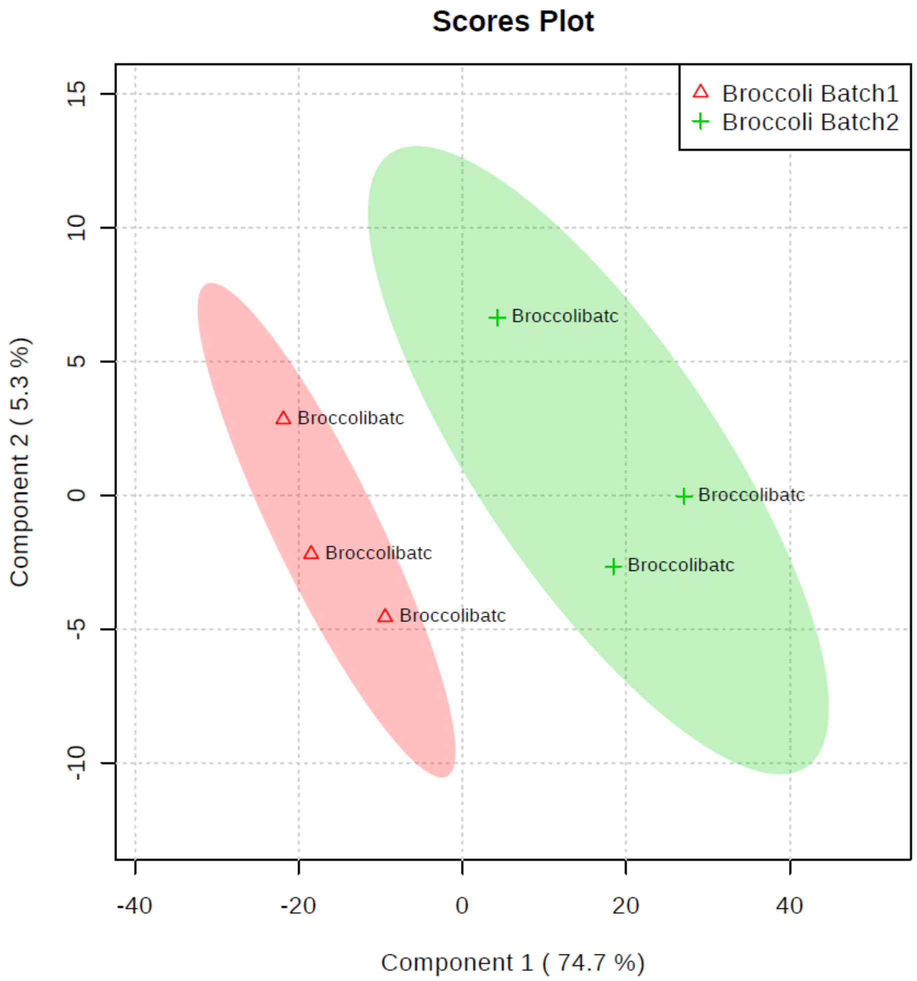

Figure 26 PLS-DA score plot comparing the polyphenolic profile of samples from two broccoli batches based on targeted analysis of 20 polyphenols

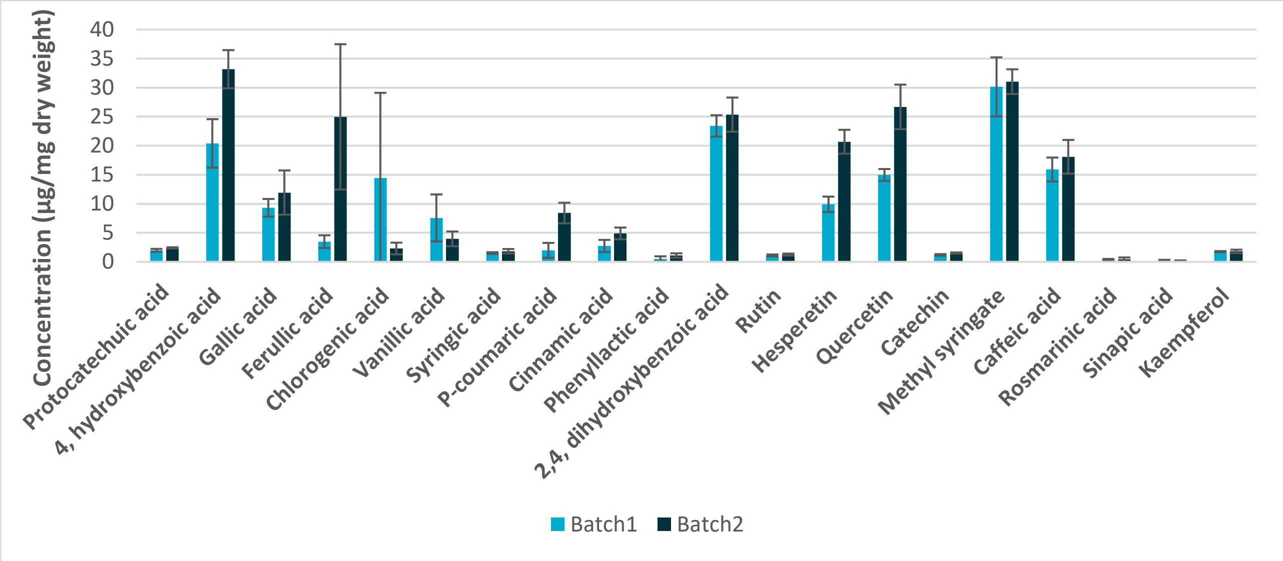

Figure 27. The polyphenolic profile of samples from two broccoli batches based on targeted analysis of 20 polyphenols

3.4.4 Changes in polyphenolic profile during fermentation of broccoli

The effects of fermentation of broccoli puree with the CSIRO and WFN cultures on the polyphenolic profile of broccoli samples were investigated. There was a significant difference between the raw and the fermented samples. However, there was some overlap between the WFN and the CSIRO fermented samples (Figure 28).

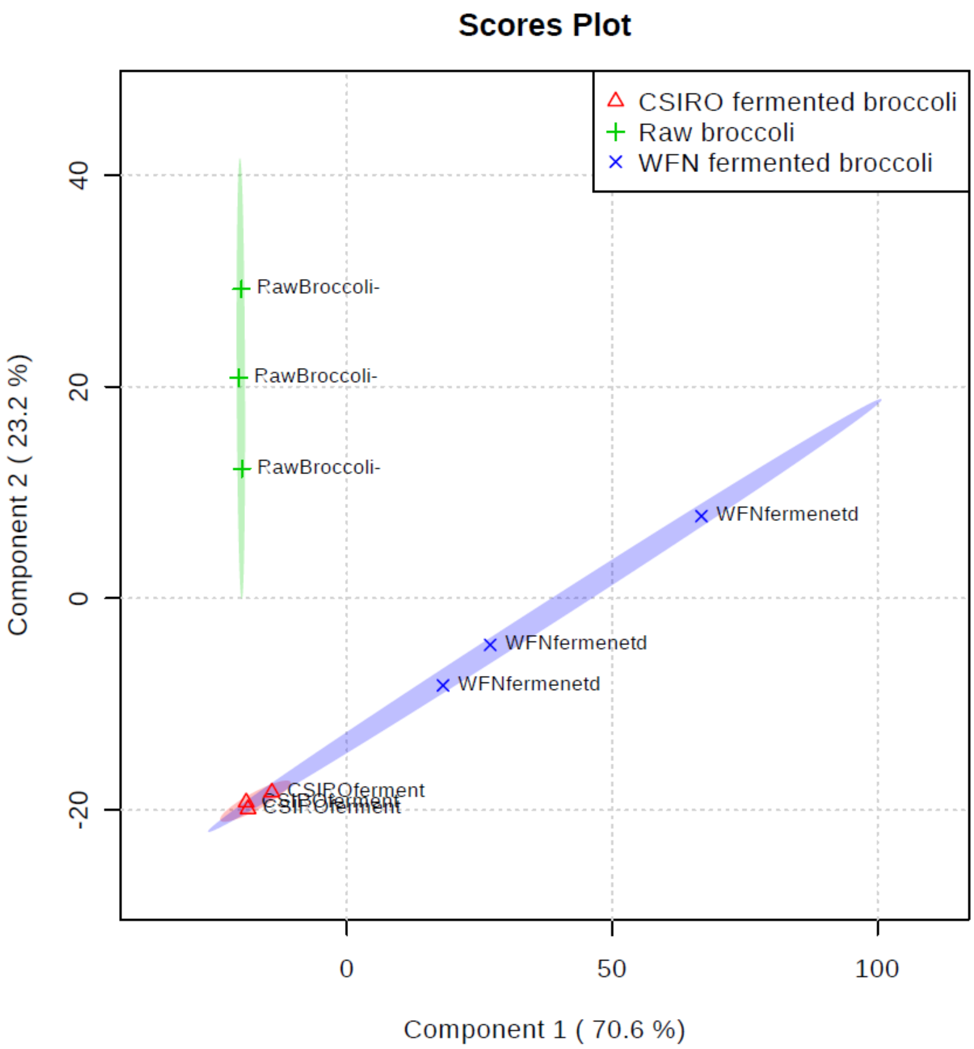

Figure 28 PLS-DA score plot based on targeted analysis of 20 polyphenols comparing raw broccoli puree samples with samples fermented by the CSIRO and WFN cultures

There was a significant increase in chlorogenic acid, vanillic acid, phenyllactic acid and caffeic acid concentrations of broccoli puree after fermentation. All the other studied polyphenolic compounds decreased or remained the same after fermentation (Figure 29). Interestingly the highest increase in phenyllactic acid, chlorogenic acid and vanillic acid was observed in the WFN samples, which explain the observed significant increase in total polyphenol content after fermentation by the WFN culture (chapter 2). However, this did not translate into higher ORAC antioxidant capacity. The antioxidant capacity of the WFN fermented samples were the lowest with 50% decrease in ORAC antioxidant capacity compared to the raw sample (Chapter 2). It seems that the compounds that increased after fermentation do not contribute substantially to ORAC antioxidant capacity.

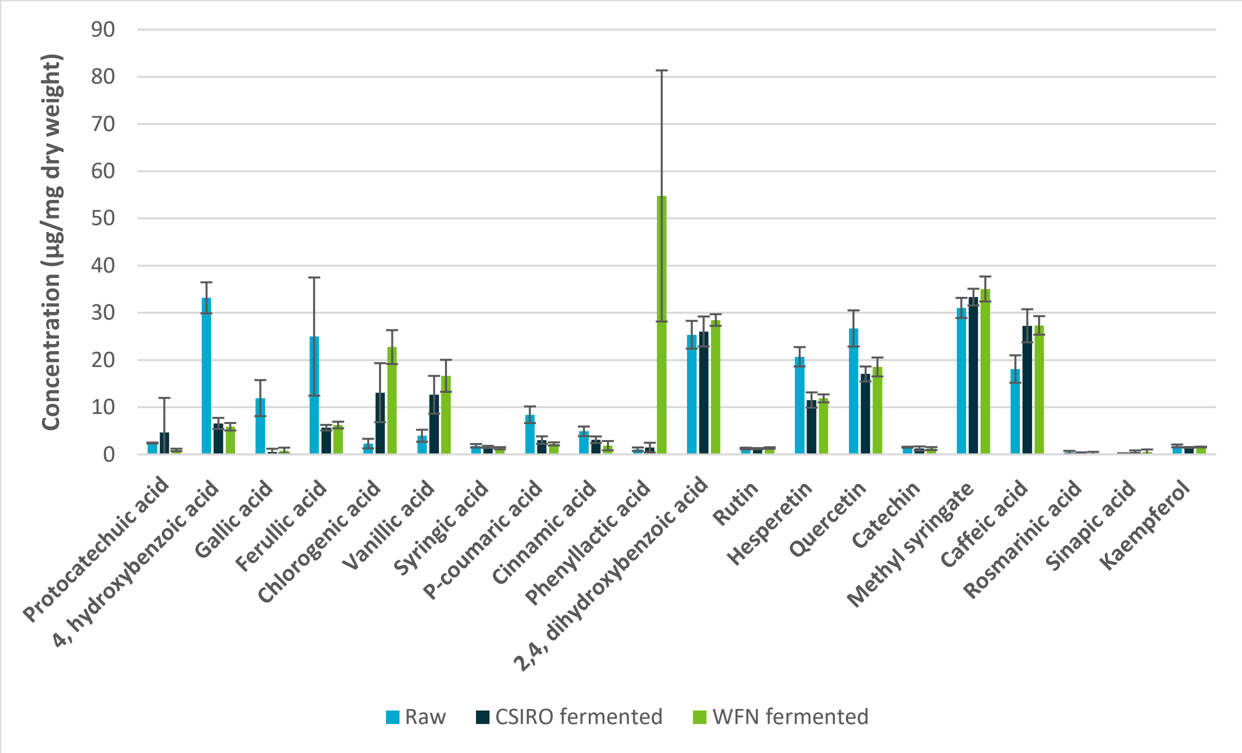

Figure 29 Changes in polyphenolic profile of broccoli samples during fermentation by the different starter cultures

3.5 Conclusions and Recommendations

As discussed in chapter 2, we observed a significant batch to batch variability in the fermentation time of specially broccoli samples. We compared the metabolite profiles of two batches of carrot and broccoli samples using a targeted and untargeted LC-MS metabolomics approach. There were significant batch to batch variations in the metabolite profile of specially broccoli samples, which can explain the substantial batch to batch variation in fermentation time. Nevertheless, further studies are required in order to identify markers that predict fermentation times of broccoli.

The targeted and untargeted analysis indicated substantial changes in the metabolite profile of both carrot and broccoli during fermentation using different cultures. The metabolite profiles of the fermented products reflected the differences in the composition of the starter cultures. The putatively identified metabolites that showed the most significant changes after fermentation include alcohols, aldehydes and ketones related to flavour profile, polyols such as mannitol and sorbitol and amino acids such as L-phenylalanine and L-tryptophan depending on the starter culture and the substrate. The concentration of most of the analysed polyphenols in the targeted analysis decreased during fermentation of both carrot and broccoli most probably due to conversion by enzymes produced by the starter cultures. The concentration of caffeic acid increased in both carrot and broccoli after fermentation whereas the concentration of phenyllactic acid increased only in fermented broccoli samples, which can both be due to improved extractability of these polyphenols after fermentation or microbial synthesis of these polyphenols. It is well known that some lactic acid bacteria strains produce phenyllactic acid, which is a potent antimicrobial compound that gives them competitive advantage against other microbial species (Valerio et al., 2004). It has to be noted that the change in the metabolite profile of a non-heated and pureed plant material during fermentation arises from a complex set of biochemical processes that involve the activities endogenous plant enzymes and microbial enzymes as well as the chemical interaction between the various metabolites in the matrix. Thus, more in-depth studies with targeted and untargeted approaches are required in order to fully understand the observed changes in metabolite profile during fermentation.

4 Microbial challenge study

4.1 Introduction

The laboratory scale fermentation process for both carrot and broccoli puree resulted in products with no detectable level of pathogenic and spoilage microorganisms. However, in order to assess the robustness of the fermentation process to control incidental contamination by pathogenic microorganisms, challenge studies were conducted. The challenge studies involved inoculating the raw material with four pathogens that can pose potential risk in the fermented products so as to determine if the fermentation process was able to inhibit the growth of the organisms. The pathogens assessed were five-strain cocktails each of *Escherichia coli*, *Salmonella*, *Listeria monocytogenes* and *Bacillus cereus*. With respect to carrot, preliminary experiments with *E. coli* strains as challenge organisms indicated that the process in its current state (i.e. without a heat treatment step prior to inoculation of culture) is not able to eliminate risks that may arise from contamination of the raw material with such organisms (data not reported). Thus, a pre-processing heating step was introduced into the process in order to develop a HACCP plan for food grade production of fermented carrot (see the HACCP plan in Appendix A). With broccoli, challenge studies were conducted as described below with the four challenge organisms as a basis for development of a HACCP plan and food grade production process.

4.2 Materials and Methods

4.2.1 Materials

Broccoli

Fresh broccoli was obtained from various local super markets so as to obtain diverse batches and potential diverse varieties.

Biochemical reagents

All microbial growth media, apart from ALOA (Agar Listeria Ottavani & Agosti), a chromogenic agar for *Listeria*, was obtained from Oxoid. ALOA was purchased, pre-prepared from Edwards Group Pty Ltd (Narellan, NSW, Australia).

Starter culture

We chose to use a commercial source of cultures in these experiments, to provide potential users of the technology the choice of using already established commercial cultures. Our screening of commercially available lactic acid bacteria vegetable starter cultures in our laboratory scale process development work (Chapter 2) showed that the Wilderness Family Naturals (WFN) (Minnesota, USA) culture was the best-performing culture out of the five cultures investigated. However, since then, the Wilderness Family Naturals Company has re-focused and changed its name to Wildly Organic and the company no longer provides the vegetable fermentation starter culture that was assessed. As a result, the next best commercial culture in terms of performance and reliability of supply was used in the challenge studies, which was Caldwell's Vegetable Starter Culture (Quebec, Canada). The culture was purchased from a local supplier.

Pathogen challenge cultures

The four pathogens used for challenge testing of the fermented broccoli were *E. coli*, *Salmonella*, *L. monocytogenes* and *B. cereus*. For each pathogen, five strains were selected based on their known food spoilage, acid tolerance or pathogenic properties (Table 11).

Table 11 Pathogenic microorganisms used in the challenge study and their source.

E. coli		***Salmonella***		***Listeria monocytogenes***		***Bacillus cereus***	
Strain	Source/ rational	Strain	Source/ rational	Strain	Source/rational	Strain	Source/rational
EC 1604	Generic E. coli isolated from beef meat	*S. Typhimurium* 1657 (PT135)	Top salmonellosis serotype 1, slight acid resistance	Lm 2987	ST38, Genetic lineage 2, acid tolerance at pH 2.5	B3078	Psychotropic
EC 1605	Generic E. coli isolated from beef meat	*S. Typhimurium* 1013 (PT9)	Top salmonellosis serotype 1, slight acid resistance	Lm 2965	ST121, Genetic lineage 2, acid tolerance at pH 2.5	B2603	Psychotropic
EC 1606	Generic E. coli isolated from beef meat	*S. Infantis* 1023	In top salmonellosis serotype 1, slight acid resistance	Lm 2939	ST204, Genetic lineage 2, acid tolerance at pH 2.5	B2601	Psychotropic
EC 1607	Generic E. coli isolated from lamb/sheep meat	*S. Singapore* 1234	Slight acid resistance	Lm 2994	Isolated from non-dairy infused oil	7571	Psychotropic, from soil
EC 1608	Generic E. coli isolated from beef meat	*S. Virchow* 1563	In top 5 salmonellosis serotypes1	Lm 2619	Isolated from vacuum packed shredded lettuce, some acid tolerance at pH 2.5, ST3 (Australia's most common ST), genetic lineage 1	7626	Psychotropic, from grain

4.2.2 Broccoli sample preparation

Broccoli samples were rinsed with tap water. After removing the stems and the leaves, the florets (900 g) were coarsely cut into pieces, and pureed in a Thermomix (Vorwerk & Co., Wuppertal, Germany) mixer with 3 to 2 broccoli to water ratio for 5 min at the maximum speed (speed 10). The chopping process in the Thermomix increased the temperature of the broccoli mixture, so the entire Thermomix bowl was placed into a 4 °C cold room to temper the broccoli to approximately 30 °C.

4.2.3 Culture preparation

Fermentation culture

The commercial Caldwell's Vegetable Starter (CLD) was provided in boxes containing 6 x 2 g sachets of dried powder. The first fermentation challenged with *E. coli* used one box (12 g) of starter culture, which was reconstituted with 25 mL of sterile deionised water (SDW). All subsequent fermentations used two boxes (24 g) of starter culture, reconstituted with 50 mL of SDW to speed up the fermentation rate. The reconstituted starter culture was warmed to 30 °C for 10 min prior to use.

Challenge cultures

Escherichia coli and *Salmonella* were sub-cultured from frozen glycerol stocks onto Tryptone Soya Yeast Extract Agar (TSYEA) plates and grown overnight at 37 °C. *Listeria monocytogenes* strains were sub-cultured from frozen glycerol stocks onto Brain Heart Infusion Agar (BHIA) plates and grown overnight at 37 °C. The plates were used as working culture stocks and kept at 4 °C. Spore crops of *B. cereus* culture were prepared with SDW at a concentration of 10^8-10^9 cfu/mL and frozen at -70 °C.

On the day before fermentation, one colony of each of the five strains of *E. coli* was sub-cultured into 10 mL of Nutrient Broth (NB). The broths were grown at 37 °C overnight, without shaking. On the day of fermentation, the cultures were combined in equal proportions and diluted to 10^4 cfu/mL, with the final dilution in SDW. The *Salmonella* cultures were prepared in the same way as the *E. coli*, except that the broths were grown overnight with shaking. *Listeria monocytogenes* was prepared as for *Salmonella*, except using Brain Heart Infusion Broth (BHIB) instead of NB.

The *B. cereus* spore crops were defrosted on the morning of fermentation, and diluted in SDW so that the final concentration of each strain was 10^7 cfu/mL. The five strains were combined in equal proportions and heat-treated at 80 °C for 10 minutes to inactivate vegetative cells. The heat-treated spore crop was then diluted to 10^5 cfu/mL in SDW.

4.2.4 Microbial challenge experiments

To broccoli puree sample prepared as described above, the CLD starter culture was added followed by 7.5 mL of the intended challenge culture. The mixture was then blended in the Thermomix at maximum speed for 1 min, with the blades reversed to blend the mixture instead of chop. With the use of the CLD starter culture, the amount of water added to the puree increased as the culture was dispersed in 30 mL of water when two packets were used. To compensate for this, the amount of water used to prepare the broccoli mixture was reduced to maintain the 3:2 broccoli water proportion. Thus, for 12 g (1 pack) of CLD, 15 mL less water was used (585 g water) to prepare the broccoli mixture, while 30 mL less water was used (570 g water) when 24 g (2 pack) of CLD was used.

Continuous mixing was not employed as this led to a continued increase in temperature when the Thermomix bowl was in the Thermomix unit, perhaps due to the exothermic nature of the process, heat generated during agitation and insulation effect of the unit. Instead, the Thermomix bowl, without the Thermomix unit, was placed into a 30 °C incubator. The bowl was removed from the incubator and mixed with reversed blades on speed 4.5 for 1 min prior to temperature and pH measurements and microbiology sampling. Temperature and pH measurements were taken at the beginning, and then hourly until 4 h, with the broccoli mixed in the Thermomix prior to measurement. The following morning, the broccoli was mixed, with temperature and pH measurements resuming every 2-4 h, depending on the length and rate of fermentation. Fermentation continued until the pH reached pH 3.8 or below. The broccoli was microbiologically tested prior to culture addition, immediately after culture addition, at 4 h after culture addition, and then daily until the end of fermentation. All samples were assessed for LAB and yeast and mould, as well as the challenge pathogen in the sample. A count was conducted on all culture preparations to confirm the inoculum level. Duplicate experiments were conducted for each of the four pathogens.

4.2.5 Microbiological analyses

Broccoli samples and culture preparations were spread plated (0.1 mL) or pour plated (1 mL with overlay) onto the required media. Serial tenfold dilutions were performed using Maximum Recovery Diluent when required. The LAB were enumerated in sample spread plated on de Man, Rogosa and Sharpe (MRS) agar and incubated anaerobically, using Anaerogen sachets (Oxoid, Thermo Fisher Scientific, Basingstoke, UK), at 30 °C for 2 d. Yeast and mould were enumerated in sample spread plated on Dichloran Rose-Bengal Chloramphenicol (DRBC) agar and incubated aerobically at 25 °C for 5 d. *Escherichia coli* were enumerated in sample pour plated on Violet Red Bile Glucose Agar (VRBGA) plates and incubated at 37 °C for 24 h. *Salmonella* were enumerated in sample spread plated on Xylose-Lysine-Desoxycholate (XLD) agar plates, and incubated aerobically at 37 °C for 24 h. *Listeria* were enumerated in sample spread onto ALOA agar plates, and incubated at 37 °C for 24-48 h. *Bacillus cereus* were enumerated in sample spread onto *Bacillus cereus* selective agar (BCA) and incubated at 37 °C for 24 h.

At the end of fermentation, the samples for all of the *B. cereus* challenge trials were also enumerated for *B. cereus* spores by heat-treating the samples at 80 °C for 10 minutes prior to plating. The samples for the *Salmonella* and *L. monocytogenes* challenge trials were enriched to detect low numbers of surviving pathogens. This involved combining 25 g of sample with 225 g of Buffered Peptone Water (BPW), stomaching the sample (Lab Blender 400, Seward, London, UK) for 1 min, and incubating the BPW for 18 h at 37 °C. Following incubation of the BPW, the sample was stomached for 1 min and spread plated onto the selective medium required for the pathogen being tested. The selective medium was incubated at 37 °C for 24 h and examined for the presence or absence of the pathogen. Any colonies of the pathogen were considered as a positive result.

4.3 Results and Discussion

4.3.1 Fermentation duration

Overall, broccoli puree fermentation using CLD culture was long with variable fermentation times (**Figure 30**). Fermentation was conducted to a target pH of around 3.8 compared to the target pH in the lab scale process development of below 4.4 so as to minimise potential risks from pathogenic microorganisms. Fermentation times for challenge trials with *E. coli* ranged from more than 28 h to greater than 80 h (**Figure 30a**). The challenge trials with *Salmonella* were both similar, requiring between 43-45 h to reach pH 3.8 (**Figure 30b**). The first challenge trial with *L. monocytogenes* used the smaller amount (12 g) of CLD starter culture and took more than 100 h (**Figure 30c**). When the CLD starter culture amount was doubled (24 g), the fermentation took more than 3 d (>72 h) but proceeded at a faster rate after 24 h. The two *B. cereus* challenge trials also had disparate fermentation times, extending from more than 40 h to more than 80 h (**Figure 30d**).

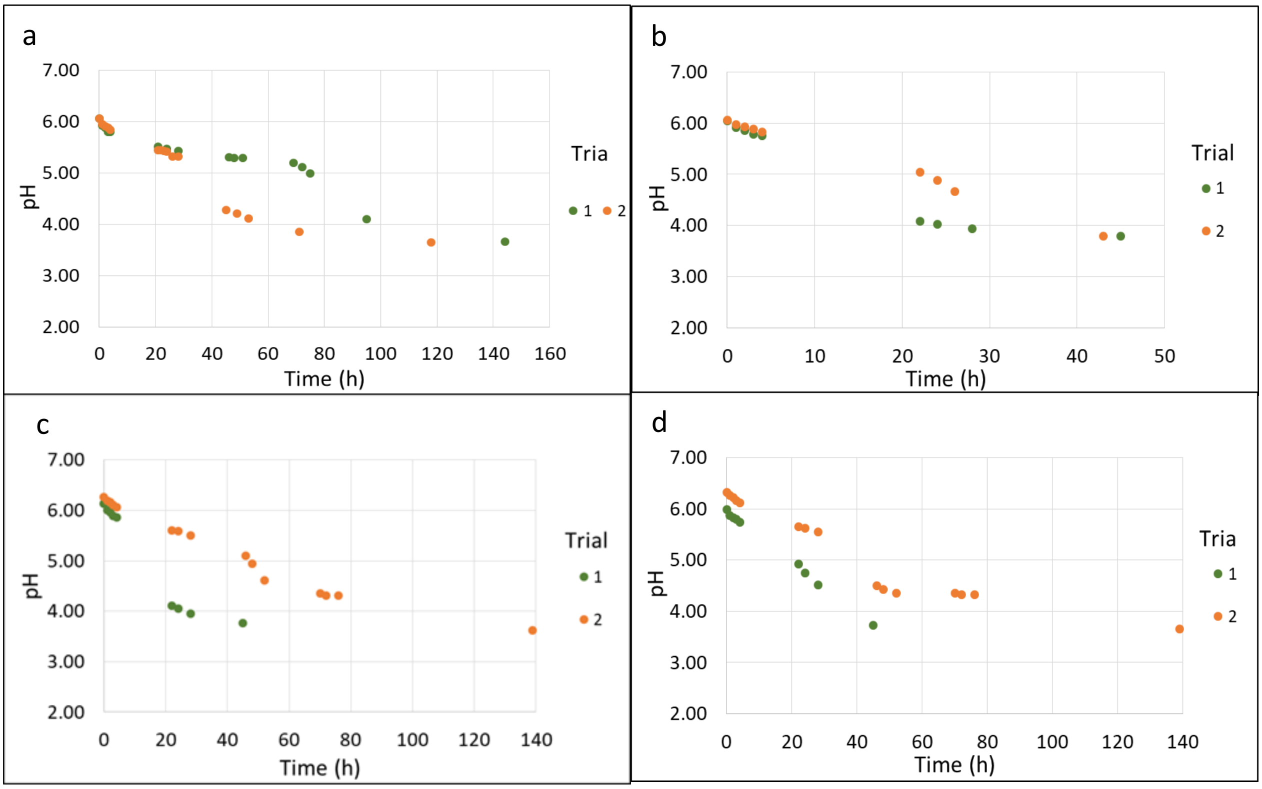

Figure 30 Broccoli pH during fermentation using Caldwell's Vegetable Fermentation starter when challenged with a) *Escherichia coli*, b) *Salmonella*, c) *Listeria monocytogenes* and d) *Bacillus cereus*.

4.3.2 Microbial count

Lactic Acid Bacteria

The LAB present in the broccoli were predominantly the added starter cultures. The raw broccoli had between 1-2 log10 cfu/mL of LAB, when they were detected (limit of detection 0.70 log10 cfu/mL). The starting inoculum of LAB in the broccoli was 7.14 ± 0.07 log10 cfu/mL when the CLD starter cultures were used as starter (Figure 31). The CLD starter culture starting concentration could not be increased further, as this would have required excessive culture powder to be added to the broccoli. The lower level of the inoculums may have contributed to the slower rate of pH drop to the target pH compared to the CSIRO culture (Chapter 2) where a higher inoculation dosage of ~10^8 was used. Further to this, the strain composition of the CLD starter cultures also potentially affected the performance of this starter culture. As can be seen in Figure 31, the CLD starter culture concentration decreased from the initial inoculum level in some fermentations. It was noticed that in these fermentations, both smaller and larger colony types were observed on the MRS plates at the beginning of fermentation, but the smaller colony types were no longer present at the end of the fermentation. It is possible that some strains/species in the CLD starter were not suited to the broccoli environment and did not remain viable throughout the fermentation, causing the initial LAB concentration to decrease. As the fermentation proceeded, the remaining LAB increased in number.

Yeast and Mould

Yeast and mould were present in all of the raw broccoli samples, with an average of 3.1 ± 0.62 log10 cfu/mL at the commencement of fermentation. By the 4 h time point, the yeast and mould had decreased by 1-2 log10 cfu/mL in all samples, and were rarely detected after this point (limit of detection 0.70 log10 cfu/mL). It is possible that the natural antimicrobial compounds present in broccoli may have caused the reduction in yeast and mould count since the fermentation did not progress significantly during the first four hours. A study by Pacheco-Cano et al. (2017) showed that mild heat treated (65 °C) crude extracts from broccoli (cv. Avenger) floret and stem have antimicrobial activity against yeast (Candida albicans and Rhodotorula sp.) and phytopathogenic fungi Colletotrichum gloeosporioides, Asperigillus niger. Further investigation showed that the antifungal activity could be attributed to an anti-fungal peptide present in broccoli.

Escherichia coli

The challenge trials were inoculated with 2.15 ± 0.24 log10 cfu/mL of the *E. coli* cocktail. After 4 h, the concentration of *E. coli* in the broccoli remained unchanged. However, after this time point, *E. coli* was no longer detected (limit of detection 1 cfu/mL) in any of the broccoli fermentations using straight enumeration of the sample. No *E. coli* were detected in 25 g of broccoli after the fermentations using CLD starter culture. This indicates that *E. coli* is unlikely to be a food safety risk in the fermented broccoli.

Salmonella

The broccoli was inoculated with 2.86 ± 0.06 $\log_{10}$ cfu/mL of the *Salmonella* cocktail. *Salmonella* was not reduced in the broccoli after the first 4 h. It was no longer detected in the broccoli fermentations after 24 h (limit of detection 0.70 $\log_{10}$ cfu/mL) in one of the fermentations but was detected (1.40 $\log_{10}$ cfu/mL) in the second fermentation using the CLD starter culture. It was not detected in any of the samples at the end of fermentation when the sample was directly plated. It was also not detected in 25 g of any of the fermentations using CLD starter cultures. This indicates that *Salmonella* is unlikely to be a food safety risk in the fermented broccoli.

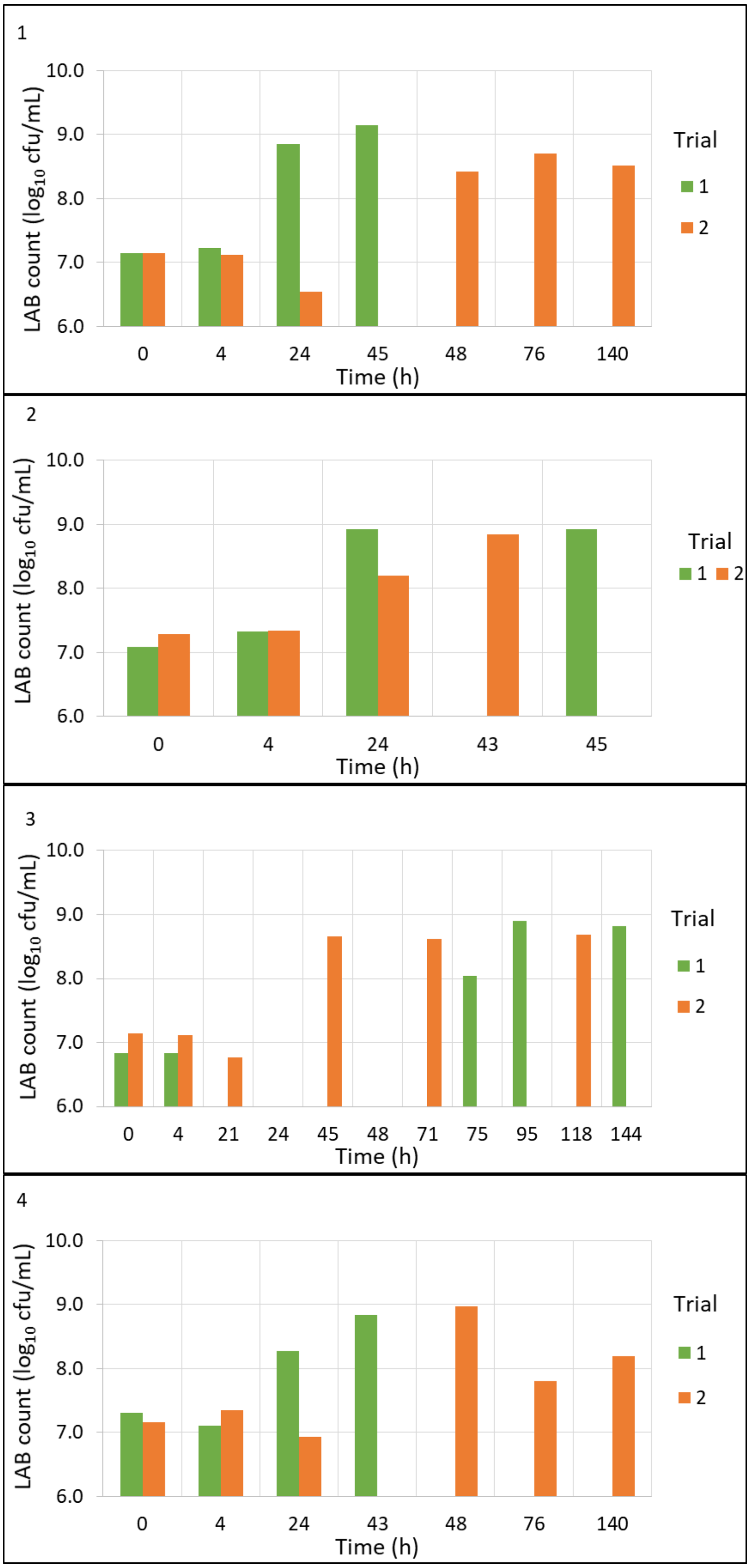

Figure 31 Lactic Acid Bacteria count (on MRS agar) during fermentation trials challenged with 1) *Escherichia coli*, 2) *Salmonella*, 3) *Listeria monocytogenes* and 4) *Bacillus cereus*.

Listeria

The broccoli was inoculated with 3.05 ± 0.24 log_{10} cfu/mL of the *Listeria* cocktail. The concentration of *Listeria* was not reduced after the first 4 h of fermentation. *Listeria* was also detected after both 21-24 h in all samples. Earlier experiments with CSIRO culture showed that fermentation to a target pH of 4.0 was not sufficient to fully reduce Listeria to undetectable level. Thus, it was decided to run the fermentation trials to a target pH of 3.8. At 21-24 h, the pH was 5.45-5.48 in the samples. A fermentation using the CSIRO starter culture was also concurrently done at this time. *Listeria* was detected in this fermentation after 21 h, when the broccoli was pH 4.03. *Listeria* was no longer detected (limit of detection 0.70 log_{10} cfu/mL) in all fermented broccoli samples at the end of fermentation (pH 3.8) when sample was directly plated or in 25 g of sample after enrichment. These results indicate that *Listeria* is a potential food safety risk in the broccoli fermentations if the pH is higher than pH 3.8 and that fermentations should proceed to below pH 3.8.

Bacillus cereus

Broccoli was inoculated with 3.49 ± 0.02 log_{10} cfu/mL of the *B. cereus* spore crop suspension. *Bacillus cereus* was detected all throughout the fermentations. At the end of fermentation, *B. cereus* spores were detected in all samples, although at lower concentrations than the initial inoculum, indicating that some of the spores have germinated but that *B. cereus* has not grown in number. Higher concentrations of *B. cereus* are required before the microorganism begins to produce toxins of risk to food safety. Since the *B. cereus* is not growing during the broccoli fermentations, *B. cereus* is not considered as a food safety risk in the fermented broccoli.

4.4 Conclusion and Recommendation

This study showed that the broccoli fermentation process is sufficiently robust to mitigate risks emanating from pathogenic organisms including *E. coli*, *Salmonella*, *Listeria* and *B. cereus* that can potentially contaminate the raw material. The antimicrobial properties of broccoli components seem to be at least partially responsible for the observed inhibitory effect on some of these organisms (Aires et al, 2009: Pacheco-Cano et al., 2017). However, the process needs to be conducted under proper Hazard Analysis and Critical Control Points (HACCP) plan so as to control potential food safety risks. The result also indicates that the target pH needs to be lowered to pH 3.8 so as to reduce the risk from *Listeria* contamination. The HACCP plan for broccoli is given in appendix B. It has to be noted that this HACCP plan is applicable only if the fermentation process is conducted as described in this study with the raw material sourced and processed in the same way following standard sanitization and good manufacturing practices and the fermentation process using the stated starter culture at the same dose. Any deviation from that would require a separate microbial challenge study for the development of a HACCP plan. Moreover, further studies are required in order to establish the shelf-life of the product at different temperature conditions. For carrot, some form of heat treatment is recommended in order to control incidental contamination by vegetative pathogenic microorganisms. However, the harsh treatment recommended in the HACCP plan may not be required and as such the pre-heating process need to be optimised focusing on surface decontamination using a short hot water blanching without necessarily heating the material to a core temperature of 80 °C as in the current HACCP plan.

5 Scale up of the broccoli and carrot fermentation processes

5.1 Introduction

As described in chapter 2, we successfully developed laboratory scale processes for the production of fermented carrot and broccoli puree products and conducted challenge studies to evaluate whether these processes are sufficiently robust to control incidental contamination of the product during the fermentation process (chapter 4). The objective of this part of the work was to evaluate the feasibility of scaling up the fermentation processes based on the results of the laboratory scale development and microbial challenge studies. As the case with Challenge study, we chose to use a commercial cultures in these experiments, to provide potential users of the technology the choice of using already established commercial cultures.

5.2 Materials and Methods

5.2.1 Materials

Broccoli and carrot puree samples were pre-processed from Australian carrot and broccoli in an external certified food grade facility in accordance with the HACCP plans developed based on the microbial challenge studies (Chapter 4 and Appendix A and B). Details of the processes are described in Figures 33. In contrast to the laboratory scale process, water was not added in the pureeing of carrot and broccoli in this case since pureeing was done using an industrial size reduction equipment (Comitrol, Urschel laboratories, Germany). In addition, carrot was pre-heated to 80 °C core temperature in order to satisfy the HACCP plan requirement for controlling incidental contamination. With respect to broccoli, not only the broccoli floret as in the laboratory scale processing but also the broccoli base was processed to puree since that was made feasible through the use of the industrial pureeing equipment reducing the amount of waste generated in the process. The pilot scale fermentation trials were conducted in a Groen tilting jacketed kettle (GPE batch and continuous processing solutions, USA) fitted with scrape surface and paddle mixers and lid made in the CSIRO workshop (Figure 32). The temperature and pH were monitored using a pharmaceutical grade pH probe (405-DPAS-SC-K8S, Mettler Toledo, Australia) and temperature probe connected to a data logger (MM-PIT-4U, EAI instruments, UK).

The commercial starter cultures that were used in the pilot scale trials namely Lyofast (for carrot) and Caldwell (for broccoli) were purchased from local suppliers as described in chapter 2. All other chemical and biochemical reagents were also sourced from local and international companies as described in chapter 2.

Figure 32 Experimental set up for small pilot scale fermentation trials of carrot and broccoli puree showing the Groen kettle used as fermentation tank and samples at the beginning and end of fermentation.

5.2.2 Carrot puree fermentation trials

The carrot fermentation process diagram is presented in Figure 33. Carrot samples were sanitised and water blanched to a core temperature of 80 °C and they were pureed using comitrol (Urschel laboratories, Germany) to a particle size <0.6mm, followed by packaging and cooling before transporting to CSIRO's food processing centre immediately after the pre-processing of the samples. The samples (~18 kg) were then transferred to the fermentation tanks (Groen kettle, USA) and inoculated with Lyofast starter culture (at a dosage of ~10^7 CFU/g) followed by mixing and temperature equilibration to 30 °C.

The fermentation tank and all other utensils that were used in the process were washed and sanitised using a food grade sanitiser (Oxysan, Applied Australian PTY LTD) prior to the use for the fermentation process. The microbial load on them was also assessed after sanitisation via swabbing and rapid ATP testing to determine their suitability for food grade production and all utensils that failed the test were re-cleaned and sanitised. Samples were not continuously mixed to avoid sample overheating due to heat generation during agitation. Preliminary experiments including laboratory scale experiments indicated that continuous mixing did not improve either fermentation rate or product uniformity in the case of carrot fermentation. The samples were also not continuously heated to reduce temperature overshoot. Rather intermittent mixing and heating as needed (approximately every three hours during the day) were implemented to maintain the experimental temperature and obtain representative pH and temperature readings. The Lyofast culture was selected for the scale up process since the laboratory scale process development work indicated that it enables fast fermentation of carrot puree and since it is available in bulk as opposed to the other commercial starter cultures. The dosage was 10 times less than what was used in the laboratory scale trials since that was higher than what is needed based on the initial assessment of the lactic acid bacteria count of the starter culture (Chapter 2). Samples were taken prior to and at the end of fermentation for physicochemical and microbial analyses. For Microbial analysis, five samples were taken from different positions in the tank so as to ensure that the analysis is representative of the bulk sample. Scale up experiments were conducted in duplicate.

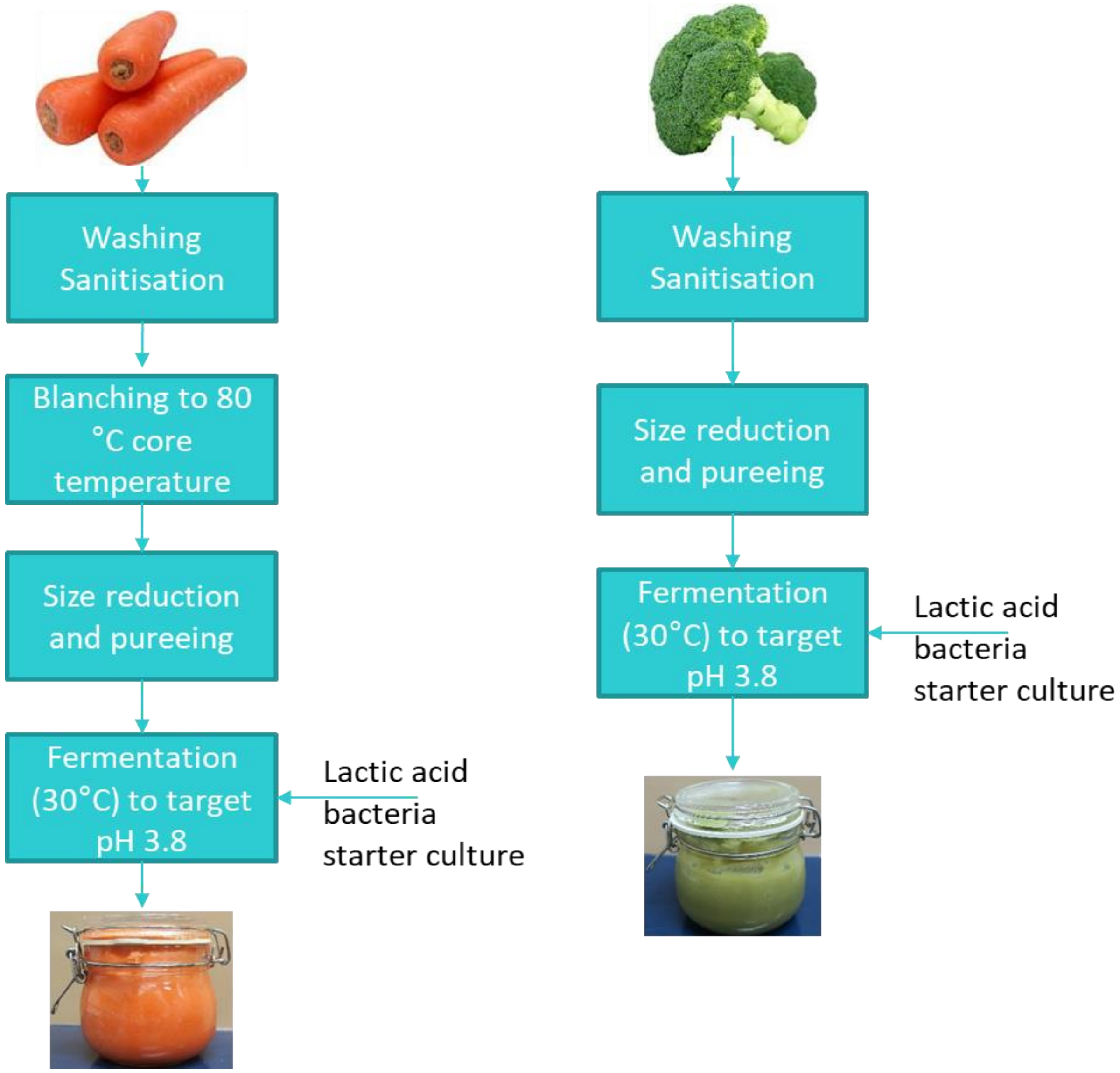

Figure 33 Process flow diagrams for the production of fermented carrot and broccoli puree in accordance with HACCP plans developed based on microbial challenge studies

5.2.3 Broccoli puree fermentation trials

In the case of broccoli, the microbial challenge study showed that non-heated broccoli puree can be used as a raw material in the fermentation process without posing unacceptable food safety risk. Thus, broccoli samples were washed, sanitised and pureed using comitrol (Urschel laboratories, Germany) to a particle size <0.6mm as described for carrot and were transported to CSIRO's food processing plant for further processing. The whole broccoli including the base was used in this process, although the fibres with size bigger than 0.6 mm were sieved out at the end of the size reduction process. The broccoli puree sample (~18 kg) was transferred to the fermentation tank (Groen kettle, USA) which was cleaned and sanitised as described for carrot puree fermentation. This was followed by inoculation with the Caldwell's starter culture at 10 times the recommended dosage of the supplier in order to get ~10^7 CFU/g in the product based on the outcomes of the laboratory scale process development and challenge studies. The samples were then preheated to the fermentation temperature (30 °C). The first batch was continually agitated to enhance fermentation rate and improve product uniformity. However, since the fermentation rate was not improved by the continuous agitation, only intermittent mixing was applied (every three hours during the day) during the second trial to reduce product heating above the fermentation temperature. The heating was also intermittent to reduce temperature overshoot as in the case of carrot fermentation. A process diagram summarising the different processing steps is given in Figure 33. Samples were taken prior to and after the fermentation end point (pH 3.8) for physicochemical and microbiological analyses. Five samples were taken from the second batch raw and fermented broccoli puree for microbiological analysis to make sure that data is representative of the bulk material.

5.3 Results and Discussion

5.3.1 Fermentation rate

Small pilot scale fermentation trials were successfully completed for both carrot and broccoli purees, although there were challenges mainly due to the difficulty to control temperature at the set point of 30 °C which were found to be the most suitable for the fermentation of both carrot and broccoli purees under laboratory scale conditions. The primary application of the Groen tanks that were used as fermentation tanks is heating and as such they are jacketed with a heating element in the jackets with no facility for cooling. Since the fluid in the jacket is not recirculating, it is difficult to maintain temperatures constant around 30 °C and there is no way of cooling down the fluid in the jacket other than moving it to a fridge in case of temperature overshoot. On the other hand, the tanks are able to hold temperature for a long period of time without continuous heating, which is very advantageous in situations like the fermentation trial where we were trying to reduce temperature overshoot by avoiding continuous heating. Overall, the temperature in the fermentation tanks ranged from 23 °C to 37 °C during fermentation of carrot and broccoli puree due to the difficulty of maintaining the target temperature of 30 °C especially during overnight operation. Nevertheless, all the fermentation trials were successfully completed indicating the robustness of the fermentation processes.

Carrot fermentation

The pilot scale up of the laboratory scale carrot puree fermentation process to ~18 kg was possible with Lyofast as a starter culture, although the rate of fermentation was slower (Table 12). The fermentation time to attain pH 4.2 during the laboratory scale trial was about 18 and 23 hrs in this trials as opposed to the 7 and 10 hours observed in the laboratory scale trials, which could be due to a number of reasons including the lower dosage of the inoculum (10^8 compared to 10^7 CFU/g in the larger scale trial), the higher viscosity of the raw material which limits nutrient transfer and availability (carrot puree without added water was used in this trial), the difficulty to maintain the desirable temperature of 30 °C, the exposure to oxygen as the lid of the fermentation tank was not airtight which may not be favourable for lactic acid bacteria which are microaerophilic and potentially unfavourable changes in the substrate due to pre-heating. The temperature during fermentation ranged from 23 to 32 °C and no intervention (heating) was feasible during overnight incubation. Fermentation to the target pH of 3.8 from food safety perspective took much longer requiring 2.5 times longer period since the process has already gone into lag phase. In fact, the final pH that was achieved after such a long period of fermentation was slightly higher than 3.8 (~3.84). As can be seen in the pH profile during fermentation of carrot by Lyofast (Figure 2, Chapter 2), the fermentation process is already in the lag phase after about 10 hrs of fermentation with a very slow change in pH afterwards. During the larger scale trials, there was fast decrease in pH up to about 17 hrs followed by a very slow decrease in pH thereafter showing a similar trend. There was also a substantial difference between the two pilot scale trials in terms of fermentation time, which could be due to the higher microbial load of batch 2 raw samples, the higher initial pH (6.39 compared to 5.85) and differences in temperature profile due to the ineffectiveness of the equipment for temperature control at the experimental set point.

Table 12 Carrot puree fermentation time (hrs) to target pH of 4.2 and 3.8 during pilot scale fermentation using lyofast culture as a starter (~10^7 CFU/g dosage)

Batch	Target pH of 4.2	Target pH of 3.8
1	18 hrs	45 hrs
2	23 hrs	67 hrs

Broccoli fermentation

As in the case of carrot puree, the fermentation of broccoli puree was successfully completed with pH dropping to the target ~3.8 and lower stipulated by the challenge study after a long period of incubation. The fermentation period to pH 4.4 was similar to what was observed in the laboratory scale process development trials using the same starter culture and the challenge test trials where longer fermentation time were observed. Batch to batch variation during the pilot scale trials was minimal with no significant effect of continuous stirring on fermentation rate.

Table 13 Broccoli puree fermentation time (days) to target pH of 4.4 and 3.8 during pilot scale fermentation using Caldwell's culture (~10^7 CFU/g dosage) as a starter

Batch	Target pH of 4.4	Target pH of 3.8
1	1.65 d	5.7 d (final pH ~3.67)
2	1.75 d	5.8 d (final pH ~3.88)

The fermentation process to the food safety target of 3.8 took much longer time in par with the slower fermentation batches observed during the microbial challenge study. Problems associated with the fermentation tank used for the pilot scale trials such as difficulty to control the temperature at the desired value of 30°C and exposure to air as opposed to a closed environment may have affected the fermentation process. For example, the temperature during the broccoli trials ranged from 26 to 37 °C. In addition, the broccoli puree was thicker and more viscous (with no water added), broccoli stem was included in the puree affecting the nutrient composition and the contamination of the raw broccoli puree with undesirable competing microorganisms was much higher than in the laboratory experiments, which can influence the fermentation process. However, despite all these changes, the fermentation did not take longer than the longest fermentation in the microbial challenge study. The difference with some of the faster fermentation batches during the laboratory scale process development and the challenge study could be attributed mainly to variability in the composition of broccoli due to factors such as differences in cultivar and postharvest storage and handling conditions which need further investigation.

5.3.2 Microbial quality of fermented samples

Carrot

The initial microbial load of the pre-heated carrot puree was different from the raw carrot puree used in the laboratory scale development. The initial lactic acid bacteria load was much higher in both carrot puree batches despite the cooking to a core temperature of 80 °C indicating that the equipment in the processing facility were contaminated with heat resistant lactic acid bacteria. Both batches were also contaminated with high load of B. cereus and the second batch highly contaminated with enterobacteriaceae and *coliforms* (Table 14). It seems that the cooking process for the second batch was not to the target temperature or there was some post-heating contamination. In both cases, the fermented products had no detectable level of pathogenic organisms. The fermentation process was also able to reduce the *B. cereus* level to below detection limit. However, the yeast count increased in both cases after fermentation perhaps due to the favourable conditions for yeast in the fermentation tank due to availability of oxygen coupled with a sugar rich substrate that allowed yeast growth and proliferation. The starter culture lyofast, was not able to control yeast growth even during the laboratory scale processing as opposed to the CSIRO culture although yeast growth was minimal in that case due to the limited availability of oxygen (Chapter 2). In the case of batch 2, fermentation was not able to fully suppress the growth of enterobacteriaceae perhaps due to the higher level of initial contamination. Both batches of fermented carrot samples were safe for consumption. However, the higher load of yeast is expected to compromise the shelf-life of the product and as such the processing conditions need to be optimised using a fermentation tank more suited to the process i.e. a tank with an airtight lid and temperature and agitation rate control is required in order to produce safe products with long shelf-life stability.

Table 14 Microbial count (CFU/g) of preheated carrot puree samples before and after fermentation

Microorganisms	Unfermented Batch 1	Fermented Batch 1	Unfermented Batch 2	Fermented batch 2
Lactic acid bacteria (CFU/g)	$1.6x10^4$ ($6.6x10^6$ after inoculation)	$2.28±0.6x10^8$	$2.7±1.5x10^5$ ($3.1x10^7$ after inoculation)	$3.8±2.9x10^8$
Coliforms (MPN/g)	<3	20.2±4.2	<3	<3
***E. Coli* (MPN/g)**	<3	<3	>1100 (for 3 out of 5 samples)	<3
Enterobacteriaceae (CFU/g)	<10	<1	$7.08±3.02x10^3$	$2.96±1.88x10^4$
Yeasts (CFU/g)	<100	$1.04±0.1x10^3$	<100	$4.18±1.48x10^5$
Moulds (CFU/g)	<100	<10	<100	<100
***B. cereus* (CFU/g)**	$8.4x10^3$	<10	$2.16±0.9x10^4$	<100
Coagulase +ve *Staphylococci* (*S. aureus* and other spp.) (CFU/g)	<100	<10	<100	<100
***Clostridium perfringens* (CFU/g)**	<10	<10	<10	<10
Salmonella	Not detected/25g	Not detected/25g	Not detected/25g	Not detected/25g
Listeria	Absent/25g	Absent/25g	Absent/25g	Absent/25g

Column 3, 4, 5: Average values for five samples± standard deviation

Broccoli

The initial microbial contamination of the broccoli puree samples were much higher than any of the raw broccoli samples prepared in-house for the laboratory scale fermentation experiments , which could have been due to a number of reasons, including cross-contamination. The samples had much higher initial loads of enterobacteriaceae, *coliforms*, yeasts and *B. cereus* and moulds in the case of batch 1. The initial lactic acid bacteria were also much higher than in house prepared samples (Chapter 2 and 4). Nevertheless, fermentation resulted in a cleaner product safe for consumption in both cases, despite the starting quality. In fact, the yeast count during the second trial was reduced to undetectable level, which is important with respect to the quality and the storage stability of the product. The result of these trials clearly indicate that the outcome of any fermentation process and the ability of the process to control undesirable microbial growth is very much dependent on the quality of the raw material. As such a clean processing environment is essential for the production of safe and shelf-stable fermented products especially when the product does not undergo a post fermentation pasteurisation step to inactivate microorganisms. Although fermentation reduces pathogenic bacteria and renders the post-fermentation product safe in this case, it is important that attention be paid to initial quality to reduce food safety risks.

Table 15 Microbial count of broccoli puree samples before and after fermentation

Microorganisms	Unfermented Batch 1	Fermented Batch 1	Unfermented Batch 2	Fermented batch 2
Lactic acid bacteria (CFU/g)	$2.9x10^4$ ($6.9x10^6$ after inoculation)	$1.9x10^8$	$2.7x10^4$ ($1.3x10^7$ after inoculation)	$1.76±0.17x10^8$
Coliforms (MPN/g)	>1100	<3	>1100	<3
***E. Coli* (MPN/g)**	<3	<3	3.6	<3
Enterobacteriaceae (CFU/g)	>3000	$1x10^3$	>3000	<10
Yeasts (CFU/g)	$3x10^2$	$>3x10^4$	$2x10^3$	<100
Moulds (CFU/g)	$5x10^2$	<100	100	<100
***B. cereus* (CFU/g)**	$1.2x10^3$	$\sim7x10^2$	$7x10^3$	$5.6±0.46x10^3$
Coagulase +ve *Staphylococci* (*S. aureus* and other spp.) (CFU/g)	<100	<100	<100	<100
***Clostridium perfringens* (CFU/g)**	<10	<10	<10	<10

Salmonella	Not detected/25g	Not detected/25g	Not detected/25g	Not detected/25g
Listeria	Absent/25g	Absent/25g	Absent/25g	Absent/25g

Column 5: Average values for five samples± standard deviation

5.3.3 Physicochemical quality attributes of fermented carrot and broccoli puree samples

Colour

There was a significant change in the colour of both carrot and broccoli puree during fermentation (Figure 32 and Figure 34). Although the total colour change after fermentation was higher in the case of carrot, the visual change in the colour of carrot was minimal. There was an increase in redness (a) and greenness (b) in the carrot samples as well as an increase in lightness (L), which contributed to the overall total colour change. However, the carrot maintained its orange colour as in the case of the raw fermented carrot (chapter 2). On the other hand, the broccoli sample became significantly lighter with significant decrease in greenness (b) and an increase in lightness (L) due to the degradation of chlorophyll under acidic condition.

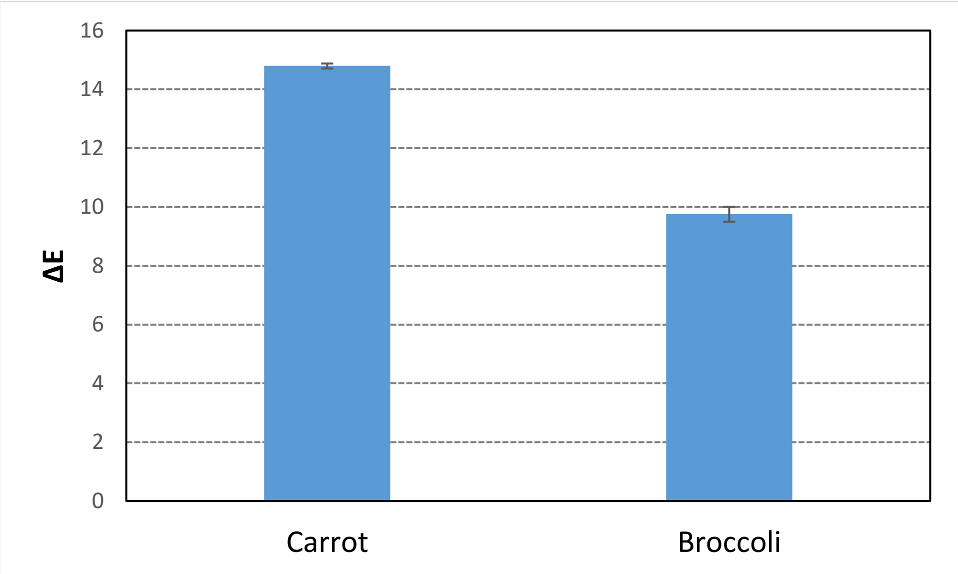

Figure 34 Total colour change (ΔE) of carrot and broccoli puree samples during fermentation at pilot scale with Lyofast and Caldwell's culture as starters respectively.

Titratable acidity

As would be expected, the titratable acidity of both carrot and broccoli samples increased after fermentation (Figure 35). The change in the titratable acidity of the carrot sample was in a similar range as in the case of the laboratory scale fermentation using the same starter, although the level was slightly lower owing to the initial lower acidity of the cooked carrot puree sample. On the other hand, the final titratable acidity of the broccoli sample was very high and different to what we observed in our previous experiments perhaps due to the lower final pH (~3.67) and the difference in the starter cultures. The highest value we observed was about 0.8 g lactic acid equivalent per kg puree in our earlier investigations (Chapter 2). However, previous analyses were done only with ferments using Wilderness Family naturals (WFN) and CSIRO cultures as starters. It remains to be seen whether that influences the sensory properties of the final product.

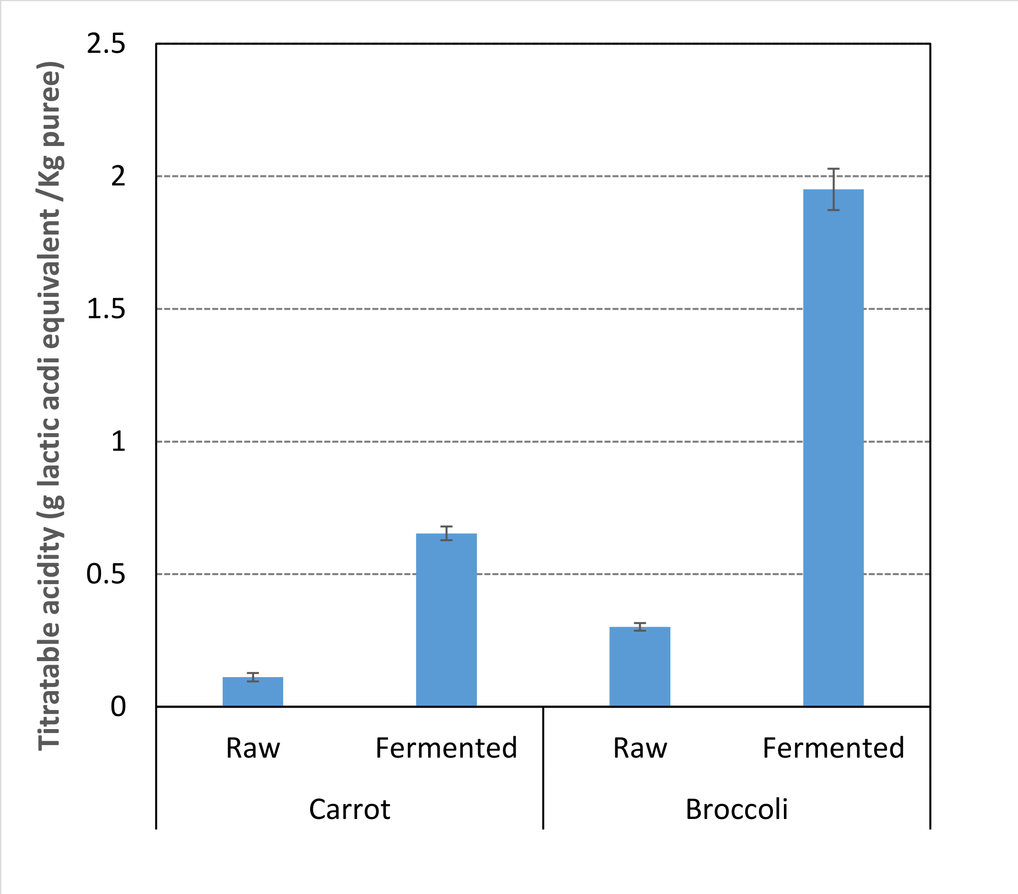

Figure 35 Changes in the titratable acidity of carrot and broccoli puree samples during fermentation at pilt scale

5.3.4 Total polyphenol content and ORAC antioxidant capacity of fermented carrot and broccoli puree samples

Total polyphenol content

The total polyphenol contents of carrot and broccoli puree samples were analysed prior to and after fermentation, Overall, a slightly higher total polyphenol content was observed for the non-fermented carrot puree samples compared to the raw carrot puree samples in our laboratory scale investigations (Figure 9, Chapter 2). The total polyphenol content of the cooked carrot puree sample was about 60% higher than the raw carrot puree (Chapter 2), which could be due to the release of carotenoids and other bioactives which contribute to the antioxidant capacity of the puree (Figure 36). During fermentation, there was an increase in total polyphenol content (~15%) although it was not as high as was observed in the laboratory scale process using lyofast as a starter (~47%). This could be due to the changes in the starting material and the fermentation conditions as well as the longer fermentation time and the lower target pH.

With regard to broccoli puree, the total polyphenol content of the broccoli puree was much lower (Figure 36) than that of the broccoli puree in the laboratory scale fermentation (compare 562 with 337 mg Gallic acid equivalent per 100 g dry matter), which could be due to the inclusion of the broccoli base in the puree. Fermentation by the Caldwell's culture resulted in a further decrease to 267 mg Gallic acid equivalent per 100 g dry matter. A significant increase in the total polyphenol content of broccoli puree was observed following fermentation by the WFN and the CSIRO culture under laboratory conditions (Figure 12, chapter 2). The difference in this case could be again due to changes in the raw material properties, fermentation conditions and the starter culture as well as the target pH.

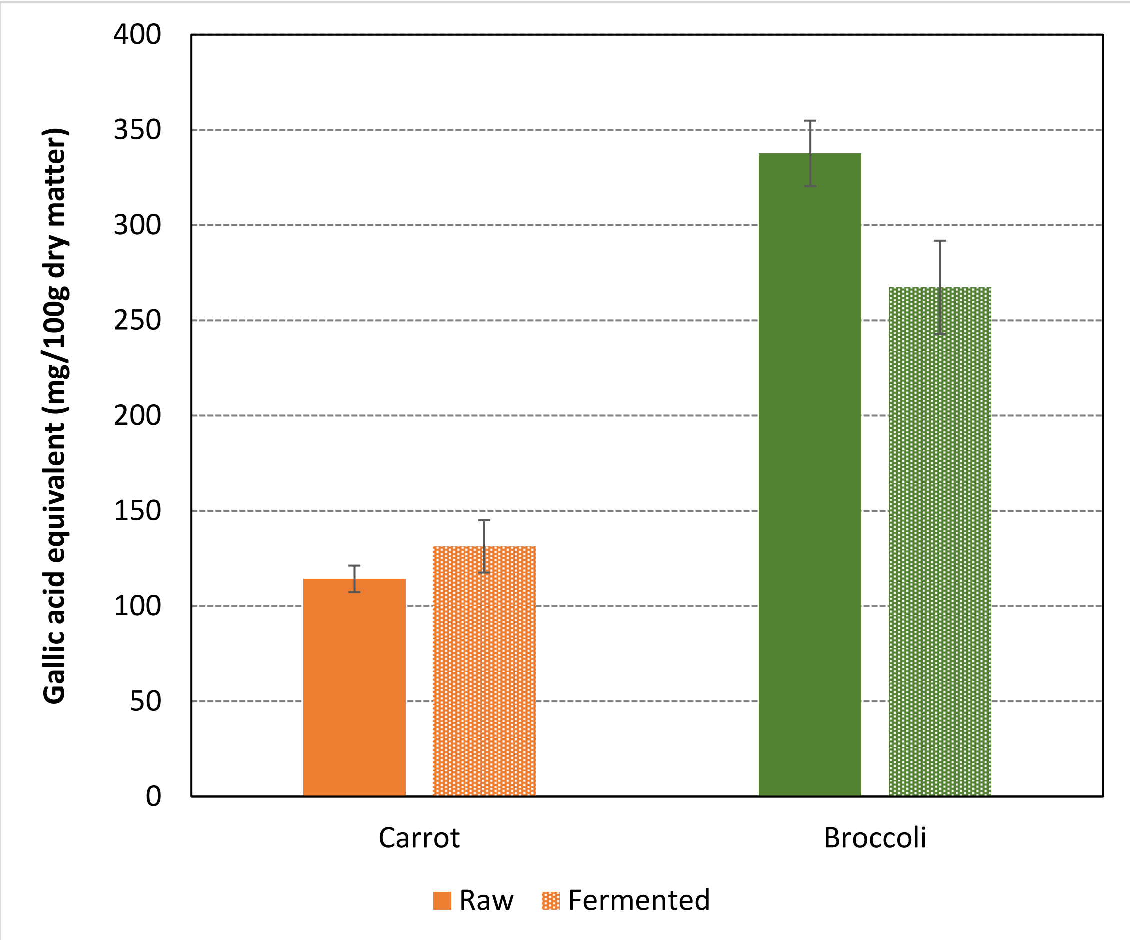

Figure 36 Changes in total polyphenol contents of carrot and broccoli puree samples during fermentation t pilot scale.

ORAC antioxidant capacity

The effects of fermentation using Caldwell's culture at pilot scale on the total antioxidant capacity of broccoli puree, as measured by oxygen Radical Absorbance Capacity (ORAC) assay was evaluated. As can be seen in Figure 37, the fermentation process more than doubled the ORAC antioxidant capacity (~ 114% increase), which is by far the highest increase observed in this study following fermentation. Interestingly, the same process led to a decrease in total polyphenol content (Figure 36). As discussed elsewhere, although both TPC and ORAC are measures of total antioxidant capacity, they are based on different chemistry and measure the antioxidant activities from different sets of metabolites. It seems that fermentation by the Caldwell's culture led to an increase in the concentration of metabolites that contribute only to ORAC antioxidant capacity. The opposite was observed during laboratory scale fermentation by the Wilderness Family Naturals (WFN) culture (Figure 11, Chapter 2). Nevertheless, the ORAC antioxidant capacity of the raw broccoli was lower than that of the laboratory scale samples in Chapter 2 (compare 27358 to 15785 µmole TE/100g DM) as in the case of TPC perhaps partly due to the inclusion of the broccoli stem in the process.

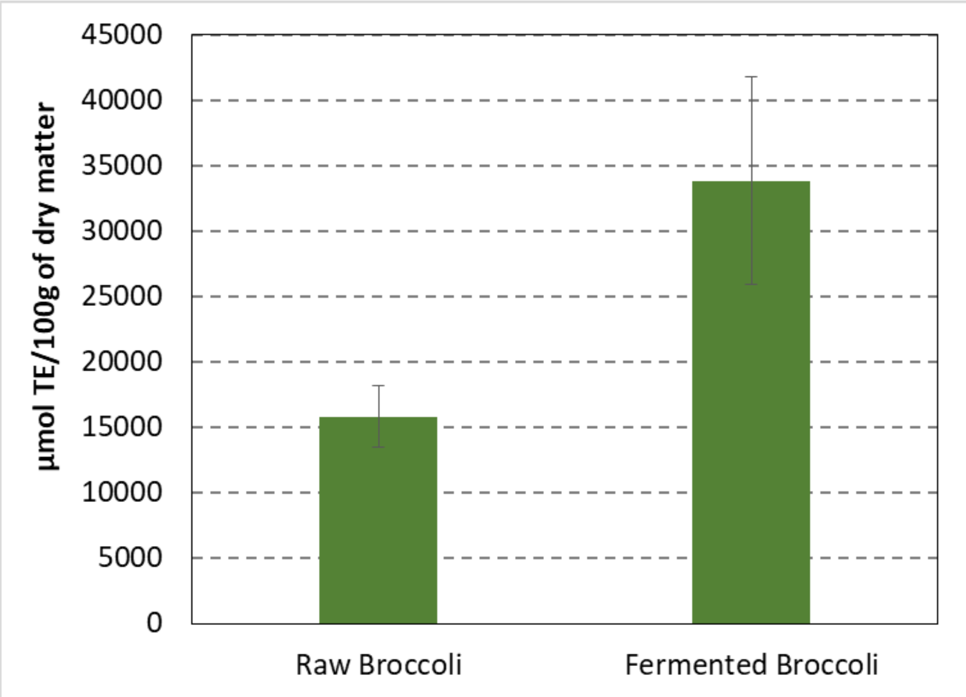

Figure 37 The effects of fermentation at pilot scale using Caldwell's culture on the ORAC antioxidant capacity of broccoli puree.

5.4 Conclusion and Recommendation

The laboratory scale carrot and broccoli puree fermentation processes were successfully scaled up to ~20 kg using commercially available starter cultures. The fermentation processes required longer periods owing to the lower target pH (pH 3.8) to minimize food safety risks and perhaps due to changes in the raw material properties and the fermentation conditions i.e. the inability to exclude air and control temperature at the desired condition. As in the case of the laboratory scale processes, the pilot scale fermentation processes resulted in products safe for consumption with no detectable level of pathogenic microorganisms, although the yeast count in the products was high in three of the four batches with potential impact on shelf life stability. This was most probably due to the high initial load, altered fermentation condition and the inability of the starter cultures to control the growth of yeast. The result clearly demonstrated that the microbial quality of the raw material determines to a large extent the quality of the final fermented product. As such, high level of sanitation and good manufacturing practices are necessary to produce safe and shelf-stable fermented products especially in cases where the products don't undergo further processing. Further process optimisation using an equipment fit for the purpose (i.e. a fermentation tank with an air tight lid and the instrumentation that enables temperature and agitation rate control) and with starters more suited to the respective substrates (e.g. the CSIRO cultures for broccoli and carrot) will be required prior to further scale up and larger scale production. It is also recommended that further challenge studies are conducted for the carrot puree fermentation process by considering optimised surface blanching so as to modify the current HACCP plan for the food grade production.

It has to be noted that the results presented in this study are for production of fermented products specifically under the conditions described. Many factors can affect the safety and sensory properties of fermented foods, including the type of raw material, the presence or absence of adventitious bacteria, the culture used, the fermentation condition and post-process contamination of the product. These trials only serve to demonstrate the feasibility of producing safe fermented carrot and broccoli products using the conditions described. Minor changes in the raw material source and quality, pre-processing condition, starter culture or fermentation condition can change the outcome of the process in terms of quality and safety and require separate investigation. Storage studies post-production, including the need for a post-fermentation pasteurisation step, will be needed to determine expected shelf life under the conditions used in supply chains.

6 Sensory analysis of fermented carrot and broccoli puree

6.1 Introduction

Lactic acid bacteria fermentation processes were developed that successfully enabled the production of safe fermented carrot and broccoli puree at laboratory and small pilot scales in the previous chapters. It has been envisaged that these purees could be used as condiments or ingredients. Deriving from their nutritional profile some of the envisaged applications are as ingredients in dips, sauces, smoothies, baby food and foods for older adults. In order to evaluate the feasibility of such applications, sensory assessment of the products were conducted using trained panels.

6.2 Materials and Methods

6.2.1 Fermented carrot and broccoli preparation

Fermented carrot samples were subsamples from Batch 2 of the scale up trial as they complied with the HACCP plan.

For the sensory evaluation, fermented broccoli puree samples were prepared as described in the microbial challenge study and the HACCP plan derived from it (chapter 4). Accordingly, broccoli samples were sanitised following the procedure of the New South Wales Food Authority for cleaning and sanitisation of fresh produce using 100 ppm (free) food grade chlorine (HYPOCHLOR, Applied Australian PTY LTD) for 5 min at pH 6.5 to 7.5. This was followed by rinsing, cutting the floret and pureeing with added water (3 part broccoli to 2 part water) using Magic bullet blender as described in chapter 2 and 4. All the utensils that were used in the process were washed and sanitised using a food grade sanitiser (0.4% OXYSAN) and swabbed for suitability for food contact prior to use. The broccoli puree was then fermented using the small pilot scale fermentation tank (Groen kettle, GPC, USA) as described in chapter 5 with intermittent mixing and periodic measurement of pH and temperature until the end point of pH 3.8. In compliance with the HACCP plan, five samples were taken at the end of fermentation for microbial analysis at DTS to ensure that the product is safe for consumption. Following fermentation, both fermented carrot and broccoli puree samples were immediately packed in 500 g high barrier pouches and frozen and shipped within four days to CSIRO Sensory Facilities in North Ryde, NSW with dry ice via air mail. Samples were received frozen and stored below <0°C.

6.2.2 Samples for sensory testing

Both broccoli and carrot fermented purees were included in the experiment in their original form. In addition, both purees were mixed with Greek yogurts (farmer's Union Greek yogurt) in two different amounts (10% and 25% puree) with the intention of understanding the potential of those purees as ingredients.

Table 16 List of samples and composition

Sample denomination	Vegetable (%)	Yogurt (%)
100% Broccoli	100% Broccoli	none
25% Broccoli	25% Broccoli	75% Yogurt
10% Broccoli	10% Broccoli	90% Yogurt
100% Carrot	100% Carrot	none
25% Carrot	25% Carrot	75% Yogurt
10% Carrot	10% Carrot	90% Yogurt

The six samples were considered as one sample set in the experiment. The required amount of frozen product was thawed overnight for tasting the next day. Mixing with yogurt was completed just prior to the tasting sessions and products were consumed within 2 hours.

6.2.3 Sensory descriptive analysis

All sensory activities took place in the sensory laboratory at CSIRO's North Ryde facilities, designed according to International Standards on Sensory Analysis (ISO 6658:1985).

Eight assessors from CSIRO's trained sensory panel were included in this experiment. Each of them had been screened for sensory acuity and had multiple experiences completing sensory tasks on a variety of food products. The assessors participated in two training sessions during which through multiple exposure to the products and moderated discussion, they developed a consensus vocabulary that best described the sensory differences (flavour, texture and aftertaste) between the products. The final vocabulary consisted of twelve attributes. For each attribute, assessors agreed on a definition and a method of assessment (Appendix C). The standardised method of assessment would ensure that the data collected from each panellist was comparable and could be collated.

First, assessors would place a levelled spoonful of product into their mouth and assessed: *flavour impact*, *fermented flavour*, *carrot flavour*, *brassica flavour* and *dairy flavour*. With a second levelled spoonful, assessors swirled the samples in their mouth to evaluate *creaminess* and *watery* mouthfeel. When ready to swallow, assessors evaluated *sour taste*, *sweet taste* and *bitter taste*. After swallowing but without rinsing their palate, assessors rated *aftertaste impact* and *residues*.

Evaluation was conducted in individual sensory booths in duplicate in one session. Approximately 10g of sample were served in plastic containers coded with 3-digit codes. Samples were presented monadically in balanced random order to account for order effects. Between samples assessors were instructed to cleanse their palate by drinking water and eating peeled cucumber slices. Sensory attributes were rated on a 100 mm unstructured line scale anchored at 5 and 95 %, respectively.

6.2.4 Data analysis

The mean panel ratings were calculated for each attribute and for each sample (Appendix D). Data was statistically analysed with analysis of variance (ANOVA), using products (N=6) and panellists (N=8) as factors in a full-factorial design. F-values and P-values were also calculated for each attribute. For each statistically significant attribute, Tukey's Honestly Significant Difference (HSD) test as a Post-hoc multiple comparison was carried out to determine which pairs of samples were different from each other. One-way ANOVA with 'Yogurt content' as a factor was completed. Data was analysed using the statistical software packages SPSS (v25.0.0).

For all analyses, a value of $p \leq 0.05$ was used as criterion for statistical significance.

6.3 Results and Discussion

6.3.1 Microbial quality of fermented carrot and broccoli puree samples for sensory analysis

Samples from batch 2 of the fermented carrot puree were used for the sensory analysis of the fermented carrot puree. As mentioned in chapter 5, the product was microbiologically safe for consumption and satisfy the HACCP requirement.

With regard to broccoli, a third batch was prepared to satisfy the HACCP requirement following the conditions used in the microbial challenge study. Data on the microbial count of the raw and fermented broccoli puree are presented in Table 17. As can be seen, the microbial quality of both the raw and the fermented broccoli puree were superior to the materials processed at the external facility since the research team had better control of the sanitisation of the raw material and the equipment and utensils used in sample preparation. The fermented broccoli sample in this case had no detectable level of pathogenic and spoilage organisms in agreement with the results from the laboratory scale process development trials. This once again reinforced the necessity of good manufacturing practices for ensuring the safety and stability of food products, which is crucial especially in the case of fermented food products which don't undergo further heat treatment. The final lactic acid bacteria count was slightly lower perhaps due to the difficulty in maintaining the temperature around 30 °C, which was found to be the best condition for the process. The fermentation time to pH 3.8 was ~4.7 days which was shorter than for the previous pilot scale batches (chapter 5). This could be due to differences in the raw material properties (dilute sample) as well as initial microbial load.

Table 17 Microbial count of raw and fermented broccoli prepared for sensory analysis

Microorganisms	Unfermented Batch 3	Fermented Batch 3
Lactic acid bacteria (CFU/g)	$2.16 \pm 2.24 \times 10^2$ (6.5x10^6 after inoculation)	$9 \pm 1.3 \times 10^7$
Coliforms (MPN/g)	80.4±49.6	<3
***E. Coli* (MPN/g)**	<3	<3
***Enterobacteriaceae* (CFU/g)**	$2.40 \pm 0.43 \times 10^2$	<10
Yeasts (CFU/g)	<100	<100
Moulds (CFU/g)	<100	<100
***B. cereus* (CFU/g)**	<100	<100
Coagulase +ve *Staphylococci* (*S. aureus* and other spp.) (CFU/g)	<100	<100
***Clostridium perfringens* (CFU/g)**	<10	<10
Salmonella	Not detected/25g	Not detected/25g
Listeria	Absent/25g	Absent/25g

Average values for five samples± standard deviation are presented; MPN – most probable number

6.3.2 Sensory characteristics of fermented vegetable purees

All attributes measured significantly discriminated between the six samples included in the experiment. The most discriminating attributes were *carrot*, *brassica* and *dairy flavours*.

Broccoli samples were perceived more intense in flavour overall than carrot samples.

100% Fermented broccoli puree was perceived with a strong *flavour impact* driven by a strong *fermented flavour*, *brassica flavour*, *sour taste* and *bitter taste*. This sample was perceived as very *watery*. After swallowing, the *aftertaste impact* was perceived as intense and the amount of *residues* left in the mouth was important. The assessors commented that fine powdery particles were left in the mouth after swallowing.

100% Fermented carrot puree was perceived as significantly less intense in *flavour impact*. *Flavour impact* was driven by a perceived moderately strong *fermented flavour*, an intense *carrot flavour*, *sour taste* and *sweet taste*. The assessors commented during training that the flavour was the one of fresh, raw carrots. The sample was perceived as slightly *watery*. After swallowing, *aftertaste impact* was moderately low and the amount of perceived *residues* was high (although significantly lower than in the broccoli sample). Assessors indicated during training that the carrot puree left hard slight sharp and crunchy particles in mouth after swallowing. As seen in Figure 38, 100% fermented broccoli puree and 100% fermented carrot puree significantly differ in all attributes expect *dairy flavour* and *creaminess*.

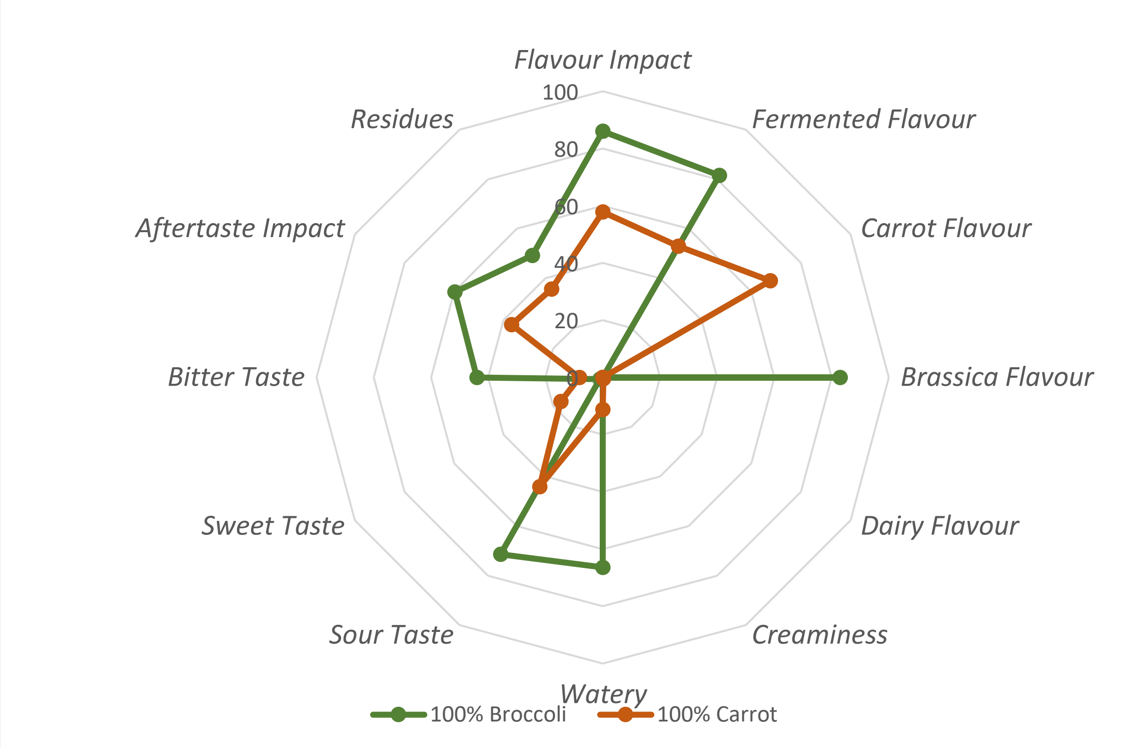

Figure 38 Comparison of 100% fermented broccoli puree and 100% fermented carrot puree sensory profiles

6.3.3 Effect of the addition of yogurt

The addition of yogurt impacted differently the sensory properties of the broccoli and carrot based samples. As could be expected, for both types of purees (broccoli and carrot), the addition of yogurt resulted in a significant increased intensity of *dairy flavour* and *creaminess*.

When comparing the sensory properties of the three samples containing broccoli, it appeared that the addition of yogurt significantly decreased perceived *flavour impact*, *fermented flavour*, *brassica flavour*, *watery*, *sour taste*, *bitter taste*, *aftertaste impact* and *residues*. For *brassica flavour*, *watery* and *residues*, the decrease in intensity seemed to be proportional to the amount of yogurt added. However for *fermented flavour*, *sour taste*, *bitter taste* and *aftertaste impact*, the addition of yogurt seem to have an effect not the amount of yogurt added (Figure 39).

Figure 39 Comparison of sensory properties of the three broccoli based samples.

When comparing the three samples made of carrot it can be seen that addition of yogurt decreased significantly the perceived intensity of *fermented flavour*, *carrot flavour*, *sweet taste* and *residues*. The amount of yogurt added only seemed to have an impact on *carrot flavour* (Figure 40) .

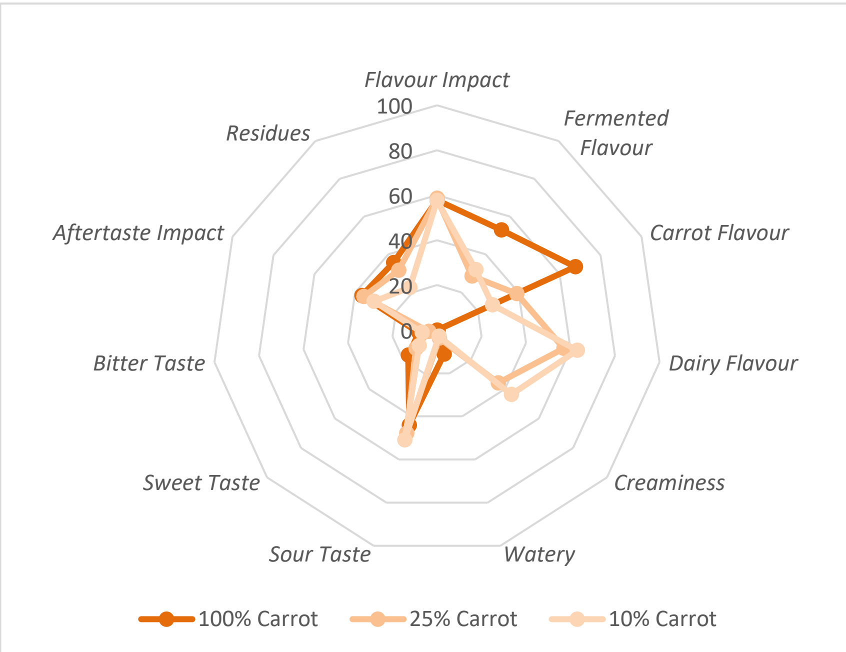

Figure 40 Comparison of sensory properties of the three carrot based sample.

Table 18 Summary table- Effect of the addition of yogurt on the sensory properties measured.

EFFECT OF YOGURT ADDITION	*Flavour Impact*	*Fermented Flavour*	*Carrot Flavour*	*Brassica Flavour*	*Dairy Flavour*	*Creaminess*	*Watery*	*Sour Taste*	*Sweet Taste*	*Bitter Taste*	*Aftertaste Impact*	*Residues*
Fermented broccoli puree	↓	↓	-	↘	↖	↖	↘	↓	↑	↓	↓	↘
Fermented carrot puree	-	↓	↘	-	↑	↑	↓	-	↓	-	-	↓

6.4 Conclusion and Recommendation

Sensory descriptive analysis was applied to a set of six samples including the original broccoli and carrot samples and a range of puree and yogurt mix. The sensory vocabulary developed describes the main flavour characteristics and some important textural characteristics. The original samples (100% broccoli and 100% carrot) had a strong fermented note although it was perceived as less intense in the carrot samples. The broccoli samples were also perceived with a strong brassica flavour, sour taste and bitter taste. After swallowing, the remaining aftertaste was also strong and the mouth was full of very fine residual particles. The carrot samples had the flavour of fresh raw carrots with a relatively intense sweet and sour taste. That left a mild aftertaste and a large amount of crunchy particles.

The experiment show that the addition of yogurt decreased the intensity of some of the flavour aspects of the original samples. The broccoli samples had a less intense fermented flavour, brassica flavour, sour taste and bitter taste. The carrot samples had a less intense fermented flavour, carrot flavour and sweet taste.

More importantly, with both vegetable purees, the texture was impacted by the addition of yogurt. The samples became creamier, less watery and less residues were left in the mouth after swallowing. The addition of yogurts impacted slightly differently the two types of matrices. We can hypothesize that this was due to the different properties of the particles in the two samples. It seemed that broccoli samples had softer particles whereas the carrot samples were made of harder, crunchier particles. This becomes very relevant when the objective is to develop products for specific populations such as young children or older adults. Here, the addition of yogurt seemed to lubricate and bind particle together therefore facilitating in-mouth manipulation and swallowing leaving a clean mouthfeel afterwards.

This study illustrated the potential of such products as ingredients in more complex food products. The mixing with other ingredients will balance the strong flavours of the original materials. The study also showed the need to study each food material separately as the addition of yogurt didn't have the same effect on fermented broccoli and carrot samples.

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Appendix A

Form 22

HACCP FOOD
SAFETY PLAN

Issue Date:
Supersedes: New

Product Description

Appendix:

Prepared by	Signature	Date
Netsanet		12/12/2019
Reviewed by		
Sieh Ng		17/12/2018
Approved by		19/12/2018
Sandra Olivier		

Hazard	**Risk**	**Result**
M – Microbiological	A – **High, likely to happen**	**1 – Critical, automatically results in unsafe product**
C – Chemical	B – Medium, could happen	2 – Serious, probably result in unsafe product
P – Physical	C – Low, not likely to happen	3 – Major, may result in unsafe product with potentially serious consequences
R - Radioactive		4 – Minor, may result in unsafe product with no serious consequence
		5 – None, will not result in unsafe product

							Monitoring				
Step	**CP/CCP**	**Critical Operation**	**Potential Risk**	**HAZ**	**Risk**	**Control Point**	**Inspection Frequency**	**Person Responsible**	**Specification**	**Records**	**Corrective Action**
1	CP	Receiving of raw carrot	Microbial contamination	M	B	Purchase from a reputable pack-	Every delivery	Project staff	Visually clean	Supplier records	**Reclean**

						house/supplier.					
2	CP	Cleaning and Sanitising of carrot	Microbial contamination	M	B	To reduce microbial load on the raw carrot	Every batch	Project staff	100 ppm (free) chlorine for 5 minutes. The optimal range of pH fro sodium hypochlorite is 6.5-7.5.	Production log	**Test chlorine concentration with test strip. If chlorine concentration is not sufficient, adjust it to the correct concentration and pH.**
3	CCP	Hot water blanching of whle carrots	Microbial contamination	M	B	To inactivate pathogenic vegetative microorganisms on the surface of the carrots	Every batch	Project staff	Temperature control; thermocouple/probe must indicate water temperature maintained at 80°C for at least 1 min once carrot is added (NOTE: cold carrots will initially reduce water temperature)	Production log	**If thermal process is not delivered as exactly described, repeat or discard**
3	CP	Chopping	Microbial contamination	M	B	Sanitise the chopping board, knife and other food contact surfaces	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**
4	CP	Pureeing	Microbial contamination	M	B	Sanitise the equipment	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**
5	CP	Transferring the material to a stirred tank	Microbial contamination	M	B	Clean and Sanitise the tank and other food contact parts (agitator)	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**

6	CP	Rehydration of culture	Microbial contamination	M	C	Use sterile distilled water	Every batch	Project staff	Right dosage	Production log	**If under dosage, ensure the right dosage is applied. If the dosage is too high, it is not an issue for the ferementation. Double check calculations so that correct amount of culture is added.**
7	CP	Innoculation	Microbial contamination	M	C	Use sterile plastic transfer pipette	Every batch	Project staff	Right dosage, sterile pipete	Production log	**If under dosage, ensure the right dosage is applied. If the dosage is too high, it is not an issue for the ferementation. Double check calculations so that correct amount of culture is added.**
8	CP	pH monitoring	Microbial contamination	M	B	Sanitise the pH meter and probe	Every batch	Project staff	ATP<100 RLU	Production log	**Reclean/sanitise**
9	CCP	Fermentation	Microbial contamination	M	B	pH evolution and end point	Every batch	Project staff	pH 3.8	Production log	**If pH doesn't go down to pH 3.8 by the end of the fermentation, discard the product**

10	CP	Filling of product into final packaging	Microbial contamination	M	B	Use food grade packaging material, utensil used to transfer the final product need to be sterile, heat seal immediately, product kept at 4°C	Every batch	Project staff	Only food grade packaging material to be used. Filling process to be conducted in a hygienic manner.	Production log	**If product was found to be contaminated with foreign matter or pack seal has product underneath it/compromised in some other way, discard the product immediately**
11	CCP	Finished product microbiological testing	microbial contamination during fermentation process not eliminated	M	C	Finished product testing for Listeria monocytogenes	5 samples per batch	Send to DTS Nata lab for testing	Listeria monocytogenes not detected (i.e. <1 cfu) in 25 g sample	DTS analysis Resutls	**Fermented product deem not fit for human consumption if Listeria monocytogenes is detected in any sample tested**
12	**CCP**	Transportation and storage of product at ≤5°C, prior to consumption	Microbiological growth during storage if temperature not controlled	M	C	Temperature of product must be maintained at ≤5°C during transport and storage	After transportation of any shipment, then daily during storage of product	Project staff		Production log and temperature logger downloads	If temperature is 5°C or higher product should not be consumed. A microbiologist should be consulted to review complete temp records for final ruling.

Appendix B

Form 22

HACCP FOOD SAFETY PLAN

Issue Date:
Supersedes: New

Product Description

Appendix:

Prepared by	Signature	Date
Netsanet		5/12/2018
Reviewed by		
Sieh Ng		7/12/2018
Approved by		10/12/2018
Sandra Olivier		

Hazard	**Risk**	**Result**
M – Microbiological	A – **High, likely to happen**	**1 – Critical, automatically results in unsafe product**
C – Chemical	B – Medium, could happen	2 – Serious, probably result in unsafe product
P – Physical	C – Low, not likely to happen	3 – Major, may result in unsafe product with potentially serious consequences
R - Radioactive		4 – Minor, may result in unsafe product with no serious consequence
		5 – None, will not result in unsafe product

							Monitoring				
Step	**CP/CCP**	**Critical Operation**	**Potential Risk**	**HAZ**	**Risk**	**Control Point**	**Inspection Frequency**	**Person Responsible**	**Specification**	**Records**	**Corrective Action**
1	CP	Receiving of raw broccoli	Microbial contamination	M	B	Purchase from a reputable pack-	Every delivery	Project staff	Visually clean	Supplier records	**Reclean**

						house/supplier.					
2	CP	Cleaning and Sanitising of broccoli	Microbial contamination	M	B	To reduce microbial load on the raw broccoli	Every batch	Project staff	100 ppm (free) chlorine for 5 minutes. The optimal range of pH fro sodium hypochlorite is 6.5-7.5.	Production log	**Test chlorine concentration with test strip. If chlorine concentration is not sufficient, adjust it to the correct concentration and pH.**
3	CP	Chopping	Microbial contamination	M	B	Sanitise the chopping board, knife and other food contact surfaces	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**
4	CP	Pureeing	Microbial contamination	M	B	Sanitise the equipment	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**
5	CP	Transferring the material to a stirred tank	Microbial contamination	M	B	Clean and Sanitise the tank and other food contact parts (agitator)	Every batch	Project staff	ATP<100 RLU	ATP Log	**Reclean and sanitise**
6	CP	Rehydration of culture	Microbial contamination	M	C	Use sterile distilled water	Every batch	Project staff	Right dosage	Production log	**If under dosage, ensure the right dosage is applied. If the dosage is too high, it is not an issue for the ferementation. Double check calculations that**

											correct amount of culture is added.
7	CP	Innoculation	Microbial contamination	M	C	Use sterile plastic transfer pipette	Every batch	Project staff	Right dosage, sterile pipete	Production log	**If under dosage, ensure the right dosage is applied. If the dosage is too high, it is not an issue for the ferementation. Double check calculations that correct amount of culture is added.**
8	CP	pH monitoring	Microbial contamination	M	B	Sanitise the pH meter and probe	Every batch	Project staff	ATP<100 RLU	Production log	**Reclean/sanitise**
9	CCP	Fermentation	Microbial contamination	M	B	pH evolution and end point	Every batch	Project staff	pH 3.8	Production log	**If pH doesn't go down to pH 3.8 by the end of the fermentation, discard the product**
10	CP	Filling of product into final packaging	Microbial contamination	M	B	Use food grade packaging material, utensil used to transfer the final product need to be sterile, heat seal immediately,	Every batch	Project staff	Only food grade packaging material to be used. Filling process to be conducted in a hygienic manner.	Production log	**If product was found to be contaminated with foreign matter or pack seal has product underneath it/compromised in some other way, discard the product immediately**

						product kept at 4°C					
11	CCP	Finished product microbiological testing	microbial contamination during fermentation process not eliminated	M	C	Finished product testing for Listeria monocytogenes	5 samples per batch	Send to DTS Nata lab for testing	Listeria monocytogenes not detected (i.e. <1 cfu) in 25 g sample	DTS analysis Resutls	**Fermented product deem not fit for human consumption if Listeria monocytogenes is detected in any sample tested**
12	**CCP**	Transportation and storage of product at ≤5°C, prior to consumption	Microbiological growth during storage if temperature not controlled	M	C	Temperature of product must be maintained at ≤5°C during transport and storage	After transportation of any shipment, then daily during storage of product	Project staff		Production log and temperature logger downloads	If temperature is 5°C or higher product should not be consumed. A microbiologist should be consulted to review complete temp records for final ruling.

APPENDIX C. Sensory vocabulary developed for this set of samples

First levelled spoonful	**Definition**	**Anchors**	**Related terms**
Flavour impact	The overall flavour intensity of the sample	low - high	
Fermented flavour	The flavour associated with the fermented notes of sauerkraut, pickles	low - high	
Carrot flavour	The flavour associated with raw, fresh carrots i.e. shredded carrot	low - high	
Brassica flavour	The flavour typical of cooked brassica (broccoli, Brussels sprouts, cabbage…).	low - high	vegetal, roasted, over cooked, sulphurous
Dairy flavour	The flavour associated with natural Greek yogurt	low - high	
2nd levelled spoonful	**Definition**	**Anchors**	**Related terms**
Creaminess	The perceived velvety, silky smoothness of the sample.	low-high	thick
Watery	The amount of liquid in the sample perceived during its first compression.	dry-wet	
Sour taste	The perceived intensity of sour taste- defined by basic solution for sour	low - high	
Sweet taste	The perceived intensity of the sweet taste - defined by basic taste solution for sweet	low - high	
Bitter taste	The perceived intensity of the bitter taste - defined by basic taste solution for bitterness	low - high	
AFTERFEEL	**Definition**	**Anchors**	**Related terms**
Aftertaste impact	The overall flavour intensity remaining in the mouth after swallow	low-high	
Residues	The amount of particles left in the mouth after swallowing.	none-much	

APPENDIX D. Mean ratings and significance for all attributes and all samples

	Flavour Impact	*Fermented Flavour*	*Carrot Flavour*	*Brassica Flavour*	*Dairy Flavour*	*Creaminess*	*Watery*	*Sour Taste*	*Sweet Taste*	*Bitter Taste*	*Aftertaste Impact*	*Residues*
100% Broccoli	86.00 *a*	81.56 *a*	0.00 *d*	82.94 *a*	0.00 *c*	0.00 *c*	66.38 *a*	71.44 *a*	1.13 *d*	43.94 *a*	59.69 *a*	49.19 *a*
25% Broccoli	71.81 *b*	48.94 *b*	0.00 *d*	63.31 *b*	48.88 *b*	41.44 *b*	7.56 *bc*	52.19 *bc*	1.56 *d*	21.06 *b*	44.94 *b*	15.94 *c*
10% Broccoli	65.31 *bc*	48.69 *b*	0.00 *d*	47.50 *c*	59.56 *a*	59.19 *a*	3.75 *c*	53.81 *b*	6.00 *c*	14.38 *bc*	39.06 *bc*	4.56 *d*
100% Carrot	57.81 *c*	52.94 *b*	67.63 *a*	0.00 *d*	0.00 *c*	0.50 *c*	11.19 *b*	44.06 *c*	16.94 *a*	8.13 *cd*	36.81 *bc*	35.69 *b*
25% Carrot	58.56 *c*	28.63 *c*	39.06 *b*	0.00 *d*	56.94 *a*	36.00 *b*	3.75 *c*	47.75 *bc*	12.38 *b*	3.75 *d*	35.88 *c*	31.56 *b*
10% Carrot	57.63 *c*	32.00 *c*	27.13 *c*	0.00 *d*	63.06 *a*	43.75 *b*	2.88 *c*	50.94 *bc*	10.50 *b*	6.75 *d*	30.81 *c*	22.44 *c*
F values	11.27	20.65	73.93	149.55	160.75	73.22	59.64	7.5	10.16	12.59	13.89	21.57
p-values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

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REPORT:
Value Chain Mapping and Business Model Development

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Value Chain Mapping and Business Model Development
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EXECUTIVE SUMMARY

CSIRO and Hort Innovation have initiated a project to advise the Australian horticulture sector of the opportunities to value-add fresh produce, based on new technical developments from CSIRO. The overall purpose of the project is to provide the aspiring horticultural grower with an understanding of the relevant market for potential products, the supply, value chains and operational models to leverage these new value-adding opportunities, and critical information on the potential prospects for their current businesses to guide strategic decision-making.

As a first step in that overall project, this Stage 1 report focuses on a broad, high level overview of the scope of the market landscape, and the value chain and business model options. The target audience for the outcomes of the report's findings is the cohort of potential early adopters within the horticulture sector. As such, the report addresses:

1. Situational analysis of three potential product types and the corresponding product landscape: to broadly outline
    - Characteristics of each product type;
    - Dynamics and nature of the target markets;
    - Key jurisdictions for target market(s); and
    - Major competitors.

2. Value chain: High level mapping and analysis of each point in the value chain for each product type.
    - Map:
        - Key operations and outcomes within the value chain;
        - Participants in the value chain from growers to end users; and
        - Business models of key participants.
    - Analyse:
        - Opportunities for participation of key proponents within the value chain for the product types; and
        - Significant risks: Challenges, limitations and constraints.

3. Benchmark the value chain and business models for analogous food products, food ingredients and supplements in other jurisdictions, to inform expectations of value chain structure, successes and hurdles for the three product types, in terms of a high level outline of:
    - Path to market;
    - Typical business models within the supply and value chain; and
    - Key risks, limitations and hurdles.

4. Recommendations: initial guidance based on this high level review, considering
    - Business models: Proposals for business models appropriate to each product type.
    - Risk mitigation and management strategies, especially for early adopters.
    - Approaches to address gaps identified to date within the existing value chain.

This Stage 1 report does not aim to provide:

- An in-depth or extended review of
    - The capabilities and capacities required within the value chains to meet the volume, quality and other supply metrics expected by the target market.
    - Operational structure within key value chain participants.
    - Benchmarked value chain and business models.
    - Market size and competitive landscape for the applications for each product.
- Scope of applications for each or all of the potential products arising from CSIRO technology;
- Assessment of level of interest within the horticulture sector to invest in value adding;
- Essential attributes required of the supply chain from the end-users' perspective;
- Drivers of success in established, vertically-integrated horticulture businesses;
- Detailed and executable proposals for revised or new business models based on each product type;
- An implementation framework, to progress the new product types within their respective supply and value chains;
- Assessment of the equipment or pre-processing, production and storage infrastructure required for the three product types;
- Economic or cost/benefit analysis of any of the opportunities or business models;
- Definition of the final commercial product formulation arising from any of the new product types;
- Identification, contact or assessment of potential commercial partners for any of the three product types; or
- Review or evaluation of the IP associated with the project.

While these aspects may provide additional intelligence for CSIRO and Hort Innovation and their growers, these are outside the scope of the Stage 1 engagement.

SUMMARY

Market opportunity

In overview, all three proposed product types have characteristics consistent with current consumer trends within the nutraceutical, food and food ingredients, snack and beverages markets, which support continued investigation of their potential commerciality. However, these markets are notoriously subject to consumer fads, are intensely competitive and price-driven. A clear view of the applications for these products and their differentiation, in terms of price, convenience, quality, shelf life, speciality, nutritional composition, local origin, and/or health benefits, is required to further reinforce an assessment of the market opportunity for any of the products.

The snack food and ingredients markets are substantial and global, but intensely competitive and fickle. Globally, the total snack foods market was estimated at ~US$374 billion in 2013-2014 and the total global market for healthy snacks is expected to reach ~US$33 billion by 2025 (2017), driven by increasing consumer awareness of healthy eating. Key emerging industry-wide themes of "healthy indulgence" in snacks increasingly feature vegetables, pulses and ancient grains.

The global fruit and vegetable ingredients market is projected to reach ~US$202 billion by 2020, with beverages dominating the applications for fruit and vegetable ingredients. North America is the most significant jurisdiction for specialty food ingredients, but the Asia-

Pacific region has the strongest growth rate. Commercial use of fruit and vegetable ingredients within the Asian sector has been less than in western markets to date, which is indicative of an untapped potential for uptake within food manufacturing within the region.

The fermented foods and beverages market is booming globally. The total fermented foods and ingredients market is anticipated to grow from US$637 billion in 2016 to ~US$889 billion by 2023. The market share of fermented dairy products is being eroded by the entry of new products: drinkable vinegars, kefir, and kombucha (fermented teas). In addition, the market for probiotics (the agents of fermentation) is emerging as one of the fastest growing markets globally, and is expected to exceed US$64 billion by 2023. The US dominates the probiotics market because US consumers expect a health benefit in terms of diabetes and weight management. Probiotic consumption in China, India and Japan continues to expand.

Fermented vegetables are a well-established traditional in foods such as sauerkraut, kimchi or tempeh, in Asia, Africa, western and eastern Europe, and Scandinavia. The global history and variety of fermented vegetables is long-established, based on extensive domestic- and village-scale production. More recently, commercially produced fermented, vegetable-based snack or ready-to-eat products are increasingly appearing on the market. These products connect to the trends both of traditional use and current consumer expectations of digestive health.

Consumer trends in the new foods, food ingredients and nutraceutical markets, encompass an emphasis on "naturally functional" and "clean and green". Current trends are for products that provide for healthy aging, high energy and athletic performance, and digestive wellness, from fermented and protein-based foods, especially plant-based protein. Examination of these consumer trends suggests a correspondence with the products from or benefits of a value-added horticulture production process that leverages CSIRO's recent technologies, with opportunities in both domestic and export markets.

VALUE CHAIN AND OPERATING MODELS

This section scopes the current landscape of value-adding from the horticultural grower's perspective, reviewing the business models of current key participants, the drivers of uptake of value-adding opportunities and technologies, and the risks, challenges, and impediments to uptake.

Drivers of uptake of VA

From the growers' perspective, the significant drivers of the uptake of value-adding technology may include: capturing a return on production investment; revenue control; revenue diversification; market control; risk management; and brand building.

Impediments, challenges, gaps and risks

The key risks, challenges, hurdles and gaps embedded within the prospect of vertically-integrating additional steps in value-adding within a grower's current business and operating models include:

- *Financial risk:* Economic analysis of the value-adding business proposition is critical prior to investment and buy-in by the aspiring grower;

- *Market pull*: The proposed business model needs to anticipate market demand: it is essential for a commercial value chain to generate a product that the customer wants to buy;
- *Market dynamics*: The food and ingredients markets are notoriously fickle and consumer trends can change rapidly and dramatically;
- *Engagement with customer*: Engagement of a new business with the end-user or customer early in the development of a new process, packaging or product may be critical;
- *Timeframes to uptake*: The uptake of new products may take time as the customer or end-user will need to conduct trials prior to discussing a supply agreement;
- *Scale of production*: Understanding the commercially realistic scale of production of any value-adding venture may be pivotal to success;
- *Feedstock seasonality* may affect the cost-effective operation of process equipment and utilisation of staff, and overall profitability of a value-adding facility;
- *Corporate Preparedness of Growers*: growers may recognise change is needed in current business and operating models to engage more with the value chain, but may lack the corporate skills and tools to achieve that goal;
- *Skills versus Control*: Growers may face challenges to retain the current high level of control over each step in their supply chain, while addressing the need for additional core skills and competencies within a prospective vertical-integrated business;
- *Investment in Marketing*: A sizeable and ongoing investment may be required in trend research and customer relationships;
- *Differentiation*: A new product needs substantial and verifiable differentiation to secure market share in a highly crowded, competitive, and price-driven market;
- *Relevance and Responsiveness*: To be both relevant and responsive to upcoming and potentially rapid changes in consumer trends, feedstocks, staff, shareholders and stakeholders may be a major challenge for the new business;
- *Growers' Level of Interest*: There may be a range of levels of interest among growers to prospects of investing in value-added or functional foods and ingredients;
- *Addressing the Export Market*: Skills gaps and uncertainties in building an export trade for the outputs of new value chains within the horticulture sector, including in initiating and securing a customer, partnership management and contract negotiation;
- *E-commerce*: Gaps in the awareness and preparedness of the horticulture grower to recognise and navigate the opportunity e-commerce presents to directly address customer and consumers, especially in the export market.
- *Government role and perception*: Government support is recognised as a key success driver in building successful value-adding businesses, but governments may underestimate the size and value of the horticulture sector, and the potential benefits from developing a value-adding industry;
- *Regional infrastructure*: Gaps in availability of demonstration scale infrastructure to prove a new process; availability or sufficiency of cold chain facilities from producer to ports; and
- *Provenance and Traceability*: Poor or low awareness of provenance and traceability as an attribute of horticultural produce compared with the consumer's expectation of reassurance of the origins of food and nutrients.

BUSINESS MODELS

This report recommends the following business model options for consideration by the aspiring grower:

- Expanded Grower Business: a single (large-scale) grower investing in establishing a *de novo* processing venture, with full control over the business, exposure to all of the risk and in receipt of net revenues.
- Cooperative Grower Venture: a number growers co-investing in establishing a *de novo* processing venture, with shared control over the business, shared exposure to risk and a proportional benefit from net revenues.
- Toll Manufacturing: provision of specialist processing capability as a subcontracted service within either the Expanded Grower Business or the Cooperative Grower Venture business models.
- Joint Venture: partnership between grower (or group of growers) and an established specialist processor; the grower or growers have a pre-agreed share of control over the business, exposure to risk, and benefit from net revenues for the duration of the joint venture.

RECOMMENDATIONS: MARKET AND MODELLING

This section will make recommendations to address gaps in delivering product to market, in extended market research, and economic modelling to provide guidance to the aspiring grower in considering how best to build further value within their current horticulture business.

Product types

This report recommends that further information is sought for the ingredients, snacks and the fermented product propositions.

- Ingredients and snacks: The challenge is to enter a market that is: a substantial global market but driven by consumer fads with revenue cycles of boom and bust; intensely competitive; and price-driven. Therefore, there is a need to confirm or clarify:
    - Highly differentiated product, responsive to (upcoming) consumer trends for production at a commercially-relevant scale;
    - Scope of applications within the foods or other markets;
    - Early stage partnering with food or nutraceutical manufacturer to collaboratively refine and define the product;
    - Early stage consumer testing and product development to develop a data package for partnering;
    - Demonstration-scale operations to generate reproducible data; and
    - Investment in ongoing innovation to develop a dynamic product pipeline that leverages CSIRO technology.

- Fermented Foods, Ingredients or Beverages
    - Clarify the market opportunity for a non-traditional commercial vegetable-based fermented product;
    - Complete sensory and consumer testing;
    - Assess risks and challenges inherent in the production of a fermented product using CSIRO technology and process, and non-standard starter cultures;
    - Survey the published data of relevant clinical trials; or sponsor a clinical trial to evidence any health claims; and
    - Undertake demonstration-scale fermentation to generate reproducible data.

Extended market research

This report recommends that further information is sought to:

- Scope the range of market opportunities for each product, and the relevant jurisdictions of interest;
- Define the key performance metrics of each product as a component of the end-users' supply chain, that includes the definition, at least, of a minimum scale of supply.

Economic modelling of value-adding process

This report recommends that further information is sought to construct an economic model to determine at least:

- Cost benefit analysis of the commercial scale operation;
- Minimum production scale for profitability and the time to profitability;
- Cost of equipment and facilities, and maintenance requirements;
- Staff costs across all unit operations;
- Assessment of options and measures to address the challenge of seasonality; and
- Investment required for marketing and brand building, both in market outreach to customers, in maintaining customer relationships and in ongoing consumer research or market insights.

Entrepreneurship, corporate preparedness and marketing

This report has identified specific gaps in corporate and executive skills within the horticulture sector as an impediment to expanding current businesses by value-adding. Therefore, this report recommends that direct assistance or networking to appropriate services be provided to the sector as:

- Entrepreneurship programs to assist aspiring growers to realise new business and growth opportunities, to improve their competitiveness and productivity, and to build connection and collaboration with innovators;
- Assistance to access grants and services (such as the R&D tax Incentive[1]);
- Coaching and mentoring to expand the executive management and negotiation skill base of growers and grower/processors, and, in particular, build e-commerce business skills;
- Establishment of the systems by which provenance of products based on Australian horticulture is evidenced, and implementation and standardisation of traceability reporting structures for use by growers; and
- Assistance with international marketplaces such as those in China and Japan. Tailored introduction services and contract negotiation services are two components of international marketing that would immediately benefit aspiring growers within the sector.

NEXT STEPS

This Stage 1 report provides an initial scoping paper for growers in the horticulture sector to consider leveraging new technical opportunities to value-add vegetables. As such, the report has focused on the general scope of the market landscape, a broad, high level overview of the value chain, and options for business and operating models. The target audience for the outcomes of the report's findings is the cohort of early adopters within the horticulture sector.

[1] https://www.ato.gov.au/Business/Research-and-development-tax-incentive/

The overarching goal of the project is to provide growers with a detailed understanding of operational models to leverage these new opportunities, and critical information on the potential prospects for their current businesses to guide strategic decision-making.

The next steps in this work are to more rigorously interrogate and test the general conclusions and recommendations made in this Stage 1 report, and to refine the recommendations into a set of priority actions, as an integrated set of final guidance and costings.

Therefore, the next steps are to provide growers with an economic modelling, delineation of potential structures of the business and operation, an evaluation of venture participants, and a model for aggregation of the required feedstock:

- **Economic modelling** of the proposed new venture is a priority, and is based on:
    - Cost benefit analysis: Detailed economic evaluation of select product opportunities by means of a realistic financial model built to provide a cost-benefit analysis framework. The model should define a minimum commercial scale of production for profitability, with input from potential end-users and customers. This model will allow for the anticipated investment in marketing required by the grower/processor for the successful commercialisation of the new product; and
    - Performance metrics: Articulation of the key performance metrics of the new product as a component of the end-users' and/or customers' supply chains, that includes the definition, at least, of a minimum scale of supply.
- **Business and operating models**, refined on the basis of
    - Drivers of success: Understand the keys to the success of established vertically-integrated horticulture businesses and select specialist processors;
    - Skills and capacities: In-depth review of the capabilities and capacities required within the value chains to meet the key performance metrics for supply expected by the end-user and customer, and assessment of the equipment and production infrastructure required for manufacture of (any of) the three product types at scale;
    - Refined business model(s): Detailed and executable proposals for revised or new business or operating models for each product type; and
    - Implementation framework: An implementation framework to progress the manufacture of select product within their respective supply and value chains, complete with stage gates and milestones.
- **Venture participants** who may include
    - Customers: Identification of, and initial contact with, potential commercial partners for offtake of any of the three product types;
    - Manufacturing partner: Identify, and assess the availability or interest of, the specialist processor as a manufacturing or technology partner to potentially participate in the value-adding venture, as a collaborator or contractor.
    - Early movers and participants: Assessment of level of interest within the horticulture sector to progress an investment in value-adding by means of the select technologies, and/or provide essential feedstock to meet production and supply targets.
- **Feedstock aggregation:** building a Logistics model to assess the aggregation radius and feedstock availability for cost-effective supply for processing, based on the scale of production required by the end-user or customer for any or all of the select products from select feedstocks.

CORELLI CONSULTING REPORT TO CSIRO
Value Chain Mapping and Business Model Development
Stage 1 Report

BACKGROUND

The Agriculture and Food Business Unit at CSIRO (CSIRO) is collaborating with Horticulture Innovation Australia (Hort Innovation) to initiate a project to develop technologies to transform brassica and carrot loss streams into value-added product types: food and snack products, functional food ingredients and supplements, and fermented vegetables and beverages.

The global purpose of the research collaboration is to achieve both reduction of harvest-associated loss for the horticulture industry, and recovery of valuable nutrients and bioactive compounds from what is otherwise a harvest residue and/or processing byproduct stream.

The anticipated impact on horticulture producers from the translation of these technologies into commercial operations is to reduce losses in harvest-associated value, reduce environmental waste, and generate additional revenues from a harvest residue stream.

However, the development of technologies will need a clear path to market to achieve the anticipated impacts for the horticulture sector.

The recommendations that follow are the opinions of Corelli Consulting based on a high level Stage 1 review within the framework of the overall project, and may require further research, confirmation and comparison prior to a strategic decision being made by CSIRO or Hort Innovation.

OUTCOMES

The purpose of this Stage 1 report is to provide the aspiring grower with a broad, high-level understanding of the potential market landscape relevant to the value-added products, the supply and value chains required to bring new products to market, operational models to leverage these new value-adding opportunities, and critical information on the potential prospects for their current businesses, in order to guide strategic decision-making.

The approach to the work has been to undertake desk research and interview with industry participants and stakeholders across the horticulture supply and value chains. Interviews were conducted with respondents from industry associations, government bodies, growers, specialist processors, and industry customers, end-users and retailers. In addition, the outcomes of the work are informed by company benchmarks which are presented as case studies.

The outcomes of the work are delivered in three sections: situational analysis of the innovative products currently proposed and the potential market landscape for those products; the value and supply chains for current participants in value-adding in the horticulture sector; and options for new business and operation models.

SECTION 1 SITUATIONAL ANALYSIS

This section describes the products that may be recovered from fresh horticultural produce using recently-developed CSIRO technologies and the global market landscape for each of those product categories.

INNOVATIVE PRODUCTS

This part of the report describes the products that may be recovered from fresh horticultural produce using recently-developed CSIRO technologies, exemplified here by the use of carrot and broccoli as feedstocks. While it is useful to understand the products' differentiation from a commercial perspective, this would require further guidance on the specific product application and relevant market segment to identify key comparables. Therefore, to define the differentiation of these potential products, further work is required.

The potential nutritional and bioactives content of carrots and broccoli and the technologies and their prospective applications have recently been summarised in recent reports by CSIRO to Hort Innovation, on which this summary is based.

Feedstock Profile

For carrots, the potential nutritional and bioactives content has been defined as including: alpha and beta carotenes, vitamins C and E, phenolic compounds (p-coumaric, chlorogenic, and caffeic acids), polyphenols (especially anthocyanins), oligogalacturonic acids, polysaccharides such as pectins and xanthan, fibre, and seed oils.

Similarly, potential nutraceuticals and bioactives from broccoli include sulforaphane, glucosinolates, isothiocyanates, vitamin C, and phenolics, such as hydroxycinnamic acids and flavonoids. Many of these are naturally-occurring plant-based components that can be recovered directly by extraction: others are obtained by conversion from broccoli-based components.

CSIRO reports that the industrial applications for these extractables from carrot and broccoli include those in the nutraceutical, food, food ingredient and beverage, and potentially in the pet food industries as bioactives and nutraceutical supplements, alternatives to gum stabilisers and starches, as functional ingredients in gluten-free baking (fibre and xanthan gum), and as natural antioxidants, sugar substitutes and colours.

The Technologies

Extrusion

CSIRO reports progress in the development of proof-of-concept products (high-fibre broccoli- and carrot-based ingredients) using dry vegetable powders followed by extrusion technologies, ie a two-stage process (drying/milling and extrusion). The aim of the process overall is to stabilize the vegetable biomass to minimise deterioration whilst retaining nutrient and sensory quality. These technologies have the potential to generate a food or snack product that is nutrient-dense due to an increased level of incorporation of vegetable biomass in a final formulation. Work continues both in process optimisation and formulation of the final product(s).

The process based on these drying/milling and extrusion technologies is proposed to underpin Product 1 for the snack foods industry.

Extraction

The approach used by CSIRO to isolate nutraceuticals or bioactive compounds from carrot and broccoli biomass is an innovative forward osmosis (FO) technology to recover concentrated bioactive fractions from the juice of raw or pre-treated feedstocks. Pre-treatment protocols are planned to improve juice yield, improve extraction of nutrients and bioactives, and/or inactivate undesirable enzymes in the juice. The overall process leveraging the FO technology that preserves the bioactivity, flavour, colour and shelf stability of the final products is still being optimised.

The process based on these extraction technologies is proposed to underpin Product 2 for the nutraceutical and food ingredients industry.

Fermentation
CSIRO reports progress in the development of fermentation processes to transform fresh produce (here carrot and broccoli) to nutritionally- and probiotically-enriched, shelf-stable, functional foods and ingredients. The work to date has generated a fermented product based on a raw substrate using lactic acid bacteria, supplied either as a commercially-available starter culture or as the vegetables' naturally-occurring microflora. While CSIRO's fermented products to date have been observed to retain good colour and odour, the nutritional and bioactive composition and sensory profiles of the products have yet to be determined. While fermentation time using the naturally-occurring microflora appears to be quicker that using commercial starter cultures, it should be noted that within the fermented food and beverages industry, significant investment has been made in starter culture development and approval. All dairy-based products, which currently dominate the global fermented food industry, use commercially-available and standardised starter cultures. This report understands that optimisation of this work continues.

The process based on these fermentation technologies is proposed to underpin Product 3 for the fermented food, food ingredients and beverage industries.

MARKET
Overall market drivers
This segment provides an overall review of market drivers for new foods and food ingredients.

Consumer trends in the new foods, food ingredients and nutraceutical markets, encompass an emphasis on "naturally functional" and "clean and green". There is a trend to products that provide for healthy aging, high energy and athletic performance, and digestive wellness, from protein-based foods, especially plant-based protein. The consumer expects that any health claims around new products will be supported by scientific evidence.

Those trends may be summarised as [1]:
- *Naturally functional*: the single, most-powerful trend is consumers' desire for foods and ingredients that are "naturally functional", evidenced by the interest in a spectrum of foods from plant-based products to the re-birth of full-fat dairy products.
- *"Clean and Green"* occupies a premium position in the branding and messaging around products, especially in export markets in Asia, particularly in Japan and the emerging middle classes in China and India. Consequently, considerations to ensure that ingredients are responsibly sourced, environmentally friendly and sustainable should be central to all nutraceutical, food and ingredient supply chains. Notably, the provenance and traceability of foods and ingredients are highly valued and sought-after attributes in those markets.
- *Healthy aging*: Seniors and baby boomers looking to maintain active, independent lifestyles, as well as millennials and middle-age consumers who are focused on a

"lifelong journey toward wellness". The critical concerns for healthy aging are maintaining mental acuity and memory, blood sugar control, muscle health, weight control, and cardiovascular health. In aged care, high protein products can be specifically designed to maintain lean muscle mass. Healthy aging products that address energy and athletic performance/recovery are also of consumer interest.

- *Science-based*: ingredients and other products that have clear clinical evidence to support health benefit claims have a competitive advantage in the marketplace.
- *Plant-based products*: even dairy companies are now leveraging the functional and nutritional benefits of plant-based ingredients in new non-dairy product development. Significant market opportunities are reported in snacking products that are explicitly plant-based, dairy-free and gluten-free. Paleo diets, with a heavy reliance on plant-based protein and oils are popular with consumers.
- *Digestive wellness*: there is significant and enduring consumer interest in products that support or improve digestive comfort, and are often gluten-, dairy- and lactose-free. Other products such as fermented yogurts, drinking vinegars and various fruit and vegetable-based snacks (from beetroot to kale) all benefit from an association with digestive wellness.

Examination of consumer trends suggests a correspondence with the products from or benefits of a value-added horticulture production process that leverages CSIRO's recent technologies. There may be opportunities in both domestic and export markets.

PRODUCT 1: SNACK FOODS

Snack food market

The snack food market is a substantial and global one that is intensely competitive and fickle. The market is subject to consumer trends that drive sales of current fads through a rocketing trajectory followed by a crash in revenues, as buyer interest turns to products that respond to the latest health fashion or taste innovation. As a consequence, industry participants invest substantially in health research and market oversight and monitoring to anticipate consumer trends and the patterns of changes in uptake across global jurisdictions, in order to actively maintain their market share and competitive position.

Market size

Globally, the total snack foods market was estimated at ~US$374 billion in 2013-2014 [2]. The segments in Europe (US$167 billion) and North America (US$124 billion) dominate total snack sales worldwide. However, annual snack sales are growing faster in the largely developing regions of Asia-Pacific (US$46 billion, growing by 4%), Latin America (US$30 billion, growing by 9%), and the Middle East/Africa (US$7 billion, grew 5%).

The total global market for healthy snacks is expected to reach US$32.8 billion by 2025 (2017), and is expected to grow at a CAGR[2] of 5% from 2017 to 2025 driven by increasing consumer awareness of healthy eating [3].

In Australia, revenues in the healthy snack segment are around A$1.2 billion (2017), and anticipated to grow at an annualised rate of 2.4% to 2022. The health snack food production industry is expected to continue to grow strongly, outperforming the general snack foods sector [4].

[2] Compound Annual Growth Rate is conventionally used to measure growth over multiple time periods.

Drivers

The commercial landscape in the snacking industry is a "fiercely ultra-competitive landscape" [2]. Current demand is driven primarily by taste and health considerations: consumers are not willing to compromise on either. Market analysts note that the right balance is ultimately decided by the consumer at the point of purchase.

In terms of consumer preferences, the predominant driver is to satisfy both taste and healthiness: consumer demand for "healthy indulgence" is strong. To "crack the code on the right portfolio balance between indulgence and healthy …will increase the odds of success in a highly competitive commercial environment" [2]. Surveys of consumer preferences for snacks rank fresh fruit, chocolate, yogurt, cheese, potato chips/tortilla chips/crisps, vegetables, and ice cream/gelato as the dominant choices but with specific taste preferences determined by jurisdiction. For example, surveys show preferred snacks in Asia-Pacific are vegetables, compared with cheese in Europe, ice cream/gelato in Latin America and potato chips/tortilla chips in North America.

Global surveys suggest that consumers increasingly care about the absence of ingredients more than their addition. Snacks without artificial colours and flavours, or genetically modified organisms are highly rated, with caffeine- and gluten-free, and low in sugar, salt and fat as emerging preferences. Conversely, snacks with all-natural ingredients are highly rated by consumers. Currently, consumers are seeking beneficial ingredients, such as fibre, protein and whole grains, as important attributes in snacks.

Rising awareness about healthy snacking along with the portability of product is propelling market growth [3]. Consumers are becoming increasingly health-conscious and seek higher quality snack foods: this trend is anticipated to continue to drive growth and deliver both challenges and opportunities for industry players. Market observers report a tangible shift towards premium snack foods, such as gourmet-flavoured chips, alongside those that are healthier options or that respond to specific dietary requirements, such as low fat, low salt, low sugar, organic, gluten-free, dairy-free, or vegan.

At a recent snack food expo[3], market observers noted a key emerging industry-wide theme of "healthy indulgence" in savoury and sweet snacks, in which new products increasingly feature vegetables, pulses and ancient grains. In addition, many industry players are meeting the healthy indulgence trend by aiming to reduce the calorific content of a snack to less than 200 calories per serve by 2022. "Even cookies (aim) for a more healthful positioning" as a high-protein, high-fibre component of the daily diet rather than just a sweet snack. Salty snacks are similarly moving to more novel, healthy products evidenced by a higher dietary protein and fibre content. Therefore, crisps production is moving away from the traditional potato to include other vegetables such as sweet potato, kale and beetroot (see Case study: Tyrrells). The trend to healthy indulgence is noted among both small, specialty snack foods manufacturers, as well as larger global players [5]. A snapshot of the products within the total snack market and their relative values are represented in Figure 1.

[3] Sweets and Snacks Expo 2017, Chicago, US, 26th May, 2017

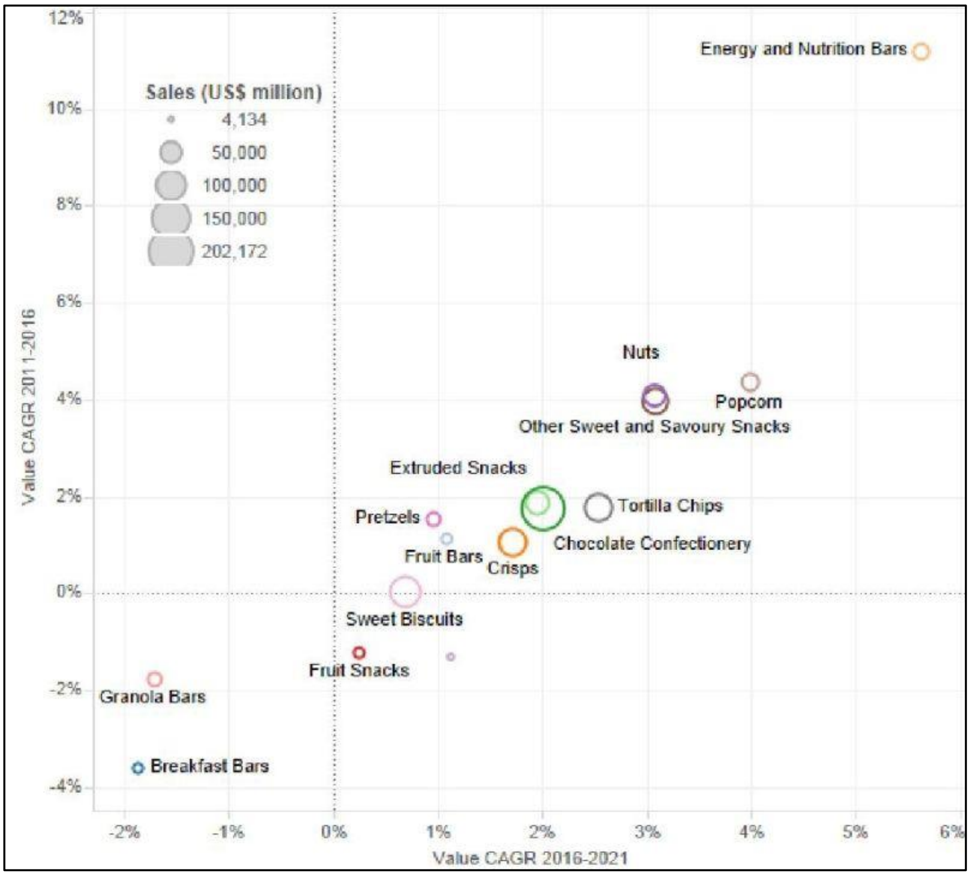

Figure 1: US snacking products' value sales 2016 and value CAGRs 2011-2016/2016-2021. Source: *www.naturalproductsinsider.com/articles/2017/01/surveying-the-international-snack-market.aspx*

Europe has been a leading region for consumption of healthy snacks due to changing perceptions about snacking among the younger consumers, who demand more nutrition from snacks and who have a growing reliance on snacking as a healthy alternative to meals [3].

Analysts in the Asian market report comparable trends in [6]:

- *Plant-based foods*: reflecting consumer preference for natural, simple and flexible plant-based diets, which will drive further expansion of vegetarian, vegan and other plant-based food and snack formulations;
- *Consumer convenience*: on-the-go convenience of foods and beverages has become as influential as nutrition or ingredient claims. In contrast, many Asian consumers are interested in products that have "slow" claims, such as being slow-roasted or promising slow-release energy; and
- *"Heath for Everyone"*: as with the healthy indulgence trend noted elsewhere, the Asian snack consumer is interested in healthy food and drink not as luxuries, but to manage food-related health issues, such as obesity and diabetes, and to address an awareness of having enough fruit and vegetables in the diet.

In particular, market analysis note the "massive" opportunity for growth of the snack sector in China, notably in healthy snacks [7]. In China's retail snack market, nuts and seeds is the largest snack category, with a retail value of RMB263.7 billion (US$38.3 billion), forecast to grow at a CAGR of 10.7% (2015-2020) to RMB345.6 billion (US$52 billion)[4].

Chinese consumers are increasingly aware of their sugar and fat intake. Therefore, more consumers are switching to fresh fruits and vegetables or dairy-based foods for snacking. This suggests a growing opportunity for food and drinks brands that enjoy a healthy perception (e.g. dietary supplements, cereals and yogurt) to tap into the Chinese snack market. Not surprisingly, market researchers observed that "Chinese females are concerned with calories, while Chinese males care about protein."

Imported snacks are popular among urban Chinese consumers and many of those who buy imported snacks do so by ecommerce means: "As consumers continue to look for new and different flavour experiences, international snacks have become a sector that many consumers are gravitating towards. E-commerce is an especially important channel for international snacks, providing easy access to foreign products, and as a less costly channel for international players to enter the Chinese market." [7]

Asian consumers have an increasing appetite for breakfast snacks, especially in major urban areas where deteriorated traffic conditions mean longer commute times. Consequently, Asia Pacific's snack industry is expected to grow faster over the next few years than elsewhere in the world: US$46 billion worth of breakfast snacks were sold in Asia Pacific in 2014. New breakfast categories include grain-based drinks, cereal bars, snack bars, yoghurt, fortified bread and smoothies. The key selling points are compelling benefits in nutrition, taste, convenience, and delivery of a feeling of vitality throughout the morning, although health benefits are the principal driver of uptake [8].

In addition, the snack industry needs to address consumer demand for [9]:

- *Food transparency and traceability*: both of the contents and origins of the food product;
- *Product personalisation*: tailored to meet the needs, both health and lifestyle, of consumer segments (from infant formulations to healthy aging and athletes); and
- *Environmental consciousness*: consumer aspirations regarding sustainability, residue reduction, integrity of food production systems and environmental impact of the food industries' activities.

Key participants

Key participants in the snack manufacturing sector include food giants General Mills, Mondelez International, PepsiCo Foods, Nestlé, B&G Food Inc, Unilever, The Kellogg Company, American Foods Group LLC among others. These companies make significant investment in increasing their global presence through product differentiation strategies [3].

Interestingly, competition also arises from the retailers through which these companies merchandise: major retailers are increasingly investing in their brand by means of their private-label product portfolios, as local and/or generic products.

In terms of vegetable-based snacks, a representative sample of manufacturers includes:

[4] 1 Chinese Yuan equals 0.15 US Dollar (2nd Oct 2017)

- Premium Snack Co (UK): Subsidiary of Chaucer Food Group, now acquired by Nagatanien (Japan). The company's core business is in freeze-dried snack foods (Premium) and food manufacture (freeze-dried and specialty bakery (Chaucer)). The Premium Snack Co was the first in the UK to produce freeze-dried vegetable snacks, sold as 'Nothing But' [10].
- Tyrrells (UK): traditional potato crisps, but now differentiated by "swanky" vegetable crisps based on taro, sweet potato, purple, candy-striped and golden beetroot, orange and purple carrot, and parsnip. (see Benchmark)
- Zweifel (Swiss): patented two-step air-drying process to produce vegetable crisps based on potato but now expanded to include other vegetables such as beetroot and tomato (Secrets Pomy-chips). This family-owned snack food company reports a 50-60% market share in Switzerland and revenues of CHF 208 million (A$277 million) pa (2013) [11].
- Plum Organics (US): baked fruit and grain snack sticks eg apple and carrot (Fiddlesticks, Plum tots) for the toddler and infant snack market. The private company was acquired by Campbells Soup Co. in 2014.
- Yorks (US): vacuum-fried vegetable crisps and snacks using sweet potato, taro root, squash, carrots and green beans (Harvest Garden chips).
- Nim's (UK): air-dried vegetable chips based on beetroot, parsnip, pepper and courgette. Nim's reports the company's proprietary process "ensures fresh produce maintains as much nutritional content, authentic taste and brightness of colour as possible, as well as a crisp texture that remains once bagged". Nim's claims to manufacture the UK's first air-dried vegetable crisps [12]. Along with Premium, Nim's claims to specific technologies that preserve nutrients and colours in vegetable products speaks to the highly competitive and demanding nature of the healthy luxury snack food market [13].
- Sensible Portions (US): fresh garden vegetable straws [14].

Benchmarks

This segment provides short case studies of horticulture-based businesses relevant to value-adding fresh produce as snack or convenience foods.

Kalfresh

Company history and structure: Private family company, established in 1992. Based in Queensland.

Operational size: The total acreage under carrot cultivation is 3000 acres (~1200 ha) in more than 5 growing districts in southeast Queensland. Reports production of 30,000 tonnes of carrots, beans, pumpkins and onions annually.

Driver to value-add: Recovery of revenues on carrots that are harvest residues, a processing byproduct or market surplus.

Company History: The company progressed from growing (producing fresh produce for the retail market) to vertically-integrating a processing and packing capability to produce snack foods and ready-to-eat products delivered to the retail customer's distribution centres.

Business model: Cultivation and supply of fresh carrots to domestic markets, and a packaged carrot stick and shred product under the 'Just Veg' brand. The company supplies

the domestic and export markets. Key produce include carrots, green beans, onions, pumpkins and fresh pre-prepared snack and ready-to-cook vegetables.
Route to market: The company runs a domestic business-to-customer (B2C) business through a major national supermarket chain, as well as on-line sales. The company reports exports of fresh produce to New Zealand, Hong Kong, Singapore and the Middle East.

Supply chain: The company owns, manages and operates the following components of the supply chain

- Production: Seed selection, crop cultivation, harvest, grade and wash;
- Packaging: bagging;
- Manufacture: Processing and packaging fresh vegetables (cut, dice); and
- Dispatch: Logistics services to deliver fresh product to the retail distribution centres.

Value chain: The Company owns and operates the following components of the value chain

- Production and packaging of fresh produce;
- Processing and packaging of fresh snack and ready-to-cook shred product (under the brand Just Veg); and
- Marketing.

By-product streams: Anticipated to be minimal. Carrots that did not meet the specifications of the retail market are used in the 'Just Veg' production line [15].

Tyrrells Potato Crisps Ltd.

Company history and structure: The privately-held company established in 2002. As of September 2, 2016, Tyrrells Potato Crisps Ltd. operates as a subsidiary of US-based Amplify Snack Brands, which acquired the company for £300 million (US$397 million). In 2016, Tyrrells Potato Crisps Ltd. expanded its brand in the Australian and Asia-Pacific market by acquiring Yarra Valley, Melbourne for an undisclosed amount. While Yarra Valley will continue to produce its own snack lines, Tyrrells will use the new site as a base to grow its snack brand in the Asia Pacific region.

Driver to value-add: The company was established by the Chase family who farmed potatoes in the UK. Because of issues with their retail marketer for fresh produce, the family diverted all their fresh produce into a family-owned crisp-making facility, establishing the Tyrells company.

Core Business: Vegetable-based snack foods. The company produces and sells premium potato chips and vegetable crisps to customers in the UK and for export markets. Produces crisps from taro, golden, red and striped beetroot, orange and purple carrots, parsnip and sweet potato. The Company has developed a range of snack products (including popcorn and tortillas) for the gourmet, gluten-free and organic markets.

Revenues: Tyrrells generated approximately US$111 million in net sales in 2016FY, and achieved a CAGR of 23% from 2013 to 2016.

Operational size: Tyrells produced 240 million pounds (109 kilotonnes) of crisps globally in 2016. Yarra Valley reportedly has a 3% share of the Australian potato chip market of A$1.1 billion pa. In 2016, Tyrrells was the number 2 player in the hand-cooked premium chip market in the UK and the number 1 player in France, with existing and growing penetration in other key Western European markets. Tyrrells has a strong presence across the potato chip, vegetable chip, cornchip and popcorn product categories and is supported by five international manufacturing facilities in England, Germany, and Australia [16].

PRODUCT 2: INGREDIENTS

The Ingredients Market

The nutraceuticals and food ingredients market, as is the case for snack foods, is a sizeable global commodity market that is, similarly, intensely competitive. The ingredients market is subject to consumer trends that drive sales of current fads through a boom and bust trajectory that may mean commercial disaster for small ingredients manufacturers[5]. As a consequence, food, beverage and nutraceutical industry players invest substantially in ongoing health research and market oversight and monitoring in order to anticipate consumer trends and the patterns of change in uptake across global jurisdictions, with a view to maintaining market share and, where possible, to gain competitive advantage.

Respondents to this report remark that the ingredients market is intensely cost-driven, such that cheap, low-quality imported ingredients are positioned in the domestic market at 10% (or less) of the price of comparable but high-quality Australian ingredients and products. Therefore, a premium price for products with Australian provenance is extremely hard to secure for commercial scale supply within the food and beverage industry, although the opportunity for a premium price may be available within the nutraceuticals industry.

Market size

The global fruit and vegetable ingredients market is projected to reach US$201.7 billion by 2020 based on a CAGR of 6.6% [17]. Market analysts report that beverages dominate the applications for fruit and vegetable ingredients.

By market size, North America is the most significant jurisdiction within the global specialty food ingredients market, followed by the Asia-Pacific region. The Asia-Pacific food and beverage sector is greatly influenced by the consumer preference for healthy food which drives uptake of ingredients with functionality such as nutrients or bioactives. The industrial landscape within the vegetable and specialist ingredients markets is dynamic: analysts report ingredient and process innovation as well as collaborations between sector participants have stimulated new product launches and expansions into emerging jurisdictions. Increased uptake of ingredients is the result of economic recovery within important markets, on-going industrialization, rising consumer demand for processed foods, along with consumer preference for quality and healthier products [18].

The Asia-Pacific region leads the fruit and vegetable ingredients market in terms of growth rate. Commercial use of fruit and vegetable ingredients within the sector has been less than in western markets to date, which is indicative of an untapped potential for uptake within food manufacturing within the region. Furthermore, rising consumption of convenience and ready-to-eat food products due to changing consumer lifestyle and increased disposable income represent opportunities for packaged food manufacturers [17].

Industry applications for fruit and vegetable ingredients, including powders, are those within bakery and confectioneries, beverages, dairy and frozen foods, convenience foods,

[5] Interview respondents

meat products, functional foods and beverages, dietary supplements, oils, fats and others (such as savoury snacks, sauces, dressings and condiments).

Drivers

The market for fruit and vegetable ingredients is driven by factors such as [17, 18]:

- Strong and rising demand for snacks and convenience food and beverage products by consumers with increased purchasing power;
- Consumer recognition of the gap between their diet and the recommended daily intake of fruit and vegetables;
- Consumer preference for healthy and natural ingredients. Market observers note that the trend toward healthier beverage choices by consumers has stimulated the dairy industry to include fruit and vegetable ingredients in their offerings;
- High growth potential in emerging markets suggests new growth opportunities for market players. In these markets, increasing disposable income and rapid urbanization have also increased the demand for fruit and vegetable ingredients;
- Advances in technology to deliver improved retention of nutrients and flavours in ingredients; and
- Convergence between nutrition and taste ("healthy luxury").

Key players

Leading players in the fruit and vegetable ingredients and specialty food ingredients markets globally include major food manufacturers and specialist providers, such as Archer Daniels Midland Co, Cargill, DuPont, SensoryEffects Ingredient Solutions, Sensient Technologies, Ingredion Inc (US); SunOpta (Canada); Tate & Lyle (UK); Royal DSM (The Netherlands); Kerry Group (Ireland); AGRANA Group (Austria); Givaudan Flavors (Switzerland); DoehlerGroup (Germany); DIANA SAS (France); CHR. Hansen (Denmark); and Olam Ltd and SVZ Ltd (Singapore) [17, 18].

In Australia, fruit and vegetable ingredients manufacturers and suppliers include Nutradry [19], A S Harrison & Co [20] and Frutex [21].

Nutradry is a private Australian ingredients manufacturing company based in Queensland. The company's core business is as a specialist processor of finished high quality specialty powders from fruit, vegetable and meat feedstocks. Feedstocks are sourced from growers by means of long-term supply contracts and are either table quality or grown-for-purpose. Feedstocks are brought into the company's facilities following pre-processing either on-site at the grower or at other processors. The company is scaled to manufacture a portfolio of 70-80 fruit and vegetable powder products, leveraging proprietary, low-temperature drying technology. Nutradry operates a purpose-built facility with in-house quality assurance capability and has HACPP and other food safety credentials, AQIS, Organic and Halal accreditation.

Nutradry's route to market is business-to-business (B2B), predominantly within the domestic market. The powders each have a wide range of applications, from nutrients to food colourants, for customers within each of the food, beverage and nutraceutical industries.

A. S. Harrisons is a privately-owned company within the Harrison Group, established in 1923, and headquartered in Sydney with operations in NZ. The capabilities within the company are broad and support contract manufacturing services, including expertise in engineering and marketing, an in-house quality control lab, extensive warehousing and logistics network to supply and service customers within Australia, New Zealand, the South Pacific and South East Asia. The company directly manages customs clearance and container cartage, ambient and chilled storage, picking/dispatching orders and distribution.

The company is a wholesale distributer of a wide array of ingredients for the bakery, dairy, prepared foods, confectionery, beverage, poultry and meat, pet foods, health and wellbeing industries. Ingredients in the company's product portfolio are outsourced from a global network of ingredient suppliers. Product range include oils, malt extract powders, fruit and vegetable powders, dairy and protein powders, fibre products, starch, sugars and sweeteners, calcium sources, polysaccharides, thickeners and antioxidants.

Harrisons reports the company’s fruit and vegetable powders are 100% natural, from either juice or puree feedstocks, with no added synthetic colours, flavours or preservatives. Spray-drying technologies preserve the maximum nutrition of the original fruits and vegetables. The company has a portfolio of 77 fruit and vegetable powders: vegetables include beetroot, carrot, cabbage, Chinese cabbage, Chinese spinach, celery, cucumber, garlic, chilli, pumpkin, red and white onion, spinach, spring onion, tomato, and taro. The route to market for fruit and vegetable powders is B2B to manufacturers within the food, beverage and nutraceutical industries.

Frutex Australia is an Australian family-owned company established in 1968, with a B2B business in delivering ingredients to the food industry. The company invests in innovation and product development on a continuous basis. Frutex sources from suppliers under long-term contracts that are governed by the company’s vendor assurance programs. Within the company’s portfolio are dehydrated vegetable products: beetroot, spinach and potato powders, and dehydrated carrot and onion shreds and granules. The company has warehousing, distribution and manufacturing facilities in Sydney and self-reports as a “technology leader in the food industry, investing heavily in state-of-the-art plant and equipment to wash and infuse dry fruit under sterile manufacturing processes in Australia”.

Benchmarks

This section provides short case studies of horticulture-based businesses relevant to value-adding fresh produce as ingredients.

Flinders Ranges Premium Grain

Company history and structure: Flinders Ranges Premium Grain (FRPG) is a private company owned by four wheat-producing families. Based in SA, established in 2001.

Driver to value-add: One of the founding wheat growers identified a market opportunity for specialist flours desired by international patisserie chefs, but difficult to obtain outside of France. The grower identified and sourced an appropriate wheat variety tailored to the needs of the end user, katana wheat, a low-yield, high protein, hard wheat variety, which was bred in South Australia initially for the Japanese sponge and dough market and considered ideal for artisan baking and patisseries. The grower now only grows this wheat for-purpose for specialist flour production.

Vertical Integration: The Company is an aggregator of local, grown-for-purpose wheat, the milling of which is outsourced. The company initially marketed directly to the end-user in India but now outsources marketing and specialist distribution in other export jurisdictions.

Business model: FRPG grows the specialist wheat on the co-located, independently-owned properties. The grain is harvested and transported to Adelaide where it is toll-manufactured into high-quality flour, then shipped to a range of B2B markets[6].

Value chain: The growers control all inputs into crop production and harvest, where possible. After harvest, the grain is milled into flour in Adelaide under an arrangement with FRPG, "whereby we (FRPG) own the wheat, they mill the wheat for a fixed price and we then have control of the flour and make our own arrangements".

Customer base: FRPG markets directly to the end-user of high quality, specialist artisan sponge and dough flours (B2B), specifically to bakeries, cafes, caterers and food service companies for the production of bread, bakery and pasta products.

Route to market: CEO established the initial client base directly with end-users (pastry chefs in Indian hotels) who trialled the flour and subsequently set up a supply contract. Currently, FRPG markets through a third party which has expanded into the United Arab Emirates, opening opportunities for supply of premium flour to a dough manufacturing plant in Dubai[6].

Lamattina

Company history and structure: Rocky Lamattina & Sons P/L is a private family-owned business, established in Victoria 1991.

Operational size: The Company operates a total of 4,800 ha (12,000 acres) between 3 sites one at Wemen Vic near Mildura and at a second, cooler climate property in Kaniva Vic for summer carrot production and a third at St George QLD. Reportedly the largest carrot producer in Australia, producing 45,000-55,000 tonnes of carrots per year. Lamattina's 28,000-square-metre production facility processes approximately 900-1000 tonnes of carrots every week.

Driver to value-add: to recover more of the investment in crop production lost as harvest residues or processing by-product.

Business model: Grow and supply premium fresh carrots to domestic and export markets via the Company's washing, grading and pack shed facility as well as, in 2017, carrot juice to the domestic market, and carrot juice concentrate to the export market. The washing, grading and pack shed facility and the juicing and juice concentration facility represented processes integrated within the company's operation. Juice production used fresh produce that did not meet the specifications of the retail market or was market surplus[7]. The company also owns and operates a plastic bag manufacturing facility, established to service the company's premium carrot pack shed business to cover a gap in the packaging market; now operating as an independent business.

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[6] Since this report was completed, FRPG is servicing the domestic market only due to reduced grain supply as a result of the ongoing drought.

[7] Since this report was completed, the company has computerised grading (among other operational optimisations) to minimize harvest residues, and the company-owned and -operated juice and juice concentrates facilities have been shuttered.

Value chains: The Company owns and operates facilities to wash and pack fresh produce; a transport fleet; and a plastic bag manufacturing operation.
Supply chain: The Company owns and operates the following components of the supply chain:

- Cultivation, harvest;
- Wash, packaging and cooling facilities;
- Inputs such as packaging;
- Metrics such as quality assurance, agronomy; and
- Trucks transport to deliver fresh product to customers in Sydney, Melbourne and Brisbane.

Value chain: The Company has owned and operated the following components of the value chain as an integrated part of the business:

- Packaging: of washed and graded fresh produce for domestic consumption.
- Packaging: of washed and graded fresh produce for export consumption
- Juice production: harvest residues of fresh product are transported to a second, in-house specialist processing site.
- Juice concentration: juice is dehydrated in-house to a juice concentrate, packaged and sold into the Asian export market (B2B).

Customer base

- Domestic: fresh produce for Coles supermarkets, wholesale markets (B2C); and
- Export market: through distributors and directly to Asia (B2B).

Risks and limitations: Inputs costs for energy and water range from expensive to prohibitive. Solar panels have been installed to help control energy costs [22].

Natural Evolution Foods

Company history and structure: Family-owned private Australian business, established in 2014 and based in North Queensland.

Operational size: In 2016, the company's 320-hectare property was at production capacity and extra bananas were sourced from other local growers. Processing capacity is currently ~8 tonnes of flour output pa. The company has recently secured distribution deals into the Japanese market.

Driver to value-add: The company was set up to address the level of market surplus or harvest residues from banana production and in reaction to retail market control of price. Generally, 500 tonnes of bananas are dumped every week in Australia based on non-compliant size or shape for supermarkets.

Business model: Banana grower of fresh produce is now a paddock-to-processing operation. The company adds value to local bananas to produce a range of high value, long shelf life flours/powders and starches for the food and beverage industry. The company aggregates local fresh produce and processes these in a vertically integrated facility, controlling all manufacturing steps from peeling, through dehydration to packaging. The company has an on-line presence to build brand as a premium product company, and services both the domestic and export consumer (B2C) and food and beverage manufacturers (B2B). The company invests in continuous innovation in both product and process development.

Value chain: the company operates a "paddock-to-processing formula" with all processing controlled in-house. The company owns and operates a nutraceutical food-grade factory on-site with custom-made equipment for pre-processing feedstocks and dehydration.

Route to market: Initial sales were made through direct marketing through the company website to domestic consumers. The company now has a network of distributors Australia, NZ, Japan, and the UK. In 2016, almost all product was exported to Japan and Europe.

Risks, limitations and hurdles: Domestic uptake of the premium flour and starch product is undermined by imported cheap, low quality product. [23].

PRODUCT 3: FERMENTED VEGETABLE PRODUCTS

The Fermented Foods Market

Market size

The fermented foods and beverages market is booming globally. The total fermented foods and ingredients market is anticipated to grow from US$637 billion in 2016 to ~US$889 billion by 2023 [24]. The US spoonable yogurt market was worth an estimated US$6.9 billion but with a slowing growth rate in 2016, as other fermented dairy and non-dairy products, such as drinkable vinegars, kefir[8], and kombucha (fermented teas) begin to take market share from this long-established product. Vinegars are a rapidly growing fermented product type, with revenues around US$544 million; kefir experienced rapid sales growth (16%) from 2013 to 2016; and kombucha, now a large and established market, grew by 7% [25]. Drinking vinegars are anticipated to become a US$1 billion market in the US, highlighted by participation of such major industry players as Coca-Cola by means of its investment in the small specialty company Suja[9] [26].

From the consumer perspective, a significant driver for consumption of fermented foods and beverages is the probiotic content. Probiotics are defined as "live micro-organisms, which, when administered in adequate amounts, confer a health benefit on the host" [27].

The probiotics market is emerging as one of the fastest growing markets globally, and is expected to exceed US$64 billion by 2023. The US continues to dominate the probiotics market because of the expectation by consumers of a health benefit conferred on a high diabetic and obese population. The Asian Pacific region, influenced by probiotic consumption in China, India and Japan, generated over US$15 billion in revenues in 2015. This region dominates the market for non-dairy fermented products [28].

Fermented vegetables

Fermented vegetables are a well-established concept for consumers in some jurisdictions and a traditional food format, such as kimchi or tempeh, in Asia. The opportunity for a fermented, chilled vegetable-based snack or ready-to-eat product connects to the trends both of traditional use and current consumer expectations of general and digestive health.

The global history and variety of fermented vegetables is a long-established one, with extensive domestic- and village-scale production to extend shelf life, remove anti-nutritional factors, and improve digestibility and nutrient content of the raw feedstock.

---

[8] A fermented milk with yeasts added to lactic acid bacteria that are used routinely in yoghurt production.

[9] www.sujajuice.com

The major traditional centres of indigenous fermented food production are in Asia (especially Japan, China and Korea), Africa, western and eastern Europe, and Scandinavia [29].

The most commonly reported vegetables and fruits used in fermentation are [29, 30] (see Table 1):

- Root vegetables: carrots, turnips, beetroot, radishes, celeriac, and sweet potato;
- Vegetable fruits: cucumbers, olives, tomatoes, peppers, okra, green peas and gourds;
- Vegetable leaves: Chinese cabbage, cabbage, and spinach;
- Vegetables juices: carrot, turnips, tomato pulp, onion, sweet potato, beet, and horseradish; and
- Fruits: apples, pears, immature mangoes, immature palms, lemons, and fruit pulps such as banana.

Table 1: Summary of traditional fermented vegetables and region of origin.

Fruit and vegetables	Region	Country
Cabbage and other brassicas, cocoa beans	Americas	Central America
Soybean, barley or brown rice	Asia	Japan
Turnip, cucumber, Chinese cabbage, ginger, eggplant, carrot, radish, mustard leaf, wax gourd, broccoli, Leaves of otaki-turnip, peaches, celery	Asia	Japan, Korea, Vietnam, Thailand, Taiwan, Philippines, China, Malaysia, Indonesia
Cabbage (Brassica), Olive, purple carrot (also turnips, capsicum), beetroot	Europe	Russia, the Baltic states, the Ukraine, Poland, Germany, Spain, Italy, Turkey
Cabbage and other brassicas, radish, mustard, cauliflower, cucumber, bamboo shoots	India	India, Nepal, and Bhutan
Taro root	Polynesia	Polynesia

Sources: Adapted from Swain *et al* 2014 [30], and Steinkraus 2004 [29].

Kimchi and sauerkraut stand out as two indigenous fermented vegetable processes that have been standardised and commercialised, with large scale production addressing consumers in international markets.

Kimchi is a traditional Korean dish of salted vegetables, particularly cabbage, seasoned with red pepper powder, garlic, green onion, ginger and jeotgal (salted and fermented seafood), among other ingredients, and then allowed to ferment. The bacterial inoculum is provided by a seafood-based sauce, and fermentation takes almost a month.

There are at least 336 reported varieties of kimchi, each with additional ingredients (radish and cucumber for example) and cooking methods. As diets change with access to a wider variety of foods, new varieties of kimchi are being developed using both traditional and non-traditional ingredients [31]. In addition, kimchi is recognised as being "rich in biologically active components" with functional and bioactive substances [32].

Koreans consume 1.5-2.0 million tonnes pa of kimchi. Of this production, only 557 kilotonnes appears to be produced by commercial kimchi manufacturers in Korea, worth an estimated US$1.3 – $2.5 billion. Japan is Korea's top export destination, accounting for about 80% of Korean kimchi exports [33].

Drivers

Consumer familiarity and expectation of health benefits drive the fermented foods and beverages market:

- *Consumer familiarity* with long-established traditional vegetables and dairy-based foods is a market driver especially in Asia, Europe and Scandinavia. In these jurisdictions, fermented foods and drinks are routinely made and consumed at home;
- *Digestive wellness*: The capacity of fermented foods and drinks to confer a sense of "digestive wellness" is now considered a robust and enduring consumer trend and the key to the success of fermented products. Consumers need to "feel comfortable inside" and are increasingly choosing lactose- and gluten-free products, and plant-based drinks. Digestive health benefits are anticipated from such products as kombucha and other fermented teas, sauerkraut, kefir, kimchi, pickles, drinking vinegars, and tempeh. The probiotic content of the fermented product has significant market value: a recent innovative start-up is Rhythm Health: its flagship product, a coconut-milk based, non-dairy kefir "shot", is reportedly the outcome of a 10-year program to develop the probiotic [34].
- *Plant-based foods*: the market for fermented products also connects to the plant-based foods trend. Companies are already tapping into this demand by creating single-serve fermented vegetable-based snacks (see Case Study: GLK Foods below).

Key players

Major players in the fermented foods market include specialty companies such as Chobani, Groupe Danone SA., and Yoplait; large multinational food and beverage corporations such as Coca-Cola, General Mills, Kellogg's, Kraft Heinz, Mondelez, Nestlé, PepsiCo, and Unilever, and large corporations in the medical nutrition segments such as Abbott and Mead Johnson. Chobani, for example, produces a high-protein Greek yoghurt generating revenues estimated at US$2 billion pa and is reportedly the biggest US yogurt brand in 2017 [35]. Danone reports sales of €21,944 million (A$33 billion) in 2016FY. Danone's Fresh Dairy Products Division (production and distribution of yogurts, fermented dairy products and other dairy specialties) accounted for 49% of company sales in 2016 based on 6.4 million metric tons of production [36].

Beverages giants Coca Cola and PepsiCo have both recently acquired small fermented drinks makers (Suja and KeVita respectively), an indication of the significance of this market internationally in corporation portfolios.

In the probiotics market, a key player is Japanese probiotics pioneer Yakult Honsha Co, which manufacturers a live probiotic-rich fermented shot. Yakult is listed on the Tokyo stock exchange with a market cap of ¥1.61 T (A$18.2 billion) [37]. Yakult reportedly sells 190,000 bottles of its probiotic yogurt-like drink in the UK daily [38].

The Australian scene
Yakult Australia was established in 1994 in Dandenong, Victoria as a subsidiary of the Yakult Honsha Co. and makes Yakult for the whole of Australia and New Zealand [39].

The Australian division of US company Chobani is based in Dandenong South, Victoria. Chobani is reportedly Australia's second-highest-selling yoghurt brand, selling 17.3 million kgs of Chobani-branded and 11.3 million kgs of Gippsland Dairy-branded products a year. Notably, in August 2017, the CEO launched an Australian version of the US Chobani Food Incubator, which, like a technology incubator, selects small food start-ups for mentoring and investment. Chobani brings to the program "expertise in sales, marketing and customer engagement" [40]. "Australian participants will receive 'no-strings-attached' A$10,000 grants and will be the first to use the food labs and industrial kitchens at Monash University's new A$3 million "incubation facility" at its Food Innovation Centre in Melbourne." In the US, the program has coached a low-carb pasta maker, a juice company that uses second-quality fruit and vegetables, and a socially-responsible cocoa producer [41].

> "Chobani has .. created the most robust incubator program in Australia, (providing access to) Chobani's expertise in sales, marketing and customer engagement (to) help start-ups improve Australia's food industry."
>
> www.chobanifoodincubator.com/australia/

Other small, local fermented food and probiotic producers include:

- Jalna Dairy Foods Pty Ltd produces dairy food products, including yoghurts, offered through supermarkets. Jalna Dairy Foods was incorporated in 1977 and is based in Melbourne [42].
- Ferment it [43].
- Mrs Oh Fermentation (kimchi) [44].
- Queensland Yoghurt Co was established in 2003 in Queensland, with B2C routes to market nationally and into NZ (Piako brand), and into the US (Noosa brand) [45].

Benchmarks

This section provides short case studies of horticulture-based businesses relevant to value-adding fresh produce as fermented foods and ingredients.

GLK Foods

Company history and structure: GLK foods is a US-based, family-owned company with a 117 year tradition of sauerkraut production. The company reports being the largest sauerkraut producer in the world and the maker of America's top selling brands. The company has 172 full-time employees and 206 temporary and seasonal employees.

Revenues: Not reported, although the company does report growth rates of 15% over the last two years, based on new product launches.

Operational size: The company processes 140,000 tons of raw cabbage pa.

Driver to value-add: Not reported, other than in response by a cabbage grower to the unmet market demand for sauerkraut in the US.

Business model: The company grows, harvests and ferments cabbage into sauerkraut for the domestic and international markets. The company aggregates feedstock grown both on company-owned farms and by co-located suppliers. The company has vertically integrated all steps in the value chain from field to fork with a consumer-ready product, and invests in a continuous process of innovation to extend the product portfolio in sauerkraut products and formats. Product is sold directly to the consumer via retail outlets.
Supply and Value chains: GLK controls every step of production, from cabbage farming, harvest, feedstock processing and fermentation, to specialist packaging (canning and jarring). The company grows about half of the required feedstock on GLK-owned farms, while the rest is grown by contract regional growers. Cabbage is processed by coring machines in company-owned facilities. Other than coring machines and trimming stations, the firm's equipment is almost completely automated. The company also has developed mobile cutting and coring machines for pre-processing raw produce in southern growing states to minimise the shipping of processing residues and whole bulky vegetables back to the Wisconsin facility. The company operates an in-house fermentation process and high-speed equipment for filling and packaging.

Product portfolio: The sauerkraut portfolio includes new products that are organic, kosher and of various flavours. Recent introductions are single-service packages and snack packs (retailed as OH SNAP! Pickles) [46].

> "We have an excellent base and platform for distribution. Our products are in every grocery store in the country. We always consider the needs of the retailers and what niches we can explore…(and) new areas to expand into."
>
> Ryan A. Downs
> Chair
> GLK Foods

SECTION 2 VALUE CHAIN AND OPERATING MODELS

This section will scope the current landscape of value-adding from the horticultural grower's perspective, reviewing the business models of current key participants, the drivers of uptake of value-adding opportunities and technologies, and the risks, challenges, and impediments to uptake.

Business models of key participants

This segment provides the aspiring grower with an overview of current participants in the value chain from growers to end-users, and key operations and outcomes.

Supply and Value Chain Participants
The functions of current participants in a supply chain based on fresh horticultural produce are as growers, feedstock aggregators, processors and customers.

In overview, each participant in the supply and value chain and their central responsibility are:

- Grower: responsible for the cultivation and harvest of horticultural produce;
- Aggregator: operates to aggregate fresh feedstocks from growing sites co-located within a defined radius for cost-efficient logistics;
- Processor: responsible for a series of operations that add increasing levels of value to the aggregated fresh produce, from washing, grading and packing, extraction and drying, to convenience food manufacture; and
- Customer: provides the market pull to the supply chain that delivers commercial supply to the consumer (B2C) or to business customers (B2B) based in domestic and/or export markets.

A simple illustration of an indicative value chain for horticultural produce and exemplars of products that are delivered to market by various levels of value-adding is provided in Figure 2.

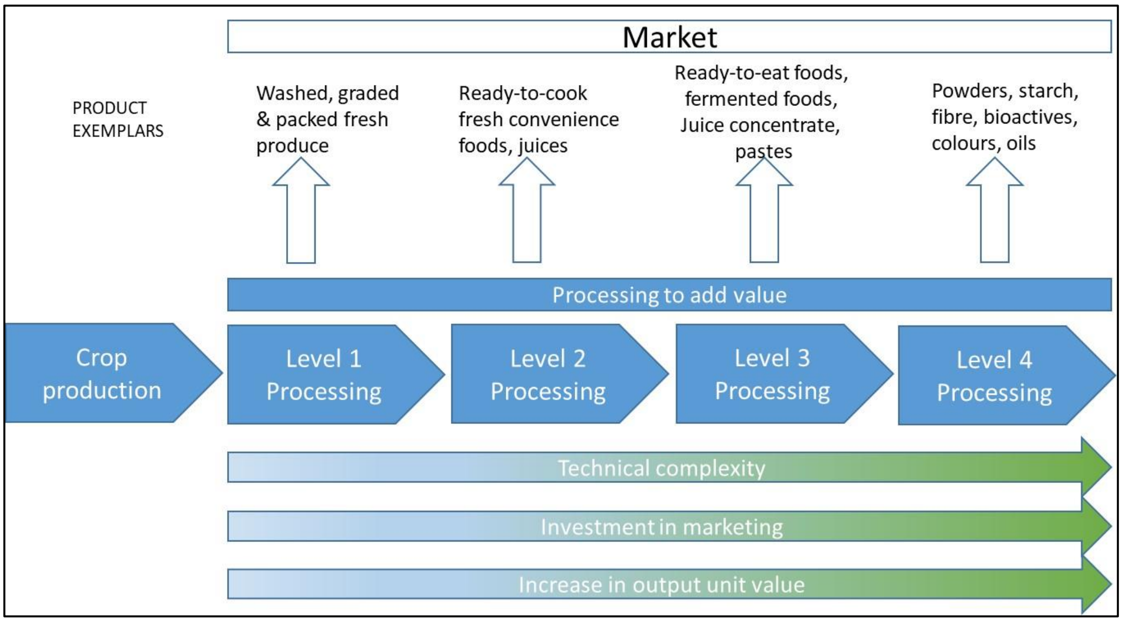

Figure 2: An indicative value chain for vegetable industry: Prospects for value-adding feedstock streams by means of level 1 to level 4 processing, each with product exemplars as indicative outputs. The sophistication of the value chain outputs increases with technical complexity of processing (from level 1 to 4), requiring a proportionate increase in investment in marketing, as market outreach, ongoing monitoring of consumer trends and management of customer relations. The increase in sophistication or complexity of the outputs is also characterised by an increase in unit value, compared with that from preceding processing level(s).

The operations of the processors are represented in a graded framework ranging from the simplest level of value-adding (Level 1) to most technically specialised (Level 4). Note that increased technical specialisation is associated with a concomitant increase in investment in market development, monitoring consumer and market trends and managing customer relationships. There also tends to be an inverse relationship in the level of direct contact between the processor and the consumer: as the level of technical specialisation moves from Level 1 to Level 4, the route to market generally transitions from B2C (direct to consumer by online sales or via retailer) through to a more B2B business, where the value-added product is supplied to the manufacturer or food service provider, and reaches the consumer after further formulation, processing and finishing (see Figure 2).

Business and operating models
In this part of the report, the business and operating models for current supply chain participants at each step of value-adding are outlined, with reflection at each step on the technical and marketing capability required and on the likelihood that participants, particularly those further down the value chain, retain the production of fresh produce within their business model.

At a high level, each progression from lower to a higher levels of processing represents an additional indicative point of value uplift relative to feedstock production. This report recommends that a more detailed estimation of value uplift would require further investigation, and would be informed by the economic model, referred to elsewhere.

The information within this section is based on industry and stakeholder interview, and on desk research to develop case studies.

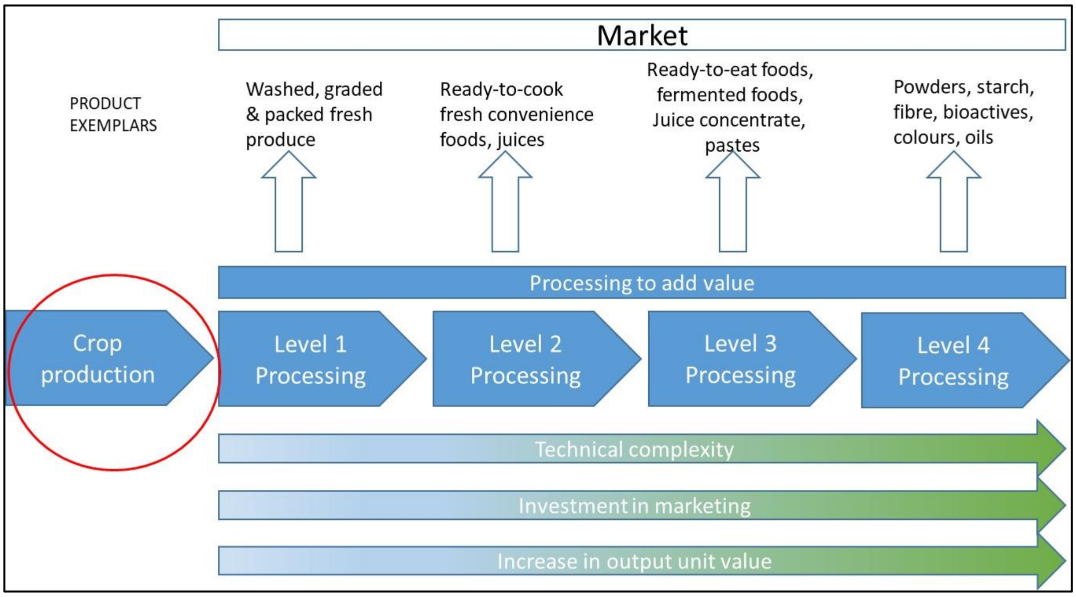

Figure 3: The production of fresh horticulture as feedstock in an indicative value chain.

Feedstock (or crop) production (See Figure 3)

- Operator: the horticultural grower.
- Inputs: seed, fertiliser.
- Outputs: harvested fresh produce.
- Core skill: planting, cultivation, harvest.
- Technical skill: expert or specialist horticultural skills.
- Marketing: low investment in market outreach to customers. No investment in market research or insight.

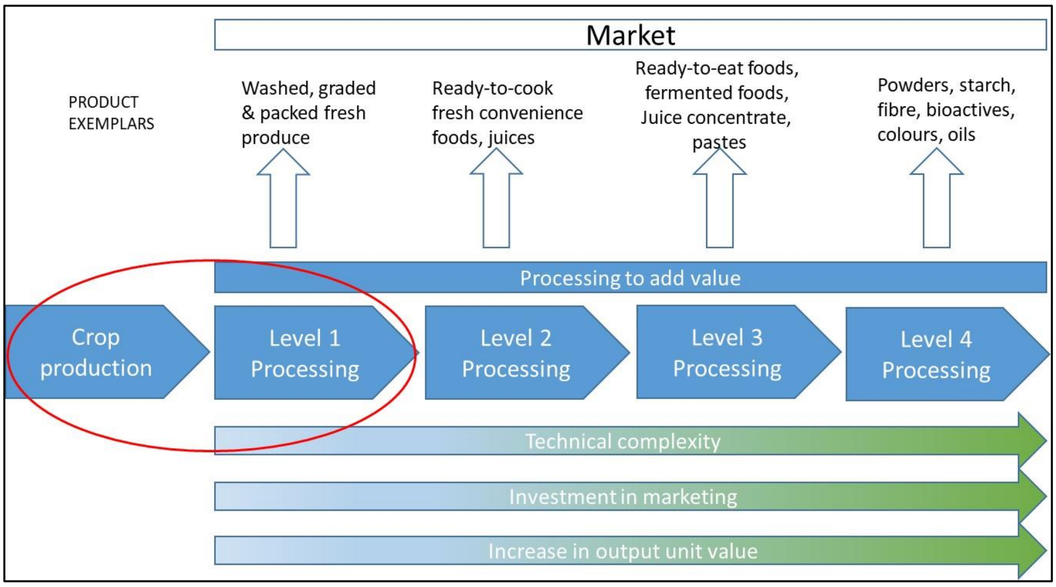

Figure 4: Level 1 processing to produce washed, graded and packed fresh produce.

Level 1 Processing
(See Figure 4)

- Operator: grower and/or aggregator.
- Inputs: harvested fresh produce.
- Outputs: clean and graded fresh produce, packed in bags or boxes. Outputs may carry grower and/or aggregator branding.
- Core skills: wash, sieve, grade and pack (bag or box) fresh produce.
- Technical skill: low technical skill.
- Marketing: medium investment in market outreach to customers. No direct consumer research or market insight.
- Customer base: B2C by means of retail customers and/or wholesale markets. Domestic markets predominantly; may address export clients.
- Level of integration within the grower’s business model of crop production: likely.

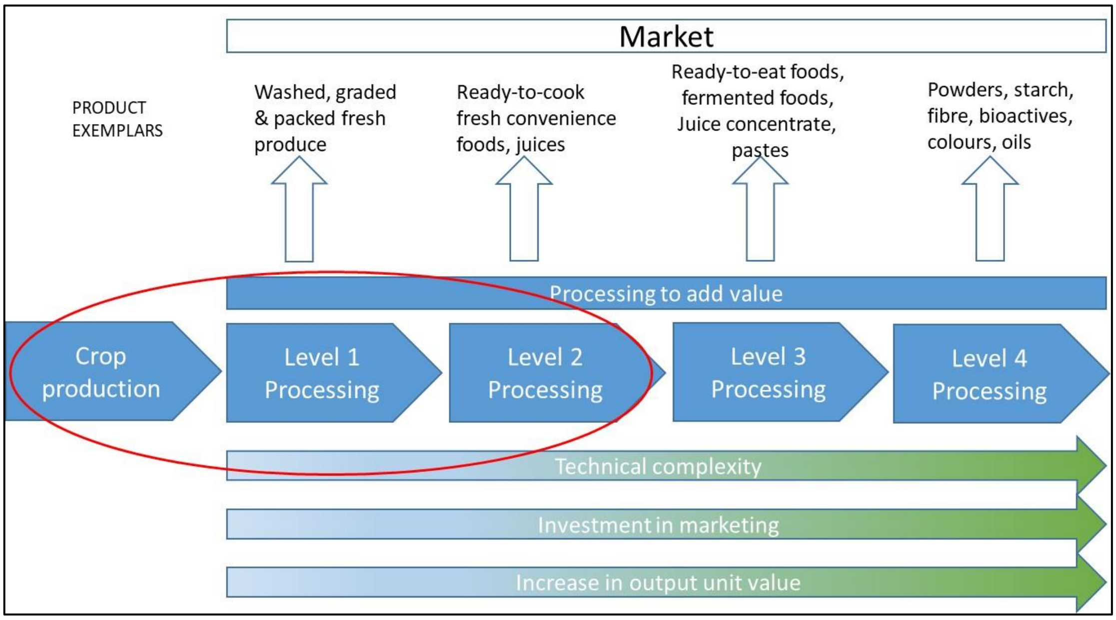

Figure 5: Level 2 processing to produce ready-to-cook convenience foods and juices.

Level 2 Processing
(See Figure 5)

- Operator: grower, aggregator, and/or specialist processor.
- Inputs: fresh produce of primary, table and/or secondary grade[10] that has been pre-processed (Level 1 processing ie washed and graded).
- Outputs: fresh produce as snack packs or convenience, ready-to-cook product. Packaging may be specialist packaging, eg microwavable bowl or dish. Outputs may carry grower and/or aggregator branding.
- Core skills: includes peel, polish, cut, juice extraction, and package. May include specialist packaging using customised materials and containers eg microwavable bag or bowl.
- Technical skill: medium technical skill.
- Marketing: medium-high investment in market outreach to, and interaction with, customers. No direct consumer research or market insight.
- Customer base: B2C by means of retail customers; may include online sales. Domestic markets predominantly; may address export clients.
- Level of integration within grower's business model: not unlikely.

Exemplar: Rugby Farms, Kalfresh.

[10] does not meet retail specification but meets specifications of other end-users

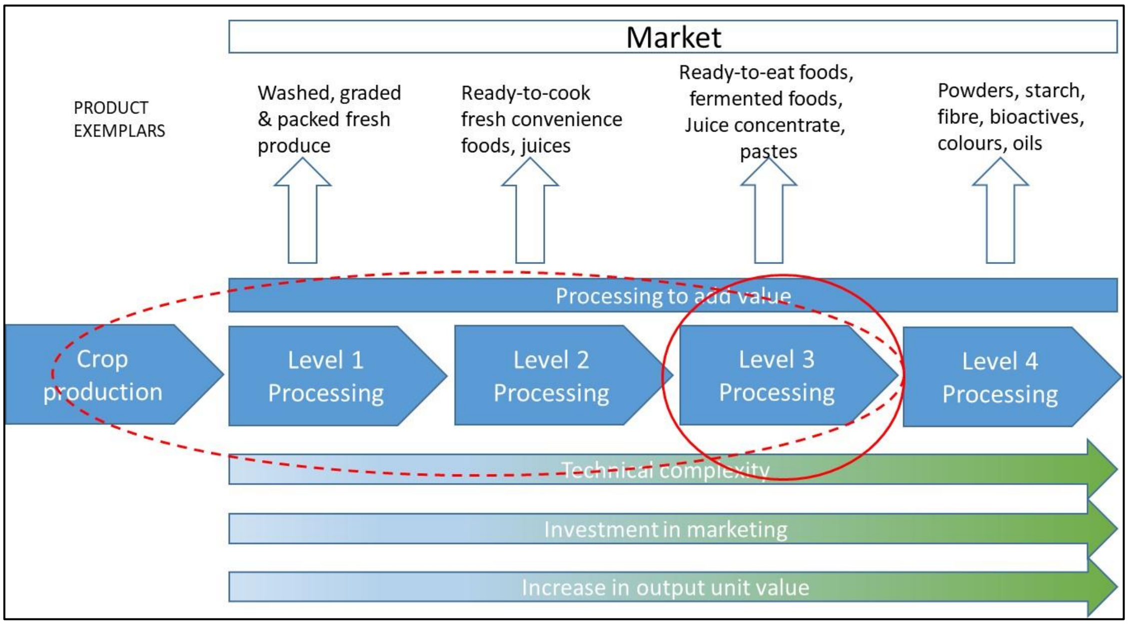

Figure 6: Level 3 processing to produce ready-to-eat convenience foods, juice concentrates, etc, and fermented products.

Level 3 Processing
(See Figure 6)

- Operator: specialist processor.
- Inputs: fresh produce as primary, table and/or secondary grade or may be grown-for-purpose; pre-processed (Level 1 processing i.e. washed and graded).
- Outputs: Finished food and beverage products as snacks or convenience, ready-to-eat foods; sauces, concentrates; juices; wine. Packaging is specialist or customised packaging eg microwavable bowl or dish; bottles or cartons. Outputs carry specialist processor or customer branding.
- Core skill: includes high-temperature processing, snap freezing (flash or blast freezing), fermentation, filtration, food finishing; customised packaging. Food safety and quality analysis, and compliance.
- Technical skill: expert or specialist technical skills.
- Marketing: high level of investment in market outreach to customers and in customer relations, and in consumer research or market insight.
- Customer base: B2C by means of retail customers; may include online sales. B2B with food service and manufacturing end-users. Domestic and export.
- Level of integration within grower's business model: low or none.

Exemplars: Kagome Australia, Rocky Lamattina & Sons, Sumich, Simplot, FABAL Group.

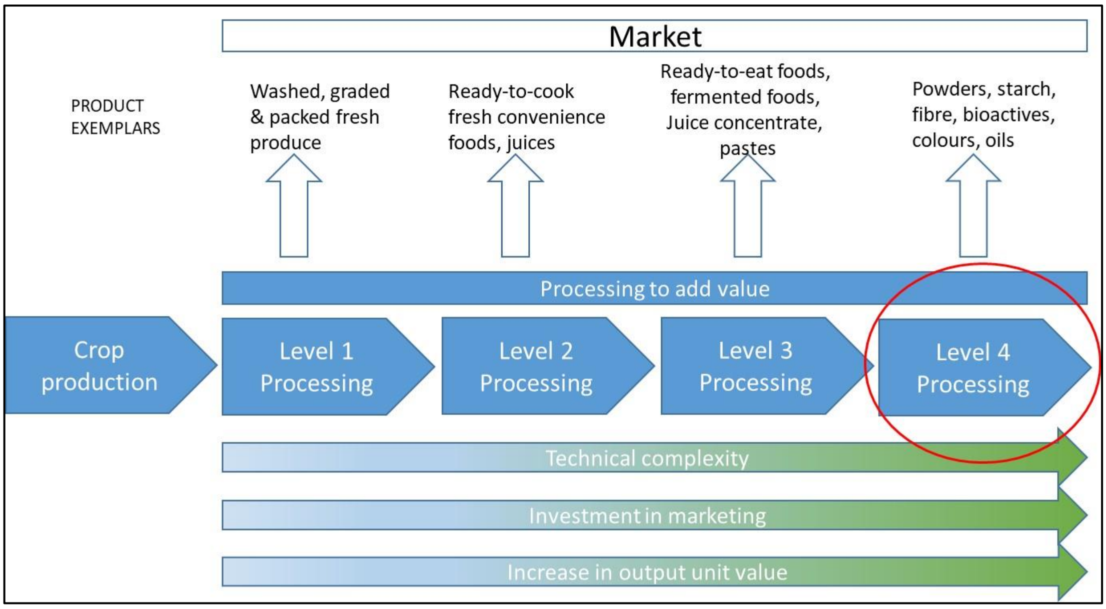

Figure 7: Level 4 processing: to produce ingredients such as bioactives, powders, colours, oils etc.

Level 4 Processing
(See Figure 7)

- Operator: specialist processor.
- Inputs: fresh produce at primary table grade and/or secondary grade, and/or grown-for-purpose; pre-processed (Level 1 processing i.e. washed, graded); by-products of value-adding (Level 3 processing).
- Outputs: Specialist ingredients as powders, juice concentrates, oils, fragrances, colours, bioactive molecules or fractions, proteins, fibre. Packaging may include bulk containers or bags.
- Core skill: includes extraction, distillation, dehydration, milling, separation, centrifugation, concentration. Quality management and analytics.
- Technical skill: expert or specialist technical skills.
- Marketing: high level of investment in market outreach to customers and in customer relations, and in consumer research or market insight.
- Customer base: B2B with customers in food, beverage and nutraceutical manufacturing. Domestic and export.
- Level of integration within grower's business model: none or low.

Exemplars: Natural Evolution Foods, Natural Fractions, Nutradry, Tarac.

Drivers of uptake of VA

From the grower/processors' perspective, the significant drivers of the uptake of value-adding technology may include capturing a return on production investment, revenue control and diversification, market control, risk management, and brand building:

- Capture full value of the growers' investment in crop production by utilizing seconds (non-specification) and by-product streams. Currently, these have low value (animal feed or ploughed in);
- Diversify revenues from a sole dependence on a return from fresh produce;
- Market control: to have a degree of control over the market entry of fresh produce under conditions of surplus;

- Control over revenues: by means of alternate routes to market. Growers want to move from "price takers" to a revenue model over which they have more control, and within which the grower retains the margins otherwise paid to processors within the value chain eg pack shed operators;
- Manage risk: by having alternative markets for fresh produce under conditions suboptimal for premium grade fresh produce or of surplus; and/or
- Building brand: (larger) growers are interested in diversified outcomes which builds their brand and, thereby, their competitive advantage.

Further insights into the attitude and drivers of aspiring growers to value-add their fresh produce may provide additional useful intelligence to this project.

Impediments, challenges, gaps and risks

This segment of the report overviews the risks, challenges, impediments and gaps embedded within the prospect of vertically-integrating additional steps in value-adding within a grower's current business and operating models. Approaches for the aspiring grower to consider to mitigate or manage those risks are noted, as is the need for further detail or actions.

This report considers that some of the risks identified may represent "stop-go" points in the decision by the aspiring grower to progress a commercial, value-adding venture. In particular, those risks may include: financial risk, market pull, market dynamics, differentiation, growers' level of interest, and seasonality. Other issues identified here may significantly undermine or support the level of success enjoyed by the venture.

Financial risk

Grower/processor and specialist processor respondents consider the "1st, 2nd and 3rd risk (in the proposed venture) is whether there is a financial incentive". Economic analysis of the business proposition is critical prior to investment and buy-in by the aspiring grower. If the economics are marginal, then growers will take the risk-free strategy of burying harvest residues or market surplus. Therefore, provision of an economic model is a priority requirement to define the costs, timelines and financial benefit to the grower, based on an in-depth market opportunity analysis and understanding of market dynamics, with detailed input and guidance from the prospective end-user or customer.

Market pull

The appropriate business model needs to respond to, or anticipate, market demand, rather than be in response to the availability of harvest residues or market surplus (feedstock push) or innovative technology (technology push). All respondents recognised that it is essential for a commercial value chain to generate a product that the customer wants to buy.

> The "single biggest piece of advice (I can give the aspiring grower) is the reality of the end point". Know your market to determine whether you can "establish a business with a commercially-relevant market share".
>
> Industry Respondent
> Specialist processor

Therefore, this report recommends that further work be undertaken to interest investors and partners. The prospective value-adding project needs to be couched in terms of its value proposition (to differentiate the end-user or customer, and to address a specific market demand or application), an outline of the manufacturing process at scale, and a preliminary estimate of capability to meet volumetric production, reliable composition and quality.

Market dynamics

The food and ingredients markets are notoriously fickle and consumer trends can change rapidly and dramatically. Respondents warn that building a business on today's trends may fail – the current demand for the product may disappear in the time it takes to get the new business operational. This report recommends that an understanding of the approaches that established and successful horticultural companies use to address stability of revenues in their value-adding businesses may provide key learnings for other aspiring growers.

Engagement with customer

Some respondents provided guidance to the aspiring grower not to be too concerned with the customer until the facility to manufacture a high-quality product is established and operational. In clear contrast, end-user respondents report a commercial imperative to be involved at an early stage in process, packaging or product development in order to confirm, guide and support projects that have evidence of commerciality. The end-user brings to that early engagement with a project an in-house capability to confirm the addressable market, to provide detailed analysis of market size and consumer demand, consumer testing, design, refinement and testing of product format, and an early definition of product specifications and performance metrics, particularly volumes of supply. Together, the end-user/customer and grower/processor will evaluate the requirements that a new business needs in order to be competitive in a market that is cost-driven.

Timeframes to uptake

The uptake of new product by the market may take time: the customer or end-user will trial a new product to assess quality and differentiation, as well as appropriateness and fit within their current portfolio, and may conduct extensive final product formulation trials and consumer testing. Therefore, there may be a delay before a supply agreement is reached: some respondents report timeframes of "maybe 2 years before an order is placed".

Scale of production

Understanding the commercially realistic scale of production of any value-adding venture may be pivotal to success. Industry respondents report that achieving sufficient scale to be viable on an ongoing basis is the biggest challenge to the processing business. Evidencing reliable and appropriately scaled production to the potential end-user is considered by respondents as key to attracting and securing a commercial partner. Added to the anticipated downtime due to seasonality for a processing or packing facility owned on-farm, the essential nature of scale of production adds to the investment risk for the aspiring grower. The majority of growers may have insufficient scale of feedstock production to operate an integrated value chain alone, unless the target is a niche market. Therefore, the report recommends that gaining an understanding of both the scale of production to meet end-user or customer demand and the economic scale needed for a commercially-realistic business is a priority.

Seasonality
Seasonality of feedstock may affect the cost-effective operation of process equipment and utilisation of staff, and overall profitability of a value-adding facility. The grower/processor may need to consider feedstock flexibility and other options to make best use of the facility's infrastructure and staff assets in the off-season. The operation must be able to amortise both capex and opex over the entire year to be cost-effective.

Corporate Preparedness of Growers
Respondents report that, in general, growers "know they need to change" their current business and operating model and engage with the value chain but may lack the skills and tools to progress a strategy to achieve that goal.

Many growers have already embraced the concept of simple value-adding to reduce on-farm costs and retain margins by leveraging an on-farm packaging shed (Level 1). The challenge is how to progress change management, such that growers transition an existing business (family farm) into a more corporate mode of operation consistent with higher levels of vertical integration within the value chain.

Therefore, this report recommends that the level of preparedness of the grower to progress along the value chain needs further investigation to identify:

- Attitude of growers to extending their existing business in the context of value adding;
- Gaps in current business skills to those corporate capabilities required of a value-adding processor (levels 2 to 4) such as business planning, governance, marketing and managing customer relations, contract review and negotiation; traceability recording; and awareness of and access to government programs and support.
- Gaps in knowledge regarding effective routes to market, and how to negotiate these routes; and
- Realistic timeframes to success for the aspiring growers in a value-adding venture.

Skills versus Control
Grower respondents report that their approach to vertical integration of value-adding is based on retaining a high level of close and careful control over each step in their supply chain, from the input side of crop production (seed and fertiliser) to innovation and quality management of the value-added outputs. This is the predominant approach the grower uses to management risk within their expanded operation. However, a consideration in integrating higher levels of technical sophistication into that value chain is the requirement for appropriate technical skills and capabilities, which are likely to be well outside the current core skills of the (Level 1 or 2) grower/processor, and certainly outside the core skill of the grower. Respondents confirm additional core skills and competencies are needed in line with an extended integration of horticultural businesses within the value chain to:

- Operate a specialist processing business to meet the quality and quantity metrics of the customer;
- Manage the marketing chain for a business in food or ingredient manufacturing, with direct interaction with the customer at each step in the supply chain; and
- Build a domestic or export route to customer.

> "Moving up the value chain is a complex business proposition for the grower".
>
> Respondent
> Grower

One solution is to slowly grow these competencies as the business grows over time: some respondents allow a 5-10 year time frame for their value-adding business to mature.

Another is to acquire or outsource those skills: for example by the incorporation of a specialist processor or relevant service provider within that value chain, an approach that may generate conflict with the grower's (or collective growers') culture of control, and the drive to retain all margins. This compromise, and any competitive advantage that it may bring, needs further exploration as an option to advance the value chain on behalf of the aspiring grower(s).

Investment in Marketing
Industry respondents emphasised the sizeable investment their businesses have made in marketing, both in trend research and customer relationships over time. One respondent evidenced the value he placed in the relationships with his customer base as having taken "10 years and millions of dollars to build". Another respondent reported that one third of the operating expenditure in his specialist processing business was invested in marketing.

Differentiation
Many respondents advised that the core attribute that a value-adding project should aim at delivering is quality. However, other respondents took this further: in a highly crowded and competitive space, and one that is price-driven, as is the case for powders as ingredients, for example, the new product needs substantial and verifiable differentiation to displace competitors. Differentiation may address price, convenience, quality, shelf life, speciality, nutritional composition, local origin, or health benefits, among others.

> "If there is a market for the product, then you must establish the point of difference to secure an edge especially in a highly competitive market" (such as the ingredients market)
>
> Industry respondent
> Specialist processor

Relevance and Responsiveness
Industry respondents report that a major challenge for a business, irrespective of scale, is to be aware of the industry and the market more broadly so that the business is responsive to upcoming and potentially rapid changes in consumer trends, feedstocks, staff, shareholders and stakeholders. Some notable grower/processor respondents report that they travel internationally, and often, in order to stay abreast of global consumer trends for their value-adding business, and stay informed of developments in best horticultural practice.

Growers' Level of Interest
While some respondents report "huge interest in and commitment from some of the largest (grower) companies in the sector" to the prospect of extracting additional value from their

businesses in such applications as value-added or functional foods and food ingredients, nutraceuticals, bioenergy and biochar, other respondents provide a distinctly contrary view. Therefore, a more expanded interrogation of the sector's level of interest in involvement in value-adding ventures may be required, especially in light of a potential demand by end-users for volumetric production, and therefore the potential need for feedstock aggregation from multiple growers.

Addressing the Export Market

A number of respondents report that the horticulture industry has a history ("remembered by all") of unsupported attempts at developing export contracts that have not gone well ("growers having their fingers burnt"). Consequently, the industry overall is shy of the export market, and "sticks to the domestic market". Therefore, this report recommends an examination of how best to support building an export trade for the outputs of new value chains within the horticulture sector, including in initiating and securing a customer, partnership management and contract negotiation.

E-commerce

Processor respondents comment that initial sales in the early stages of their new business was entirely dependent on their online presence and direct e-sales to consumers. However, industry association respondents report that a preponderance of growers do not understand the scale of the opportunity that e-commerce represents for the export market in general, but particularly to China. This direct route to market enables growers to circumvent distributors and agents, both of which take a percentage of the grower or grower/processor's profit margin. The initiation and management of a successful e-commerce business needs skills currently outside of the core business of horticulture sector.

Interestingly, respondents advise that some regional governments and authorities (eg in Queensland) are "gearing up" to meet the opportunity represented by e-commerce, with infrastructure in place or planned to accommodate direct sales from regional agribusinesses to markets in Singapore and Hong Kong. So, this report considers there is a gap between the awareness and preparedness of regional infrastructure to leverage the opportunity of e-commerce with Asian consumers and customers, and the awareness and preparedness of the horticulture grower to recognise and navigate that opportunity.

Government role and perception

Respondents report that State governments may currently under-estimate the size and value represented by the horticulture industry, and consequently the potential benefits of economic growth and job creation from developing value-adding within the industry. From the perspective of the grower respondents, government support is recognised as a key success driver in building successful value-adding businesses within the sector. Therefore, this report recommends that the recognition by government of the economic role of horticulture, the value proposition of investing in the sector, and the willingness of government to pay a role, needs further investigation.

Regional infrastructure

As the technical opportunity to value-add fresh produce is rolled out, there is a need for demonstration scale infrastructure to, at least, prove a new process and generate market-ready quantities of product for commercial assessment by prospective partners. The investment by any one grower in commercial scale equipment is significant: a freeze dryer costs an estimated $500,000 and HPP[11] facilities ~$1 million[12]. In addition, consideration needs to be given to the availability and sufficiency of cold chain facilities to effectively manage the movement of produce to ports.

Provenance and Traceability

There is export market interest, especially from Asia but increasingly from western markets such as the US, in the importance of knowing the origins of food and nutrients. That a premium price can be ascribed to high protein foods with demonstrable provenance and traceability has been leveraged already within the Australian agricultural scene, most notably in meat and dairy. While there is some argument amongst respondents whether horticultural produce can similarly demand a premium or a higher value for the same level of evidence, domestic and export end-users and customers increasingly demand clarity and certainty around the origins of foods, at least. Consequently, provenance is now becoming a fundamental requirement within the performance metrics of supply from the horticulture sector to end-users and customers. In contrast, the awareness of provenance and traceability as an attribute of horticultural produce, how to evidence provenance, and implementation of traceability reporting structures by growers within the sector is reportedly mixed but low. Therefore, a further recommendation of this report is to explore the value proposition of the provenance of value-added products from Australian horticulture, the level of awareness among aspiring growers, and implementation of consistent and standardised traceability reporting and certification systems for validation.

SECTION 3: RECOMMENDED BUSINESS AND OPERATING MODELS

This section will propose business structuring options for the aspiring grower to consider to build further value within their current horticulture business.

To date, this report has considered the size and scope of the market, the nature of the technology and examples of prospective products derived from horticultural feedstocks, the levels of increasingly specialised processing required to add value, and the risks, impediments and challenges facing the aspiring grower. This section then will consider operational and organisational approaches that provide the opportunity for the aspiring grower to embrace those challenges, mitigate and manage the risks, and leverage the asset inherent in the horticultural feedstock.

Business and operating models

This section considers what is required in a successful venture to value-add fresh horticultural produce. The assumption is that the prospective venture will be based on specialised CSIRO technologies that add value by processing fresh produce to derive new products, and to deliver those products to the customer or end-user.

The supply chain for the venture needs to account for feedstock production and aggregation, feedstock pre-processing, specialised processing, packaging, warehousing and distribution. The unit operations that support the value chain within the venture include those from quality management of feedstock (input) and product (output) and traceability reporting, through to process engineering, marketing and sales, and logistics management.

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[11] High pressure processing (HPP) uses cold pasteurisation and intense pressure to kill bacteria and preserve food.

[12] Cost estimates are from respondents

Prior to establishing the business, a number of interdependencies or foundation parameters need to be satisfied, including the financial modelling of the economics of the prospective business, and the required commercial scale. The operation of the prospective business will be supported by commercial contracts that may be concerned with, for example, feedstock supply, pre-processing, processing and sale.

An indicative overview of the prospective venture to value-add fresh produce, scoping the interdependencies or foundation parameters, unit operations and contracts is represented in Figure 8.

<table>
<tr><th>Business operations</th><th>Feedstock production</th><th>Aggregation</th><th>Preprocessing</th><th>Specialist processing</th><th>Packaging, warehousing</th><th>Distribution</th><th>Customer</th></tr>
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</table>

Figure 8: Indicative overview of the requirements for a prospective business value-adding fresh produce by means of CSIRO technologies. The supply chain from feedstock to customer is described, along with the parameters or interdependencies for the foundation of the business, the unit operations within the value and supply chain, and the contracts to underpin business operation.

Foundation Parameters

In proposing business and operating models to growers for uptake of value-adding technologies into a new operating structure, this report assumes that the grower has the following contracts and intelligence in place as the foundation parameters of the business:

- Upskilling of the corporate preparedness of the aspiring grower or growers as managers of the new business.

- Route to market decided: as business-to-business (B2B) or –to-consumer (B2C). These are very different marketplaces requiring different sets of core skills, risks and supply chain management[13].
- Offtake agreement in place with customer: potentially progressed to a negotiated preliminary heads of agreement.
- Product parameters[14] defined: specifying exactly what the customer requires in and of the product.
- Volume of supply of the product to the customer defined: this is required to define the volumes of feedstock supplied to the processing site.
- Logistics model completed: to determine the cost-effective supply of feedstock to the processing site, or, conversely, the location of the processing site within a radius of cost-effective supply of feedstock.
- Contracts with feedstock suppliers agreed: preferably long-term agreements for aggregation of feedstock either at the specialist processing facility or at a pre-processing site co-located with the feedstocks suppliers.
- Pre-processing agreements: Separate contracts may be required for decentralised pre-processing feedstocks on-farm or with a Level 1 processor (see Figure 2).
- Technology license in place: license to access and make commercial use of the required technology, with clear guidance specifying:
  - Technical support, especially during early establishment of the specialist processing operation; and
  - Ownership of any ongoing innovation or process improvement.

This report assumes that, prior to the establishment of the commercial scale business, negotiated use may be made of CSIRO as the pilot facility for an intermediate- or demonstration-scale operation by which means the horticulture producer or other interested parties can transition to a commercial-scale operation based on CSIRO technologies.

Business Models

This section considers options for business models from the perspective of the aspiring grower, to enable the recovery by the grower of additional value by further processing fresh produce leveraging CSIRO technologies within a Level 3 or level 4 operation (see Figure 2). The structure and operations of the business models proposed below take into account the risks, challenges, limitations and gaps, as well as an overview of the potential benefits that may be associated with any of the three potential value-adding propositions proposed by CSIRO.

This report recommends the following business model options for consideration by the aspiring grower:

- Expanded Grower Business: a single (large-scale) grower investing in establishing a *de novo* processing venture, with full control over the business, exposure to all of the risk and in receipt of net revenues.
- Cooperative Grower Venture: a number growers co-investing in establishing a *de novo* processing venture, with shared control over the business, shared exposure to risk and a proportional benefit from net revenues.

[13] Based on interviews with respondents

[14] Based on a negotiated agreement with CSIRO as the pilot facility, providing both staff and facilities.

- Toll Manufacturing: provision of specialist processing capability as a subcontracted service within either the Expanded Grower Business or the Cooperative Grower Venture business models.
- Joint Venture: partnership between grower (or group of growers) and an established specialist processor; the grower or growers have a pre-agreed level of control over the business, exposure to risk, and benefit from net revenues for the duration of the joint venture.

Expanded Grower Business

In this business model, the individual grower invests in the establishment of a *de novo* processing venture, potentially integrating this new venture into an existing horticulture production business. The investing grower has full control over all aspects of the business, full exposure to risk, including financial, while benefiting from receipt of net revenues.

In this option, the new processing (Level 3 or 4) venture is established either from the ground up (*de novo*) or by acquiring and refurbishing an existing horticulture (or similar) processing business. In this report, only the *de novo* business will be considered further, although many of the considerations would equally apply to the refurbishing and potentially repurposing of an acquired specialist processing business.

In the Expanded Grower Business, the value-adding venture is envisaged as a fully integrated business unit within the framework of the grower's existing commercial horticulture operation.

In this model, the grower is responsible for establishing and operating all components within the supply and value chains, from field to customer. Those components are notionally: feedstock aggregation; feedstock pre-treatment; technical processing; product finishing and packing; storage and distribution (see Figure 9). The specialist skills needed for the operation may include those outside the core skills of the grower and/or are those that require a higher level of investment: in marketing and customer relations; quality assessment and management; technical operation and trouble-shooting; in-coming and out-going inventory management; specialist packaging; and logistics. Depending on the structure and operation of the aspiring grower's existing business, there may be in-house operational capability that may be leveraged by the new venture, such as that in feedstock pre-processing, logistics or packaging.

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Figure 9: Indicative overview of the structure for a prospective Expanded Grower Business. The role of the investing grower in business operation is indicated in red. This report recognises that the key considerations for the aspiring grower in this model may include financial exposure, diversion from core business, and acquisition of the skills essential to successfully operate a processing business at higher technical level (eg Level 4) (refer to Figure 2).

The financial investment required to establish and operate a new purpose-built, value-adding processing facility and operation for any or a combination of the potential products at a commercial scale has yet to be determined. Nonetheless, in an Expanded Grower Business model, that financial risk is borne by the aspiring grower alone. In addition, the grower needs to account for management of the financial consequence of the timeframes required for both commercial uptake of a new product and for establishing production at scale, as well as for any impact of the new business on the existing one (of horticulture production and/or Level 1 or 2 processing).

The processing operation needed for production of any of the proposed value-added products requires specialist skills in both manufacture (process engineering) and quality management, as well as marketing, administration and logistics. The skills required are likely to be a significant expansion of, and in some cases substantially different to, those deployed within the existing operations of the grower or grower/processor (Level 1 or 2 refer Figure 2). Therefore, in the Expanded Grower Business, those additional skills will need to be acquired by the establishment of a new workforce, as well as potentially by upskilling team members of the grower's current workforce.

In the Expanded Grower Business, the aspiring grower retains all net benefits from revenues. To date, the cost-benefit analysis of any of the product scenarios, and therefore the quantum of benefit or timeframe for delivery of benefit for any scenario, has not yet been determined.

Cooperative Grower Venture

In the Cooperative Grower Venture business model, a number of growers co-invest in the establishment of a *de novo* processing venture, with shared control over the business, shared exposure to all of the risk and a proportional return on net revenue (see Figure 10).

The Cooperative Grower Venture requires the establishment of a new company as an independent business separate and distinct from all of the investing growers' existing horticulture businesses, and co-owned and operated by the investing growers.

Business operations	Feedstock production	Aggregation	Preprocessing	Specialist processing	Packaging, warehousing	Distribution	Customer
Interdependencies	Varietals determined by specialist processor or customer	Market opportunity confirmed					Early review of manufacturing facility & production process
		Scale of supply (customer heads of agreement)					
		Cost benefit analysis (financial model)					
		Scale of commerically realistic business (financial model)					
Unit operations	Feedstock production	Quality mgmt of feedstock received & dispatched	L1 or similar process	L3 or 4 process	Specialist packaging	Logistics management	Market insights
				Process engineering			Formulation of final product
	Harvest engineering	Traceability reporting		Quality analysis: inputs & outputs	Cold chain management		
				Marketing & sales	Inventory management		Customer testing
Contracts	Supply agreement with contract growers		Contract with pre-processor	Shareholder agreement to establish specialist processor venture			Supply agreement with customer
				Agreement with toll manufacturer for specialist processing			
				JV or partnership agreement with established specialist processor			

Figure 10: Indicative overview of the business structure for a prospective Cooperative Grower Venture. The role of the cooperative growers in business operation is indicated in red; note inclusion of the shareholder agreement or venture agreement as a required contract.

In the Cooperative Grower Venture, many of the issues and considerations within the Expanded Grower Business equally apply. However, within the cooperative business model both risks and benefits are shared by the investing growers in a proportion negotiated in the venture agreement. In addition, the venture will benefit potentially from the combined skills and experience of its founders as well as potentially from their collective operational infrastructure in pre-processing, packaging, logistics, marketing etc.

One issue within the Cooperative Grower Venture that needs to be addressed at the outset is the decision-making and management structure within the business. This report recommends that one disincentive for any individual grower to participate in a cooperative venture may be a sense of a diluted role in decision-making and in business control: this issue should be addressed on venture establishment by a clear and agreed governance structure and executive succession plan.

Toll Manufacturing

In this model, an external toll manufacturer replaces the specialist processing unit operation that otherwise needs to be established *de novo* within the Expanded Grower Business or the Cooperative Grower Venture business models. In this model, a toll or contract manufacturer is commissioned to provide specialist processing services to the grower-owned value-adding business (see Figure 11).

Business operations	Feedstock production	Aggregation	Preprocessing	Specialist processing	Packaging, warehousing	Distribution	Customer
Interdependencies	Varietals determined by specialist processor or customer	Market opportunity confirmed					Early review of manufacturing facility & production process
		Scale of supply (customer heads of agreement)					
		Cost benefit analysis (financial model)					
		Scale of commerically realistic business (financial model)					
Unit operations	Feedstock production	Quality mgmt of feedstock received & dispatched	L1 or similar process	L3 or 4 process	Specialist packaging	Logistics management	Market insights
				Process engineering			Formulation of final product
	Harvest engineering	Traceability reporting		Quality analysis: inputs & outputs	Cold chain management		
				Marketing & sales	Inventory management		Customer testing
Contracts	Supply agreement with contract growers		Contract with pre-processor	Shareholder agreement to establish specialist processor venture			Supply agreement with customer
				Agreement with toll manufacturer for specialist processing			
				JV or partnership agreement with established specialist processor			

Figure 11: Indicative overview of the structure for a prospective Expanded Grower Business or Cooperative Grower Venture business models with toll manufacturing. The role of the investing grower(s) in business operation is indicated in red. Note the addition of the toll manufacturing agreement; the requirement for a potential shareholder agreement in the Cooperative Grower Venture is indicated by a dotted line. The specific roles subcontracted to the toll manufacturer are noted in yellow.

The benefit of this model is that the investing grower(s) has immediate access to skills, capabilities and production experience that is otherwise outside of their core skills, particularly in process engineering, and in technical and quality management. However, as is the case with the Expanded Grower Business or the Cooperative Grower Venture models, the role of the investing grower(s) is to establish and operate the overall value-adding business and to provide the marketing, customer relations, supply chain management, specialist packaging and logistics for successful business operation.

Note that the toll manufacturing model may be an interim transitional model for either the grower-owned or JV models. A financial analysis of the cost-effectiveness of subcontracting operational units (such as specialist processing, marketing or packaging etc), which can be used to support decision-making on the optimal business configuration, has yet to be done.

Joint Venture

In the Joint Venture business model, the business is based on a partnership between grower (or group of growers) and a commercial specialist processor. In this model, the grower(s) has an agreed level of control over the business, a proportionate exposure to risk, and proportionate return on net revenue for the duration of the joint venture.

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</table>

Figure 12: Indicative overview of the structure for a prospective Joint Venture. The roles of the investing grower(s) in business operation is indicated in red; the roles of the specialist processor partner is indicated in blue. Note the addition of the joint venture partnership agreement; the potential requirement for a shareholder agreement for a joint venture with a growers is indicated by a dotted line.

The advantage to the investing grower of the Joint Venture business option is in the provision by the specialist processor of a set of skills and capabilities that are essential within the value-adding venture and are complementary to those brought by the grower(s).

The specialist processor partner is anticipated to bring such relevant core skills as experience in commercial scale manufacture, technical and quality management capabilities, market outreach, and customer and supply chain management skills. In addition, the joint venture partner may also contribute access to established routes to market for comparable products (and experience in building those routes), existing relevant customer relationships, as well as reputation and branding. While the grower would recognise that control of the business and any potential benefit is shared between all partners in a joint venture, the significance of the specialist processor may be to deliver an acceleration of the technical and commercial aspects of building the value-adding business, risk reduction, as well as potentially shortening the time to revenues.

The role of the grower or growers within the joint venture may be in three capacities: in feedstock management and aggregation, in traceability reporting, and as the licensee of the innovative technology to be deployed in the venture. The value of the license to the joint venture should not be under-estimated: it is likely that access to the technology for the manufacture of new products from fresh produce was the key attraction for the specialist processor to consider a joint venture relationship. Therefore, the partnership agreement with the specialist processor needs to reflect the commercial significance of the grower as the technology licensee.

RECOMMENDATIONS: MARKET AND MODELLING

This section will make recommendations to address gaps in delivering product to market, in extended market research, and economic modelling to provide guidance to the aspiring grower in considering how best to build further value within their current horticulture business.

Product types

This report recommends that further information is sought for the ingredients and snacks and the fermented product propositions.

- Fermentation
    - Clarify the market opportunity for a non-traditional commercial vegetable-based fermented product;
    - Complete sensory and consumer testing;
    - Assess risks and challenges inherent in the production of a fermented product using CSIRO technology and process, and non-standard starter cultures;
    - Survey the published data of relevant clinical trials; or sponsor a clinical trial to evidence any health claims; and
    - Complete a demonstration-scale fermentation to generate reproducible data.

- Ingredients and snacks: The challenge is to enter a market that is: a substantial global market but driven by consumer fads with revenue cycles of boom and bust; intensively competitive; and price-driven.
    - Need to confirm a highly differentiated product, responsive to (upcoming) consumer trends for production at a commercially-relevant scale;
    - Early stage partnering with food or nutraceutical manufacturer to collaboratively refine and define the product;
    - Early stage consumer testing and product development to develop a data package for partnering; and

- Invest in ongoing innovation to develop a dynamic product pipeline that leverages CSIRO technology.

Extended market research

- Scope the range of market opportunities for each product, and the relevant jurisdictions of interest;
- Define the key performance metrics of each product as a component of the end-users' supply chain, that includes the definition, at least, of a minimum scale of supply.

Economic modelling of value-adding process

Construct an economic model to determine:

- Cost benefit analysis of the commercial scale operation;
- Minimum production scale for profitability and the time to profitability;
- Cost of equipment and facilities, and maintenance requirements;
- Staff costs across all unit operations;
- Assessment of options and measures to address seasonality; and

Investment required for marketing and brand building, both in market outreach to customers, in maintaining customer relationships and in ongoing consumer research or market insights.

Entrepreneurship, corporate preparedness and marketing

This report has identified specific gaps in corporate and executive skills within the horticulture sector as an impediment to expanding current businesses by value-adding. Therefore, this report recommends that direct assistance or networking to appropriate services be provided to the sector as:

- Entrepreneurship programs to assist aspiring growers to realise new business and growth opportunities, to improve their competitiveness and productivity, and to build connection and collaboration with innovators;
- Access grants and services (such as the R&D tax Incentive[15]);
- Coaching and mentoring to expand the executive management and negotiation skill base of growers and grower/processors, and in particular build e-commerce business skills;
- Establishing the systems by which provenance of products based on Australian horticulture is evidenced, and implementation and standardising of traceability reporting structures by growers; and
- Assistance with international marketplaces such as those in China and Japan. Tailored introduction services and contract negotiation services are two components of international marketing that would immediately benefit aspiring growers within the sector.

NEXT STEPS

This Stage 1 report provides an initial scoping paper for growers in the horticulture sector to consider leveraging new technical opportunities to value-add vegetables. As such, the report has focused on the general scope of the market landscape, a broad, high level overview of the value chain, and options for business and operating models. The target audience for the outcomes of the report's findings is the cohort of early adopters within the horticulture sector.

[15] https://www.ato.gov.au/Business/Research-and-development-tax-incentive/

The overarching goal of the project is to provide growers with a detailed understanding of operational models to leverage these new opportunities, and critical information on the potential prospects for their current businesses to guide strategic decision-making.

The next steps in this work are to more rigorously interrogate and test the general conclusions and recommendations made in this Stage 1 report, and refinement of the recommendations into a set of priority actions, as an integrated set of final guidance and costings.

Therefore, the next steps are to provide growers with an economic modelling, delineation of potential structures of the business and operation, an evaluation of venture participants, and a model for aggregation of the required feedstock:

- **Economic modelling** of any new venture is a priority, and is based on:
    - Cost benefit analysis: Detailed economic evaluation of select product opportunities by means of a realistic financial model built to provide a cost-benefit analysis framework. The model should define a minimum commercial scale of production for profitability, with input from potential end-users and customers. This model will allow for the anticipated investment in marketing required by the grower/processor for the successful commercialisation of the new product; and
    - Performance metrics: Articulation of the key performance metrics of the new product as a component of the end-users' and/or customers' supply chains, that includes the definition, at least, of a minimum scale of supply.
- **Business and operating models**, refined on the basis of
    - Drivers of success: Understand the keys to the success of established vertically-integrated horticulture businesses, and of select specialist processors;
    - Skills and capacities: In-depth review of the capabilities and capacities required within the value chains to meet the key performance metrics for supply expected by the end-user and customer, and assessment of the equipment and production infrastructure required for manufacture of the three product types at scale;
    - Refined business model(s): Detailed and executable proposals for revised or new business or operating models for each product type; and
    - Implementation framework: An implementation framework to progress the manufacture of select product within their respective supply and value chains, with stage gates and milestones.
- **Venture participants** who may include
    - Customers: Identification of, and initial contact with, potential commercial partners for offtake of any of the three product types;
    - Manufacturing partner: Identify, assess the availability or interest of the specialist processor as a manufacturing or technology partner to potentially participate in the value-adding venture, as a collaborator or contractor.
    - Early movers and participants: Assessment of level of interest within the horticulture sector to progress an investment in value-adding by means of the select technologies, and/or provide essential feedstock to meet production and supply targets.
- **Feedstock aggregation:** building a Logistics model to assess the aggregation radius and feedstock availability for cost-effective supply for processing, based on the scale of production required by the end-user or customer for any or all of the select products from select feedstocks.

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APPENDIX 5

AGRICULTURE AND FOOD BUSINESS UNIT
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Creating Value from Edible Vegetable Waste

Project VG 15076

Final Report for Extension Activities

Stakeholder Engagement: January 2017 – June 2018

Client

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[Insert ISBN or ISSN and cataloguing-in-publication (CiP) information if required]

[CSIRO Agriculture and Food]

Citation

Krause D & Augustin MA (CSIRO) and McInnes S (Human Capital International) and (2018). Creating value from edible vegetable waste. Stakeholder engagement. CSIRO, Australia.

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Acknowledgments:

Funding for this project was provided by Horticulture Innovation Australia and CSIRO

Contents

Executive summary

The Horticulture Innovation Australia project on ‘Creating Value from Vegetable Waste’ commenced at CSIRO in October 2016. The stated aims of the project were to optimise the value from the edible waste in the vegetable supply chain, by creating healthy food ingredients and products from edible biomass left in the field, lost biomass after harvest or from side streams of food processing.

Feedback from visits to stakeholders highlighted the need for greater interaction between researchers, growers and stakeholders and an extension program was proposed. The extension program was aimed at the development of a collaborative network of various stakeholders to;

- facilitate stakeholder engagement for knowledge transfer of project outcomes to growers
- facilitate potential partnerships for growers in the vegetable supply chain

A collaboration between players along the value chain was identified to facilitate the translation of research outputs to industry. Extension activities were developed for the course of the project (January 2017- June 2018) to communicate project progress and receive feedback to shape the direction of the project. Activities included; meetings and facilitated workshops with growers, food manufacturers, retailers, food companies and nutraceutical companies, development of links with National Vegetable Extension Network, for translation of project outcomes, development of communication material, and design and facilitation of stakeholder workshops.

Over the eighteen month project extension activities have engaged with stakeholders along the value chain from growers through to retailers and the general public showcasing the outcomes of the ‘Creating value from vegetables project’ (vegetable powders, extruded snacks, concentrates, fermented products.

Fifteen activities specifically aimed at connecting to grower networks, including ‘taking the extruder to the farm’ visits in three Victorian locations. A highlight of these activities was Danyang Ying being recognised with the ‘Industry Impact Award’ for ‘taking the extruder to the farm’ at the AUSVEG Annual Awards Dinner.

A series of 6 workshops (attended by 250) were planned and executed. The number of attendees to workshops grew from 46 at the first workshop held in August 2017, to around 80 at the May 2018 workshop, with several interstate attendees from as far Northern Queensland, reinforcing the growth in the spread of our extension networks across the period of the project.

The development of a series of ten fact sheets, 25+ media articles and interviews, 9 online articles and presentations at conferences and workshops further promoted the project.

Extension activities have facilitated interest in the commercial uptake of some of the project outcomes, expressions of interest to extend to other vegetable types and fruits. The extension team has worked closely with business development (led by Lloyd Simons, CSIRO for this project), who has liaised with Hort Innovation to respond to the interest generated. Overall, the extension and stakeholder engagement activities have served as a catalyst for stimulating interest in the technology, not only for broccoli and carrot products, but for other vegetable and fruit products.

1 Introduction

A Horticulture Innovation Australia project on "Creating Value from Vegetable Waste" commenced at CSIRO in October 2016. The stated aims of the project were to optimise the value from the edible waste in the vegetable supply chain, by creating healthy food ingredients and products from edible biomass left in the field, lost biomass after harvest or from side streams of food processing. It was anticipated that the development of new/ novel food ingredients, and adoption of the outputs form industry, has the potential to increase the economic value derived from vegetable production and reduce waste disposed to landfill.

The first part of the project (October – December 2016) involved speaking with stakeholders. This included visiting farms in Werribee South, East and South Gippsland to determine if growers saw value in the development of new/novel differentiated healthy food ingredients and products from vegetable waste. Growers were also interested in forming links with established supply chains that could facilitate route to market (e.g. nutraceutical companies, ingredient suppliers, retailers).

Feedback from the visits to stakeholders highlighted the need for greater interaction between researchers, growers and stakeholders and an extension program was proposed. The extension program was aimed at the development of a collaborative network of various stakeholders. The stakeholders considered included the CSIRO research team, Horticulture Innovation Australia decision makers, partners, customers, Horticulture Innovation Australia industry Development officers in the Vegetable extension network, State government, supplement, food ingredient manufacturing companies and bodies involved in the vegetable industry (e.g. producer / grower entities, etc). A collaboration between players along the chain identified to facilitate the translation of research outputs to industry. Extension activities were developed to communicate timely progress and receive feedback to shape the direction of the project.

This is the final report for Activity 5 (Extension) and covers the extension activities undertaken for the project from January 2017- June 2018.

2 Approach

Conversations between various stakeholders along the vegetable supply chain were aimed at developing an appreciation of the interest and hurdles of bringing new value-added products from vegetable waste (with an initial focus on Brassica) into the market.

The approach involved one of more of the following activities, which was dependent on the interest and availability of the various stakeholder groups to engage in conversations, around the concept of value adding to vegetable waste. The range of activities undertaken were:

- Planning meetings for extension and stakeholder engagement activities (CSIRO team, Human Capital International, Business Development – to be identified and HIA as appropriate)
- Establish a network of stakeholders along the value chain
- Interaction between extension team, scientists, growers, and a range of stakeholders along the value chain
- Preparation of material/documents for extension activities
- Communication of science outcomes to a range of audiences
- Visits / facilitated workshops with farmers, food manufacturers, retailers, food companies and nutraceutical companies
- Attendance at events planned and conducted with HIA Industry Development Officers in various regions (as advised by HIA) that are part of the National Vegetable Extension Network, as appropriate
- Meetings with other customers/ partners (e.g. Vegetable Producer Groups)
- Design and Facilitation of HIA Stakeholder workshops and sessions
- Follow-up with targeted stakeholders to ensure continued stakeholder engagement
- Review of and feedback on workshops, progress and stakeholder engagement

3 Stakeholder engagement activities

Stakeholder engagement encompasses a range of activities including;

- Meetings with various businesses, government, funding bodies, to help enable connections of interested parties along the value chain
- Attendance at forums, meetings, conferences, to engage and network with others
- Organisation of workshops

3.1 Developing stakeholder connections along the value chain

Connections with stakeholders along the value chain occurred across the project, through face to face meetings, attendance at forums and presentations at forums. In many cases meetings enabled stakeholders along the value chain to develop connections. A summary of the major connections is shown below:

- Connecting stakeholders in the horticulture value chain (Jan – March/ Apr 2017)
    - Introducing various players and assessing pathway to possible uptake of future project outputs - Growers, nutraceutical company representatives, HI, vegetable extension network officer (Gippsland), Gippsland Food Cluster, Vic State Government (DEDJTR)
    - Exploration of processing hub interest
    - Consideration of possible funding sources (e.g. Food Source Grant, DEDJTR)
- Connections relating Farmer interests (Feb – June 2017) (further details in Table 1)
    - Agribusiness Forum – Gippsland/KPMG
    - Farmer's update – Gippsland
    - Innovation Days on Farm –Gippsland
    - VegNET – Sydney
- Connections to facilitate planning and conducting stakeholder workshops (June 2017 – May 2018) (further details in Table 2)
    - 2 major stakeholder workshop in Werribee (Aug 2017, May 2018)
    - 2 workshops in North Queensland (March & April 2018) – Responding to request
    - Workshops related to CSIRO McMaster's Fellow (Prof Alan Irwin) visit
        - Eliminate Food Loss Workshop – Melbourne (Feb 2018)
        - Waste to Wellness workshop in South Australia – (March 2018)
- Interactions with major retailer (August 2017 – June 2018)
    - Introduction of project to retailer
    - Several meeting with major retailer
    - Workshop to showcase research
    - Facilitate interactions with stakeholders
- Connecting with wider interests in Australia - Attendance at Food Waste Forums (Aug – Nov 2017)
    - Vic govt initiative (Aug 2017)

    - Federal govt initiative (Nov 2017)
- Interactions with market analysts (Aug 2017 – June 2018)
    - Interactions with KPMG (with Hort Innovation)
    - Interactions with CSIRO Market Analyst
- Connections to improve networks and identify future opportunities along the supply chain
    - Meetings with FIAL (Barry McGookin), Swisse (Justin Howden), Foodbank Vic (David McNamara),YUME (Katie Barfield)
- Interactions to facilitate adoption of technology (over the period Jan 2017- June 2018)
    - Several meetings with Fresh Select, CIS, Coles, Swisse and others
- Connecting with the general public (August 2017)
    - Science week, Living Science at the Victoria Market, Melbourne. Samples of extruded snacks available for the general public to taste and give their feedback.

Further details of some of the activities are given below.

3.2 Connecting to grower networks and beyond

A series of visits to farms in Gippsland helped to inform the scope of the project and highlighted the need for extension activities to help communicate the science outcomes of the project to growers and the broader horticulture industry. Fifteen activities specifically aimed at connecting to grower networks are outlined in Table 1. A highlight of these activities was Danyang Ying being recognised with the 'Industry Impact Award' for 'taking the extruder to the farm' at the AUSVEG Annual Awards Dinner.

Table 1: Grower network connections

Activity	Outcomes
Farm visit to Gippsland November 2017	The CSIRO team met with growers to discuss the project and determine their interest in the project
Food & Fibre – Our Future 27th February 2017, Melbourne	Mary Ann Augustin and Steven McInnes attend the annual Agribusiness Leaders forum organised by Agribusiness Gippsland-KPMG and connected with horticulture industry representatives
Gippsland Grower's Forum 9th March 2017, Sale, Victoria Discussions with farmers on 'Creating value from vegetable waste' project	Positive feedback from many attendees and expression to participate further
East Gippsland Vegetable Innovation Days 3rd – 4th May 2017, Lindenow, Victoria	The CSIRO team and HCI interacted with agronomists, growers, seed suppliers, logistics companies, processors and extend networks to the Gippsland community and horticulture industry
Hort Connections 15th – 17th May 2017, Adelaide	Luz Sanguansri, Mary Ann Augustin and Steven McInnes attend the conference and engaged more farmers interest in the Food Loss project

Activity	Outcomes
VegNET newsletter June, 2017 Research activities were promoted via the VegNET newsletter	Increased awareness of this HI funded project, for vegNET networks, and who to contact for further information
Foodpro Industry Exhibition 17-19 July 2017, Sydney Extruded snacks displayed at CSIRO trade show booth and apple pomace biscuits for tasting Presentation by Luz Sanguansri at industry seminar; Future of a sustainable value chain by eliminating food loss	Interaction with food industry businesses and increased awareness of project
Vegie Growers Forum 27 July 2017, Korumburra Presentation by MAA at event; Update on Food Loss transformation	Interaction with local farmers and increased awareness of project
Living Science , National Science Week 13th August 2017, Queen Victoria Market, Melbourne As part of CSIRO's showcase, the carrot and broccoli extruded snacks were available to the general public for tasting. Members of the team (Deb Krause, Luz Sanguansri, Peers Sanguansri, Mary Ann Augustin, Filip Janakievski and CSIRO Comms (Pamela Tyers) were handing out snacks and discussing possible product applications with the general public.	Interaction with the general public to get consumer feedback on the extruded snacks. Feedback included many people asking where they could buy these type of snacks. Feedback on potential applications, included 'astronaut food', hiking food, kids (and adults) lunch box snacks, ingredients for recipes, soups, quiches etc. A snippet of the stand is shown on the new Living Science at the Market video which is now on YouTube; **https://youtu.be/jfiLsVVSit8**
Taking the extruder to the farm The team has been involved in a number of outreach activities to bring science and technology to the field. These demonstrations have been organised in conjunction with VegNET Development Officers. This has enabled local growers to see firsthand how the extrusion process can be used for the production of nutrient rich extruded vegetable snacks and potentially add value to their underutilised crops for commercial and competitive advantage. Growers were able to taste products and ask questions about the technology and products. **East Gippsland Region** *21st September 2017* Bonaccord farm, Walpa **Western Region**	The extrusion process for the production of nutrient rich extruded vegetable snacks was demonstrated to growers at three locations across Victoria. The East Gippsland demonstration was organised in collaboration with Shayne Hyman, from the East Gippsland Food Cluster. Mr Tim Weight, Deputy Chair of Regional Development Australia, Gippsland, and Dr Nicola Watts, Executive Officer of the East Gippsland Food Cluster welcomed CSIRO Scientists to the event. The demonstration was reported; ', in The Bairnsdale Advertiser, 25 September 2017. Approximately 12 growers were in attendance from Bulmer Farms, Mulgowie Farms, Hine Vegies, Frais Farms, Bonaccord and RDA Gippsland. The Western region demonstration was organised in collaboration with Clinton Muller, RMCG, on behalf of The National Vegetable Extension Network (VegNET) Project and Carolyn Thomas, Fresh Select.

Activity	Outcomes
24th October 2017 Fresh Select, Werribee South **South Eastern Region** *28th March 2018* Taranto Farms, Tyabb	Approximately 12 growers were in attendance from Fresh Select, Fragapane Farms, Harvest Moon, Perfection Fresh and Riverside Produce. Representatives from KPMG were also in attendance and discussed the market demand study that will be undertaken. The South Eastern region demonstration was organised in collaboration with Carl Larsen, RMCG, on behalf of The National Vegetable Extension Network (VegNET) Project. Approximately 27 participants were in attendance from Taranto Farms, Brown's Fertilisers, Gazzola Farms, Schreurs & Sons, Peter Schreurs & Sons, Bruynen Farms, Coolibah Herbs, Lamattina & Sons, Victorian Farmers Federation, Gravitas Energy, E.E. Muir & Sons, Chemdome Chemical, AUSVEG, Cesar, RMCG
Coles/FIAL Health & Wellness Seminar for Food Processors *6th March 2018 (at Treasury Theatre Melbourne)*	Met with industry suppliers and processors. Heard about Coles new Health & Wellness brand strategy launch.
North Queensland Growcom Innovation workshop **(Bowen Gumlu Growers Association)** *13th March 2018 (at Bowen Farmers meeting)*	Met with regional farmers and local industry representatives. Strong interest indicated to become involved.
North Queensland Growcom group *14th March 2018 (at JCU Townsville)*	Met with regional funders (CRC NA), State Govt & Local Govt representatives, local council, JCU and industry representatives. Strong interest indicated to become involved.
AusVeg Vic Awards Event *13th April 2018 (at Kooyong LTC Melbourne)*	CSIRO was nominated and Danyang Ying was recognised with the 'Industry Impact Award' for 'taking the extruder to the farm' at the AUSVEG Annual Awards Dinner. Met more farmers who have expressed interest in the project.

3.3 Stakeholder workshops

A series of 6 workshops (attended by 250) were planned and executed over the past year, with a focus on bringing a diverse range stakeholders along the horticulture value chain together to share knowledge and discuss opportunities for creating value from vegetable waste. The number of attendees to workshops grew from 46 at the first workshop held in August 2017, to around 80 at the May 2018 workshop, with several interstate attendees from as far Northern Queensland, reinforcing the growth in the spread of our extension networks across the period of the project. The workshops and outcomes are outlined in Table 2.

Table 2 Stakeholder workshops

Workshop	Who	Outcomes
Creating value from vegetable waste *8th August 2017, Werribee* - Research update and show-case of technology and products (Powders and Extruded snacks, juice concentrates, fermented products - Extruded products available for tasting - Business development and commercialisation opportunities - Facilitated discussions	46 invited attendees representing stakeholders across the value chain which included growers, processors, retailers, nutraceutical companies, vegetable industry body and government representatives	- Connecting stakeholders along the value chain from a range of industries and geographical locations - Knowledge sharing and between stakeholders along the value chain - Discussion of the opportunities coming from broccoli and carrot waste - Suggestions for applications of technologies to a range of other crops - Other food, nutraceutical, and non-food applications , supply chain value-adding opportunities, waste streams, export - Discussion of hub processing facility - Calls for expressions of interest in project outputs
Coles – CSIRO workshop *2nd November 2017, Coles* - Workshop to identify opportunities for project development? - CSIRO's food loss projects - Coles Products development team show examples of broccoli powder and other product innovation - CSIRO processing technologies showcase - Table conversations with a focus on 'what could we continue to develop together?'	Attended by ~30 Coles staff, Hort Innovation (Greg Murdoch), grower (John Said) and the CSIRO team and HCI (Steven McInnes, Michael Howard). The meeting was facilitated by Steven McInnes.	- The Coles team provided samples of a wrap (where they substituted 30% of the flour with broccoli powder provided by CSIRO - The CSIRO team provided samples of extruded snacks made from broccoli and carrot powder and apple pomace biscuits (output of CSIRO internal project). - Discussion around other possible product applications, particularly bakery applications, nutritional aspects (Health Star Ratings) - Interest in sourcing further powder samples for product development trials and the cost

Workshop	Who	Outcomes
		of powder production for commercial application
Eliminate Food Loss *22nd February 2018, Melbourne* - A workshop designed to bring multiple stakeholders together into a conversation around 'Creating value added products from underutilised biomass' and facilitated by Steven McInnes, HCI - Professor Alan Irwin, a world renowned social scientist from the Copenhagen Business School, shared his ideas on increasing transformative innovation in the horticulture supply chain.	Attended by approx. 50 delegates from the food industry, government, research providers, growers and related organisations. to share their insights for collaboration and to stimulate interest in generating transformative innovation across food chains to address global challenges in agribusiness.	- Bringing together, a diverse group of stakeholders for a discussion of the potential to transform food currently lost in the supply chain into a raw material supply for new value-added ingredients - The opportunity for the formation of new partnerships.
Transforming innovation in the horticulture value chain *23rd February 2018, KPMG, Melbourne* - A workshop designed to bring executives and scientists together to share their insights for collaboration in horticulture and facilitated by Steven McInnes, HCI - Prof Alan Irwin launched the session with an interactive lecture, around how to generate transformative innovation across food chains to address global challenges in horticulture - Hort Innovation, FIAL and KPMG provided the external view on innovation in the agribusiness industry	Attended by 45 delegates from the food industry, government, universities, research providers, funding bodies, growers and related organisations.	- This workshop brought leaders in the horticulture industry from across the value chain together to discuss how businesses in the agriculture, food and nutrition sectors can innovate to address global challenges in horticulture. - Sharing of knowledge amongst a diverse group of stakeholders to gain an understanding of challenges along the horticulture value chain
Centre of Excellence Hub in Food Transformation for Townsville region *12th April 2018, Townsville* - The key stakeholders were guided through the emerging value chain and gained an appreciation on how their contribution via expertise &	Attended by 19 representatives from the Townsville, Burdekin/Gumlu, Mareeba, growers, and grower groups, local government, state government, federal government, CRC for Developing Northern Australia,	- The interaction of stakeholders in the Townsville horticulture value chain with the CSIRO team provided opportunities for discussion. - Interest in downstream processing for value adding to

Workshop	Who	Outcomes
funding could be driven by a common purpose, which will translate into urgently required new economic and jobs growth for the region.	James Cook University, Northern region TAFE, CSIRO and HCI	vegetables and fruits grown in the region. - Formation of stakeholder group for research gap analysis project. - Growers and regional leadership realise the opportunity, and will develop a coordinated a regional plan - Grower driven pilot projects in development
A value chain for vegetable waste – from farm to fork *10 May 2018, Werribee* Final in the series of stakeholder workshops - Research update and show-case of technology and products (Powders and Extruded snacks, juice concentrates, fermented products - see and taste some of the concept products - discuss the research activities with the CSIRO scientists, external partners and suppliers - explore suggested business models and commercialisation pathways - network with other participants in the value chain to identify potential opportunities	Approx 80 invited attendees representing stakeholders across the value chain which included growers, processors, retailers, nutraceutical companies, vegetable industry body and government representatives	- Connecting stakeholders along the value chain from a range of industries and geographical locations - Research updates, potential business models, pathways for commercialisation, market opportunities and for project activity following project completion communicated - Funding model options discussed with interested parties - Collaboration between Townsville group and Gippsland group for progressing 'Hub' feasibility development - Potential for utilising technology platforms in other fruit and vegetable product applications

3.4 Outreach

3.4.1 Fact sheets

The science team has prepared a series of fact sheets for delivery of project outcomes to stakeholder audiences.

The fact sheets are;

- 100% broccoli powder
- 100% carrot powder
- 20% broccoli snacks

- 20% carrot snacks
- 100% extruded broccoli
- 100% extruded carrot
- Functional broccoli based products through fermentation
- Functional carrot based products through fermentation
- Extraction of health promoting components from broccoli
- Extraction of health promoting components from carrots

These were made available at stakeholder workshops and communicated through other channels (as requested) to facilitate appreciation of the state of the work and further BD activities.

3.5 Media & PR

There has been significant activity to increase profile of Hort Innovation project and other related CSIRO work on food loss and waste with at least 36 media and on line stories presented.

3.5.1 In the media

- ABC interview with Dominique Schwartz, ABC Rural, Jan 2018
- ABC Far North Queensland, Pre-recorded interview, Jan 2018
- ABC Goulburn Murray, Pre-recorded interview, Nov 2017
- Ag Innovators, 'CSIRO's new Food Loss bank seeks input from broccoli, apple industries', Nov 2017
- Australian Food News, 'CSIRO comes up with innovative way to reduce food waste', Nov 2017
- Weekly Times, 'Food waste: CSIRO uses science to map losses', Excess crops to become base or healthy snacks', November 2017
- Weekly Times Now, 'Science to map losses', Excess crops to become base or healthy snacks', November 2017
- ABC Rural, Western Australia Country Hour – October 2017
- ABC Radio Riverland, August – September 2017:
    - https://soundcloud.com/stacey-lymbery/whats-the-difference-between-food-loss-and-food-waste
    - https://soundcloud.com/stacey-lymbery/farm-to-fork-where-are-the-opportunities-in-horticulture
    - https://soundcloud.com/stacey-lymbery/is-food-security-a-problem-in-australia
    - https://soundcloud.com/stacey-lymbery/science-for-societal-outcomes
- ABC Goldfields
- Eddie Summerfield, Macquarie National News, June 2017
- Hot FM, Townsville, June 2017
- ABC Radio Geraldton, June 2017
- ABC Radio Gippsland, May 2017
- ABC Ballarat, Victorian Country Hour, May 2017
- ABC Gippsland, Rural Report, May 2017
- ABC Southern Queensland, Qld Country Hour, May 2017
- ABC Wide Bay, Rural Report, May 2017

- ‘Researchers are working with growers to get more people eating veg…’ 2GB Sydney, June 2017
- ‘Australia’s unused and unwanted vegetables could soon find their …’ 2NM, Muswellbrook (National Rural News), June 2017
- ‘Australia’s unused and unwanted vegetables could soon find their way into tasty snacks or drinks. The CSIRO is investigating three techniques on how draw nutrients from vegetables to turn them into ingredients or products. Researchers are working with growers to turn imperfect fruit and …’, 2NM, Muswellbrook (National Rural News), June 2017
- ‘Researchers are working with growers to get more people eating he…’, BAY FM, Geelong, June 2017
- ‘Extruded vegetables a market carrot’, Bairnsdale Advertiser, September 2017
- ‘The food loss bank’ article, published in Food Australia, Jan-Feb 2017
- Broccoli latte – HI/CSIRO media release 6 June 2018, (organised jointly by Kelly Vosrt-Parkes-HI & Pamlea tyers, CSIRO) followed by several TV (ABC News Breakfast, Ch 9 news and Ch 10 news and radio interviews/newspapers – AAP, SBS, Sydney Morning Herald, Herald Sun, The Guardian, ABC online, NZ TV filming with Hort Innovation, 3AW, Trending on Twitter, Buzzfeed and others (Interviews fielded by CSIRO, Fresh Select and HI),

3.5.2 Online

- ‘The holes in santa’s stocking: mapping food loss from the farm and beyond’, CSIRO blog: https://blog.csiro.au/holes-santas-stocking-mapping-food-loss-farm-beyond/, Dec 2017
- ‘Giving ugly vegetables a nutrient-rich face lift’, HIA media release: http://horticulture.com.au/giving-ugly-vegetables-a-nutrient-rich-facelift/ and CSIRO blog: https://blog.csiro.au/giving-ugly-vegetables-nutrient-rich-face-lift/, June 2017
- ‘The food loss bank’ Food Australia article on CSIRO blog, https://blog.csiro.au/food-loss-bank/, May 2017
- Novel extruded food products for reducing food loss and waste: https://www.csiro.au/en/Research/AF/Areas/Food/Making-new-sustainable-foods/Extrusion
- Podcast: https://blog.csiro.au/interronauts-episode-10-caterpillars-brainwashed-into-cannibals-sampling-the-abyss-croque-monscience-and-transforming-uggo-fruit-into-stars/
- CSIRO’s Food and Agribusiness Roadmap, sustainability and the food loss bank – https://blog.csiro.au/fast-healthy-and-sustainable-what-we-want-from-our-food-in-the-future/
- Research.csiro.au: https://research.csiro.au/aim/home/aims-research-test-beds/eliminate-food-loss/ and https://research.csiro.au/foodlossbank/
- Converting food waste: https://www.csiro.au/en/Research/AF/Areas/Food/Making-new-sustainable-foods/Converting-food-waste-into-nutritious-ingredients
- Farming Together, October 2017, Food waste map survey

3.5.3 Responding to media releases

There were occasions where the team had to respond to media releases. This involved clarifying the position of the HI project and the work of CSIRO in relation to other work on Horticulture Loss and Waste. This was part of the necessary support to provide an analysis of the media and the stage of the research.

3.6 Other activities related to extension

There has also been a series of activities that have been initiated following discussion at meetings.

- **Stakeholder Engagement for 1st Generation Value Added Products**
  - Responding to enquiries and creation of new contacts interested in 1st Generation Value Added Products (Coles and Foodbank (Vic))
  - Engagement with FIAL (Barry McGookin and Rod Arenas) to explore opportunities

- **Advancing 2nd Generation Value Added Products (Brassica)**

  - Series of meetings with Fresh Select and Swisse to discuss Sulforaphane-rich fermented products

- **Evidence-based nutritional information on Brassica– Proposal to HIA**

  - This was considered an important aspect to facilitate adoption as it enables stakeholders to make a more informed decision on Brassica products of most interest/value and also to assess and communicate the allowed level of claim to the market
  - A proposal for this activity was prepared in conjunction with Dr Manny Noakes (Research Director within Health and Biosecurity). The brief relating to a search and interpretation of available nutritional information on Brassica was submitted to HIA

- **McMasters Fellowship - Engaging with food loss and waste: a multi-stakeholder perspective on transformative innovation**

  - A letter of support for the proposal was provided by HIA
  - CSIRO hosted Prof Alan Irwin (Professor of Organizations, Risk and the Environment, Department of Organization, Copenhagen Business School, Denmark) out to Australia for 2 weeks in 2018, following a successful McMasters Fellowship application.
  - Through a series of facilitated workshops, the project aimed to:
    - Address the possibilities for developing new approaches to the food loss & waste issue based on stakeholder engagement, cross-disciplinary research and scientific development.
    - Recommend strategies for translation of research on creating value added food ingredients and products from horticultural food loss in line with stakeholder concerns, needs and expectations.

  - Information on the 'Eliminate food loss' and the 'Transforming innovation in the horticulture value chain workshops is outlined in section 3.3.

- **Exploration of a Commercialisation Incubator Hub**

- Identification of market driven opportunities that relate to HI projects (including Vegetable waste project and 2nd Generation products) and wider range of horticulture products
- Work with manufacturers and retailers to produce products aligned to customer needs
- Work with CSIRO (Martin Cole and BD&C) - HI (Greg Murdoch) – CIS (Greg Spinks) – HCI (Steven McInnes) to develop business model for adoption of technologies (including discussion with farmers)

CSIRO has an activity related to the Exploration of a Processing Hub in East Gippsland. Major stakeholders are the East Gippsland Food Cluster (Nicola Watts), Latrobe Valley Authority (Scott McArdle) and Agribusiness Gippsland (Paul Ford). This activity is being led by Pablo Juliano (CSIRO).

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APPENDIX 6

Milestone Report

Project title:

Creating value from edible vegetable waste

Project code:

VG15076

Milestone number:

MS107

Project leader:

Mary Ann Augustin

Delivery partner:

CSIRO Agriculture and Food

Report author:

Pablo Juliano et al.

Milestone due date:

30/09/2018

Submission date:

30/09/2018

Confidentiality:

Is this report confidential?

☒ No

☐ Yes (whole report)

☐ Yes (sections of report are confidential)

If sections of the report are confidential, list them here:

Milestone description:

Progress report

Milestone achievement criteria:

Third 6 monthly progress report submitted to HIA. Report to include an update on next steps following outcomes of the 'Feasibility options for an innovative food manufacturing hub' and status of discussions with potential investors (e.g., local state and federal governments or other investors)

Detailed commercialization/exploitation plan for the project (refer to Hort Innovation template)

Funding statement:

- *Retain the appropriate funding statement (no heading) below. Delete the remaining funding statements and this instruction.*

Levy funds – R&D projects

This project has been funded by Hort Innovation, using the horticulture research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

General project overview

This project undertook a pre-feasibility study for the development of an innovation manufacturing hub that supplies fruit and vegetable ingredients from regional fresh produce to local and export markets. The approach taken in this project consisted of a high level evaluation of the various critical business and regional aspects that justify the establishment and operation of the hub.

Summary

The hub is proposed as a long term, financially sustainable venture with specialised modular food processing capability to manufacture specialty fruit and vegetable (f&v) ingredients. Specialist f&v ingredients to be manufactured in the hub may include powders, liquid concentrates, fermented ingredients and fibre powders. In addition, given advances in food processing equipment connectivity, the hub may operate as a demonstration smart factory for interconnectedness through Industry 4.0 type infrastructure.

The attached report summarises the key findings and recommendations from dedicated chapters. Each chapter develops considerations used to build a detailed business case for commercial feasibility. The business case activities assessed the following: (1) market opportunities; (2) business models for the hub; (3) venture infrastructure and cash flow; (4) aspects of competitiveness and risk associated to setting up the venture; (5) flow-on regional benefits; (6) hub ownership models and governance options; and (7) a sensitivity analysis for scenario modelling and forecasting. The information gathered here will be extended to key stakeholders including growers, food processors, investors, government representatives, and innovators. This information is intended for use as a baseline for informed discussion, engagement and decision making of multiple parties, within a focused feasibility study, to identify key business options that justify this venture in target regions in Australia.

Achievements

Identification of market opportunities

There are a myriad of opportunities to add value to existing horticultural crops to generate commodity and specialist ingredients for the food markets both nationally and internationally. We have identified the major markets and determined the growth potential for horticultural ingredients both in Australia and in major Australian export destinations.

Major markets for premium Australian fruit and vegetable ingredients with very promising projected growth in demand include China, Indonesia, India and the UAE, where growth was found to range between 15-49% for 2017-2021. These specialty ingredients are commonly utilised in the beverage, packaged foods and nutraceutical categories, with packaged foods being one of the largest categories (16.8m tonne production of USD 157B f&v ingredients). The estimated 2017-2021 growth of such ingredients in Australia is 6% (i.e., a USD 41B market). Australia currently grows sufficient fresh produce to fulfil its domestic f&v premium ingredient demand, but can only supply a small fraction to meet the overseas market demand. Subsequently, for example, a typical regional f&v ingredient hub may only supply 0.001-0.33% of the total national and international market demand.

A Market Knowledge workshop with key experts in the field was carried out at the Monash Food Innovation Centre in January 2018, where major gaps in knowledge for market, product, and consumer category gaps were identified to inform a project feasibility study.

Preliminary case study on the venture infrastructure and cash flow

A preliminary capital infrastructure and operating cost assessment for the hub considered the unit operations to manufacture the above-mentioned ingredients. An example of a viable hub infrastructure and processing facilities to progress the commercialisation of value-added products was estimated at AUD 24.8M with a ±30% error as a first approximation. Alternatively, considering the hub becoming a modular facility, a smaller investment may be required for initial infrastructure, depending on the products and volumes selected, and then incrementally build the start-up venture. The preliminary estimate for the example on annual revenue of the hub from sale of the manufactured ingredients was AUD 66.4M with an annual operating cost estimate of AUD 45.8M. The cash-flow and profitability analysis of the venture indicated the hub Net Present Value of AUD 93.1M over a 15-year life span with a 3-year payback period.

Sensitivity analysis for scenario modelling and forecasting

The infrastructure investment costs for the hub were used to model the profitability criteria through a risk sensitivity analysis. A range of price points of the feedstock (i.e., fresh produce), price points of the specialty ingredients (final products), and scenarios on incremental utilisation of the hub were used in the analysis. Based on the assumptions used, all scenarios predicted good financial health for the hub over the 15 year period, with payback times ranging from 2.4 to 4.1 years for each product or variable considered. The greatest effects on return-on-investment were driven by variations of the fibre extract powder production volume and price, followed by the price of fresh produce used as manufacturing feedstock.

Understanding business models for the hub venture

A strategy for business to business (B2B) market positioning is recommended for clearer financial planning and stakeholder forecasting for the hub venture. The venture will have core business unit operations consisting of manufacture and sales of specialty f&v ingredients through specialised processing that will ensure revenue generation and financial sustainability. Parallel business activities may also include toll f&v processing (module hiring), ingredient development (R&D), marketing and quality assurance. The business may be initiated by creating a proprietary company, an incorporated cooperative or joint venture. Specialist legal and tax advice must be sought in pursue of such options.

The selection of the business model will depend on (a) the availability of a keystone participant from within or outside of the horticulture sector, (b) aspiring growers as co-investors in a company or as members of a cooperative, or (c) interest from a specialist processor or customer as a joint venture partner. The cost benefit and operational advantages of these models were considered through specific case studies. The venture may also consider decentralisation for primary processing, diversion or feedstock stabilisation. The hub may outsource some of its activities to bring opportunities for new specialised businesses to the region. A list of potential suppliers and developers of integrated technologies for Industry 4.0 links into advanced manufacturing and interconnectivity is provided in this work.

Identifying hub ownership models and governance options

The project shortlisted a set of potential ownership arrangements, including a proprietary company or public limited company, co-operative ownership, partnership contract, anchor, leasing, and government- or employee-owned models. However, how various ownership models maximise returns depends on the strategic vision of the enterprise, management and governance structure, the availability of finance, the treatment of profit or surplus revenues, regulation, and other factors.

Successful corporate governance will support the creation of sustainable long-term value on behalf of all owners and shareholders. This project reviewed the essential elements of good governance, the relationship between the governance framework and the management of business and other risks, and the ideal governance and reporting structure between the owners and the executive team, and within the company structure.

Case studies illustrated exemplars of selected ownership structures from within and adjacent to the horticulture sector, and their respective governance frameworks.

Analysing the risks of setting up the venture

The major business risks for the hub venture were identified and analysed. Some key risks that were highlighted, include: (a) failure to launch, (b) financial failure, (c) failure in business execution, and (d) failure in market delivery or in meeting market expectations.

To address these, a risk mitigation matrix was developed with a set of strategies including, at least: (1) completing a robust business plan, (2) reaching alignment between key venture participants, (3) defining the critical economic production scale, (4) confirming the final products to be manufactured, and (5) completing key supplier and customer engagement. Other risk mitigation aspects included developing a robust corporate governance framework, protecting the supply chain and developing the adequate responsiveness to market dynamics. The specifics of these risks and mitigation strategies will be further developed during the hub's feasibility evaluation stages.

Hub competitiveness needs identified

Even though Australia has a high global competitiveness ranking, its national ranking has slipped over recent years compared to other developed countries. Key export markets for food and ingredients in Asia and the UAE are notorious for being subjected to consumer fads, intensely competitive and price-driven.

Therefore, to build the competitiveness of the hub venture, we need to leverage clearly differentiated advantages such as: (1) branding as an Australian rural business delivering "green clean safe" products; (2) investment in provenance and traceability certification; (3) direct and evidenced control over the supply chain, on behalf of end-users and customers; (4) verification of product quality, nutritional composition and bioactivity, according to market needs; (e) clear product differentiation and specifications, (5) validation of financial drivers for competitiveness in specific markets, including critical scale of production.

First evaluation of flow-on regional benefits

An economic impact analysis for the proposed establishment of a processing hub in horticultural food producing regions across Australia reflected on the flow-on effects to the wider economy, both regional and national. A case study considered a hub being established in Gippsland, Victoria. The annual financial impact of the hub was estimated at AUD 74m per annum or 1.5% to 2.0% of the Gross Regional Product for the region. The impact on the broader Australian economy was estimated at around AUD 94m per annum. Around 55 jobs would be created from the operation of the hub, including those directly employed (35 full time employees) or engaged as contractors. Another 50 or so jobs would be created in the region from the flow-on effects as newly generated income is spent in the region. An increase in entrepreneurial activity is also expected to create many jobs from newly formed micro and small enterprises, which will potentially result in substantial employment opportunities, particularly for the young and disadvantaged.

Outputs

The activities summarised below define the scope and key deliverables of the pre-feasibility study with the goal of progressing the development of a regional food manufacturing hub, generating commercial returns for growers, and deploying innovative technologies. The food manufacturing hub concept addressed here is applicable within the context of most horticultural regions across Australia.

The key findings and preliminary recommendations to set the alternatives for a business case are included the attached summary report. More in depth detailed information can be found in the respective chapters included as Appendices:

Chapter 1 - market opportunities,

Chapter 2 - venture infrastructure, cash flow and sensitivity analysis for scenario modelling and forecasting,

Chapter 3 - business models for the hub (corporate structure, risks, ownership, governance, competitiveness)

Chapter 4 - flow-on regional benefits.

Outcomes

Once clearance is received from Hort Innovation, socialisation of the mentioned report will occur with the Industry Steering Committee and various stakeholders towards feasibility studies for the development of regional hubs with selected groups in target regions:

- Companies – potential owners or users of the hub (e.g. Fresh Select)
- Grower clusters - potential feedstock suppliers (e.g., East Gippsland Food Cluster, Growcom)
- Food Waste CRC
- Potential investors

- Councils (e.g., Labtrobe Valley), State Governments (e.g., Ag Min Jaala Pullford, Latrobe Valley Authority) and Federal Government (e.g., Agriculture Minister David Littleproud, Federal Members, Ayr&Bowen Electorate, Senators)

A glossy document summarising key findings, recommendations and next steps in being prepared by CSIRO with inputs from East Gippsland Food Cluster. Growcom is also creating glossy report to socialise the concept among various stakeholders in Northern Australia.

Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report

Issues and risks

No issues and risks to report

Other information

No additional information to report

Appendices

Summary Report:

Juliano P, Glenn D, Deane J, Sanguansri P, Krause D, Abbott M, Esposto A, Achariya A, Watts N, and DeSilva K (2018) Feasibility options for an innovative food manufacturing hub. CSIRO, Australia.

Attached to this report are the following chapters:

- Chapter 1: Deane J, Andres M, Juliano P, Krause D, Achariya A, et al. (2018) Market opportunity for value added horticultural products. CSIRO, Australia.
- Chapter 2: De Silva K, Sanguansri P, Janakievski F, Juliano P (2018) Feasibility options for an innovative food manufacturing hub. Hub processing infrastructure and capital, scenario modelling and forecasting. CSIRO, Australia.
- Chapter 3: Glenn, D (2018) Business models and structuring. Corelli Consulting, Australia.
- Chapter 4: Abbott M, Esposto A (2018) Modelling the economic impact of a food processing hub. Swinburne University of Technology, Australia.

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Pre-feasibility options for an innovative food manufacturing hub

Final report

Participants: CSIRO, Corelli Consulting, Monash Food Innovation Centre, Swinburne University team

Co-initiator: East Gippsland Food Cluster Inc.

Supported by: Horticulture Innovation, CSIRO, Swinburne University, Monash Food Innovation Centre

Citation

Juliano P, Glenn D, Deane J, Sanguansri P, Krause D, Abbott M, Esposto A, Achariya A, Watts N, and DeSilva K (2018) Feasibility options for an innovative food manufacturing hub. CSIRO, Australia.

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Contents

Executive summary

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Market opportunities

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The selection of the business model will depend on (a) the availability of a keystone participant from within or outside of the horticulture sector, (b) aspiring growers as co-investors in a company or as members of a cooperative, or (c) interest from a specialist processor or customer as a joint venture partner. The cost benefit and operational advantages of these models were considered through specific case studies. The venture may also consider decentralisation for primary processing, diversion or feedstock stabilisation. The hub may outsource some of its activities to bring opportunities for new specialised businesses to the region. A list of potential suppliers and developers of integrated technologies for Industry 4.0 links into advanced manufacturing and interconnectivity is provided in this work.

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Case studies illustrated exemplars of selected ownership structures from within and adjacent to the horticulture sector, and their respective governance frameworks.

Risks of setting up the venture

The major business risks for the hub venture were identified and analysed. Some key risks that were highlighted, include: (a) failure to launch, (b) financial failure, (c) failure in business execution, and (d) failure in market delivery or in meeting market expectations.

To address these, a risk mitigation matrix was developed with a set of strategies including, at least: (1) completing a robust business plan, (2) reaching alignment between key venture participants, (3) defining the critical economic production scale, (4) confirming the final products to be manufactured, and (5) completing key supplier and customer engagement. Other risk mitigation aspects included developing a robust corporate governance framework, protecting the supply chain and developing the adequate responsiveness to market dynamics. The specifics of these risks and mitigation strategies will be further developed during the hub's feasibility evaluation stages.

Hub competitiveness

Even though Australia has a high global competitiveness ranking, its national ranking has slipped over recent years compared to other developed countries. Key export markets for food and ingredients in Asia and the UAE are notorious for being subjected to consumer fads, intensely competitive and price-driven.

Therefore, to build the competitiveness of the hub venture, we need to leverage clearly differentiated advantages such as: (1) branding as an Australian rural business delivering "green clean safe" products; (2) investment in provenance and traceability certification; (3) direct and evidenced control over the supply chain, on behalf of end-users and customers; (4) verification of product quality, nutritional composition and bioactivity, according to market needs; (e) clear product differentiation and specifications, (5) validation of financial drivers for competitiveness in specific markets, including critical scale of production.

Flow-on regional benefits

An economic impact analysis for the proposed establishment of a processing hub in horticultural food producing regions across Australia reflected on the flow-on effects to the wider economy, both regional and national. A case study considered a hub being established in Gippsland, Victoria. The annual financial impact of the hub was estimated at AUD 74m per annum or 1.5% to 2.0% of the Gross Regional Product for the region. The impact on the broader Australian economy was estimated at around AUD 94m per annum. Around 55 jobs would be created from the operation of the hub, including those directly employed (35 full time employees) or engaged as contractors. Another 50 or so jobs would be created in the region from the flow-on effects as newly generated income is spent in the region. An increase in entrepreneurial activity is also expected to create many jobs from newly formed micro and small enterprises, which will potentially result in substantial employment opportunities, particularly for the young and disadvantaged.

Background

There is a recognised need for regional diversification in the Australian Horticultural industry. Through innovation and collaboration, regional areas have an opportunity to respond to global market trends by leveraging existing capabilities and developing new ones. The concept of a regional food manufacturing hub opens up an opportunity to focus national and state resources to strategically grow the agribusiness sector regionally. Regional hubs have the potential to drive the market uptake of Australian high value fruit and vegetable ingredients through innovation, while providing economic benefits to the region in which they operate. Hubs are expected to be located in regions with strong food clusters and a strong horticultural base to supply both national and target international markets.

Figure 1 represents an indicative supply chain for a specialised hub. Fresh horticultural produce as feedstock would be diverted from regional farms directly to the hub (or via decentralised facilities for pre-processing stabilisation) for processing to specialty or commodity ingredients. It provides a vision of the supply chain dynamics and the interaction among potential stakeholders along the chain, with some of the key questions being addressed in this report. The present concept of the potential hub assumes inputs of fresh or pre-processed horticultural produce that is used to manufacture bioactive concentrates or powders, fermented or non-fermented, fibre powders, extracts, or bulk stabilised fruit and vegetable powders. However, the venture may invest in the equipment to enable processing of other complementary feedstocks from other industries in the respective regions, such as dairy or grains, to enable manufacturing of other innovative ingredients to target niche markets.

The hub concept in Figure 1 also recognises the opportunities represented by innovative enterprises that may create successful new product or technology concepts, but fail to bring these products to the market due to the high risks involved in capital investment for small scale food processing infrastructure. Such companies may consider hiring processing modules of a centralised regional facility, should the facility's business model provide for a toll processing service option. In this way, some commercial clients of CSIRO's Food Innovation Centre may more likely overcome the challenge of reaching the manufacturing stage after an early investment in R&D.

Regional food processing hub

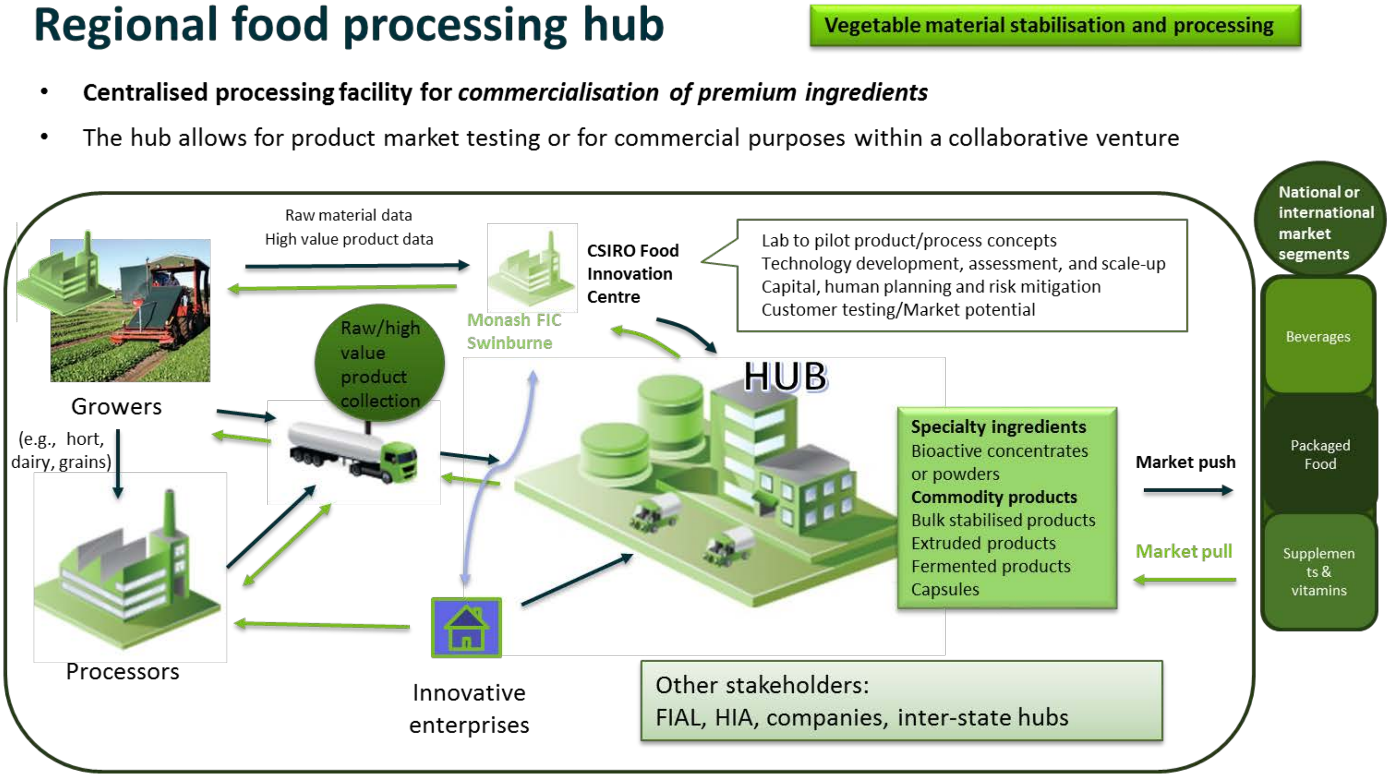


Figure 1. Indicative supply chain for a food processing hub established to manufacture specialty fruit and vegetable ingredients.

The regional food processing hub is proposed to address the needs of horticultural clusters by facilitating:

- high margin value-add to regional fresh produce through transformation into extended shelf-life ingredients,
- regional diversion of underutilised fresh fruit and vegetable feedstock for economic utilisation,
- opportunities to grow new crops on marginal lands for extended or alternative value chains,
- inflow of further investment into the region,
- better returns to growers,
- new skills, training and job creation beyond the food industry, and
- new regional capabilities for stakeholder interconnectivity and efficient decision making through ‘smart specialisation’.

To launch this initiative, a collaboration framework has been developed between the East Gippsland Food Cluster, the Latrobe Valley Authority, Corelli Consulting, Swinburne University, the Monash Food Innovation Centre (Monash FIC) and CSIRO to support and progress the concept of food manufacturing hubs focused on horticulture products.

This report includes the contributions from all parties to the pre-feasibility study, and provides a high level assessment of the establishment of an innovation manufacturing hub with specialist capabilities for modular food processing with integrated technologies for Industry 4.0. These smart specialisation technologies underpin the utilisation of blockchain processes that are currently being used to make commercial operations more efficient. The project was led by CSIRO in collaboration with Corelli Consulting, Swinburne University, and the Monash Food Innovation Centre. Further inputs into this report are being provided by an Industry Steering Committee.

The activities summarised below define the scope and key deliverables of the pre-feasibility study with the goal of progressing the development of a regional food manufacturing hub, generating commercial returns for growers, and deploying innovative technologies. The food manufacturing hub concept addressed here is applicable within the context of most horticultural regions across Australia.

Even though the key findings and preliminary recommendations to set the alternatives for a business case are included in this report, more in depth detailed information can be found in the respective chapters included as Appendices:

Chapter 1 - market opportunities,

Chapter 2 - venture infrastructure, cash flow and sensitivity analysis for scenario modelling and forecasting,

Chapter 3 - business models for the hub (corporate structure, risks, ownership, governance, competitiveness)

Chapter 4 - flow-on regional benefits.

1. Market opportunity for value added horticultural products

1.1 Background

Chapter 1 explores the national and export market opportunities for premium f&vingredients. The chapter covers information drawn from a range of market reports and guidance on market knowledge gaps provided through workshops run by The Monash Food Innovation Centre.

Among the trends shaping the food, beverage and nutraceutical sectors, the move to Health and Wellness, that is, the growing demand for healthier and more natural ingredients to counter consumers' increasing health concerns, is one of the strongest drivers for market growth and innovation. Within these sectors, f&v ingredients are becoming increasingly sought as a natural fit to address the concerns of baby boomer and aging consumers. Health and wellness trends are raising the profile and demand for f&v ingredients in both local and international markets, as horticulture products are increasingly recognised and valued for their nutritional and health benefits. This is creating opportunities for growth through new and innovative products. Australia, for example, is potentially one of the most lucrative global markets for naturally healthy foods and plant-based products as demand for such products becomes more prominent.

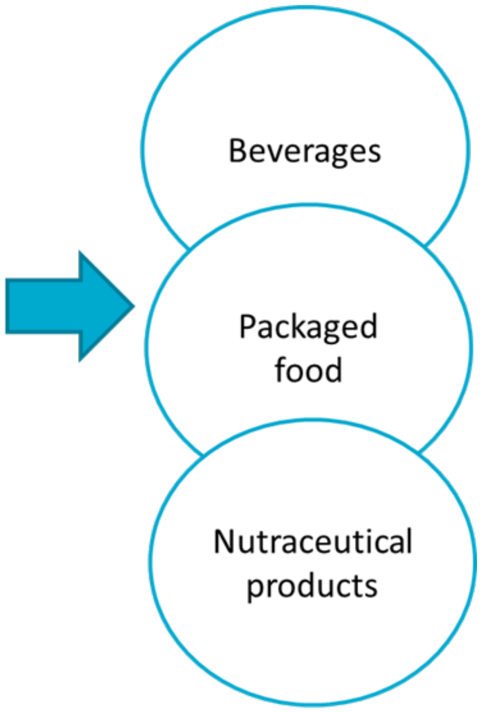
Significantly, the financial opportunities represented by plant-based, natural and organic -related businesses are increasingly being recognised by investors from outside the horticultural sector, with the result that plant-based foodstuffs are anticipated to progressively raise their profile in the shopping aisle. The plant-based food and beverage private equity firm PowerplantVentures for example announced the closing of a USD 42 million fund to invest in emerging plant-centric businesses as they were over-subscribed.

1.2 Markets for fruit and vegetable ingredients

Premium f&v ingredients extracted from fruits and vegetables can be used to add nutritional, bioactive, structural or flavour benefits to processed foods, beverages or nutraceuticals. While shelf-stable and frozen f&v products are of interest, the focus of this study was on a variety of ingredients that are (or can be) added in the manufacture of a broad range of packaged food, beverages and other nutraceutical products, all major end uses of ingredients.

Categories of fruit and vegetable ingredients from Euromonitor's market database have been classified into two groups: (a) commodity ingredients, and (b) specialty ingredients. Figure 2(a) shows the ingredients listed under each selected group and Figure 2(b) shows the end-use products for f&v ingredients. The ingredient selection was based on opportunities to create high value health driven commodity and specialty ingredients from fruit and vegetable sources. These can be used to partially substitute existing ingredients with a broader nutritional balance of fibre, protein, and phytonutrients such as antioxidants. Examples of the business to business (B2B) provision of broccoli and carrot powders to ice cream manufacturers and the recently launched "broccoli latte" in Australia's coffee shops is represented in Figure 3.

Commodity ingredients	Specialty ingredients
USD 1 – 90 per kg	**USD 50 – 500 per kg**
320 – 1,180 thousand tonnes	**280 – 700,000 tonnes**
Fruit (dried)	Botanicals
Fruit Juice	Carotenoids
Vegetable (dried)	Colours and flavours
Potato products	Non-cereal flours
	Polysaccharides and Oligosaccharides
	Antioxidants
	Proteins
	Fermented/ bioactive



(a) The green lines provide indicative commodity and specialty ingredient prices in the global market. Volumes are given for the Chinese market. No data is provided on cost of goods.

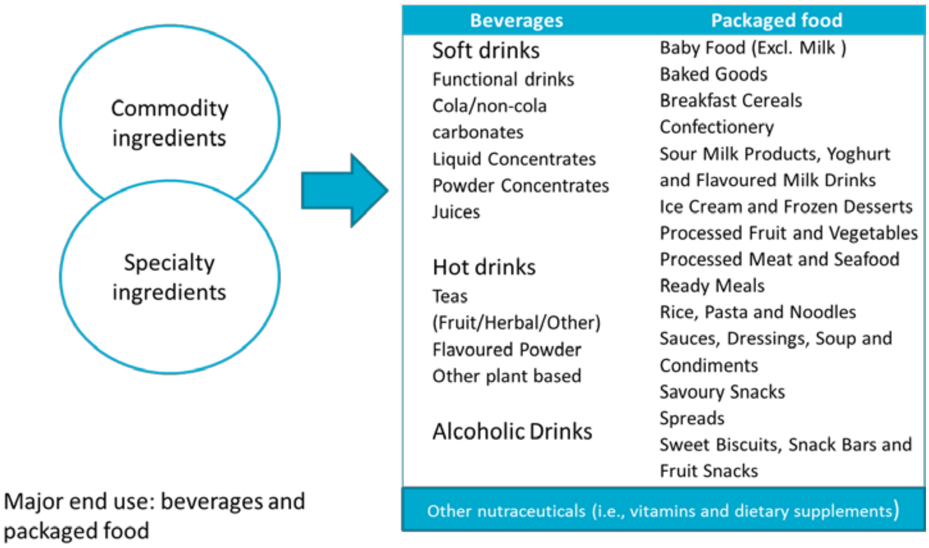


Figure 2. Details of market segments for (a) commodity and specialty ingredients and (b) the end use of those ingredients in consumer products (Source: Euromonitor 2017).

Figure 3. Exemplars of the incorporation of fruit and vegetable ingredients in commercially manufactured food products (Compilation of photos from several sources including CSIRO, Haagen-Dazs, and MizterSiah - DeviantArt).

Major opportunities abound for premium Australian f&v ingredients, particularly in Australia's key agriculture and food export markets of Asia Pacific (APAC) and the Middle East. Chapter 1 includes the supporting information obtained from the Euromonitor database, showing that high growth is expected in these categories in several countries.

Australian market

More than 1500 new products with vegetables as ingredients were launched in Australia between 2015 and 2016. Of these products, 5% were fresh or frozen vegetables and the other 95% were dips, spreads, dairy, bakery, ready meals, beverages, pet food, and others, which suggests an opportunity of enormous potential for f&v ingredients. Australia is a lucrative USD 41B market for packaged foods containing premium f&v ingredients, with f&v ingredient consumption having an estimated annual growth of 6% (Figure 4).

Export markets

Exports of Australian processed fruit and vegetables are a key source of revenue for many local f&v processors, accounting for approximately 49% of revenue and under 27% of the total volume produced (the majority is consumed domestically). The value of exports has increased strongly over the past five years as larger Australian players have aimed to serve the expanding populations and incomes of the middle class in Asia and the Middle East.

A f&v ingredient market of around USD 157B (representing 16.8m tonne of product) was estimated for a global USD 610B packaged food market. As shown in Figure 4, China, Indonesia, India and the UAE are expected to achieve significant growth in demand for selected ingredients which can be derived from f&v or replaced by f&v ingredients between 2017-2021 (estimated at 15%, 49%, 28% and 33% annually, respectively). Other growing sources of revenue for f&v ingredients includes use in beverages.

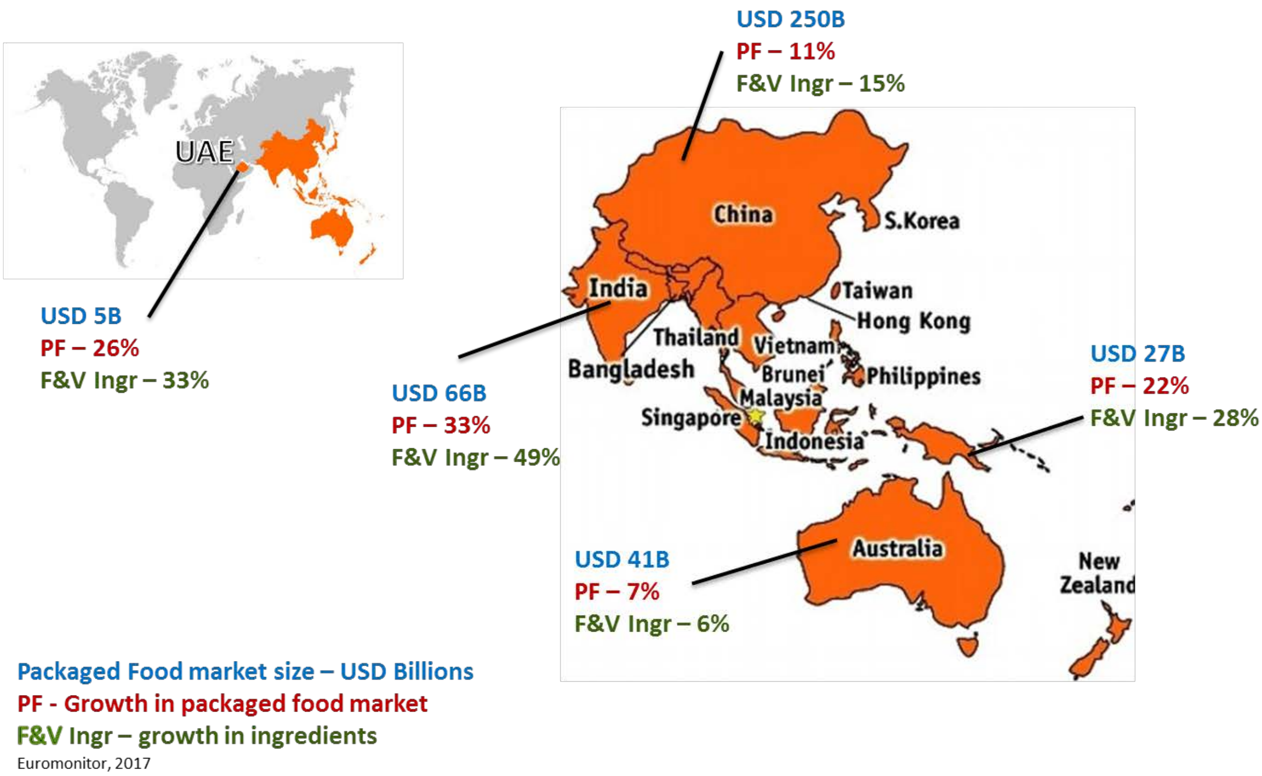


Figure 4. Market size and growth (2017-2021) of the packaged food markets including Australia (indicated by figures coloured blue and red) and growth in consumption of fruit and vegetable ingredients in such markets (indicated by figures coloured green) (Source: Euromonitor 2017).

Nutraceutical ingredients

Many of the specialty ingredient categories described above can have nutraceutical properties, and often offer higher marginal returns on sales. Nutraceuticals are defined as active ingredients offering health benefits beyond basic nutrition. Health benefits may be either physiological or cognitive, for example reducing the risk of chronic diseases, promoting growth, or enhancing the performance of body and/or mind. Ingredients sourced from fruits (particularly so-called “super fruits”), vegetables, plant-based oils and wholegrains that are rich in natural sources of specific nutrients, such as antioxidants and vitamins, are becoming highly sought. Some examples include pro-health natural compounds such as prebiotic fibres, proteins, peptides, amino acids, fatty acids, vitamins, tocotrienols, carotenoids, plant sterols and stanols, polyphenols and flavonoids. Note that in some cases, this category, as listed by BCC Research (2017), may overlap with the specialty ingredients category listed above taken from the Euromonitor database.

The market for nutraceutical ingredients represents a USD 200B opportunity with an expected growth between 7-8% from 2016-2021 (Figure 5). These present not only a regional opportunity in Australia’s key export markets, but also a global opportunity, especially in Europe and USA. High growth is expected in nutraceutical beverages in Indonesia, India, Australia and UAE in the coming five years. Figure 5 shows some examples of beverages and packaged foods containing nutraceuticals.

Global nutraceutical market by product; $ billions

Product	2015	2016	2021	CAGR% 2016-2021
Functional beverages	66.6	71.5	105.5	8.1
Functional food	60.1	64.6	92.3	7.4
Dietary supplements	58.3	62.6	87.2	6.9
Total	185.0	198.7	285.0	7.5

Nutraceuticals: Global Markets, BCC Research, 2017

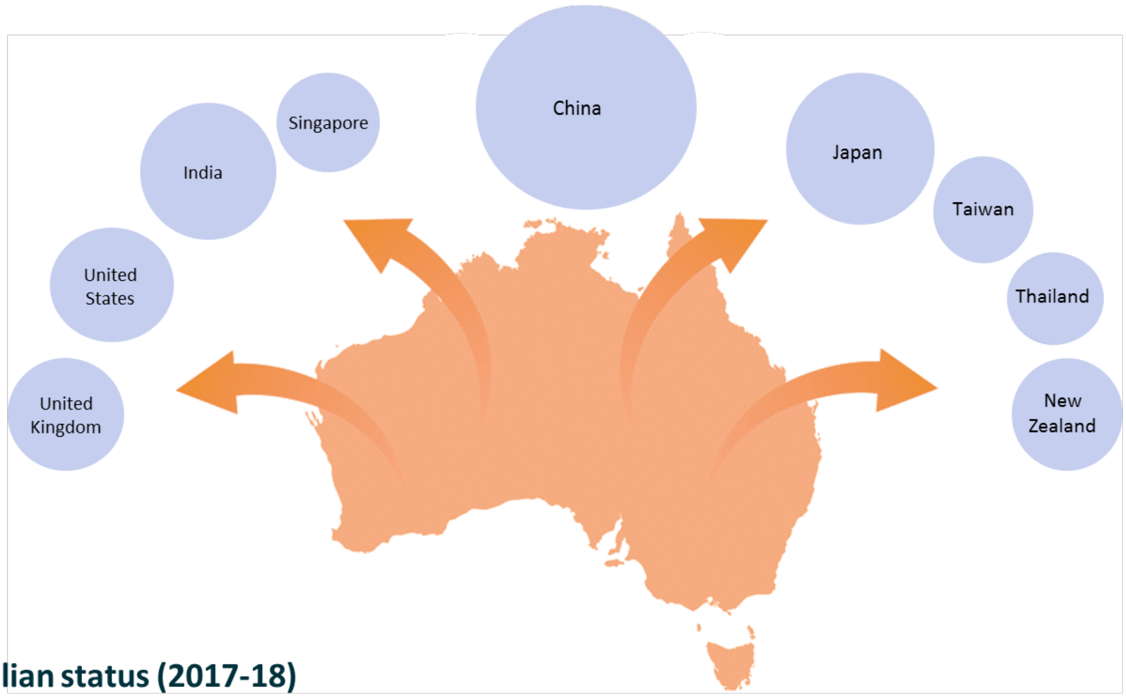
Figure 5. Examples of packaged foods containing nutraceuticals and global estimates of market size (Source: BCC Research, 2017).

Connecting Australian feedstock supply with demand for f&v ingredients

Chapter 1 has evaluated Australia's supply (8.72M tonnes fresh f&v per annum), as well as demonstrated that the current demand for f&v ingredients in selected export markets is significant and growing. The scale of opportunity was calculated by dividing the amount of ingredients that may be produced from fresh produce available in Australia (supply) by high level indicative sizes of the current market in selected countries (demand). Based on the available feedstock production, Australia has the potential to supply locally grown fruit and vegetable ingredients that account for 0.2% to 35% of selected domestic ingredient market demands, depending on the ingredient category. On a regional level, an example was calculated for Gippsland. As with other regions, Gippsland's current availability of fresh produce could satisfy a very small fraction (0.001-0.33%) of the demand for selected f&v ingredients for export markets. This highlights an opportunity to grow for marginal land for the manufacture of ingredients. In this case, appearance and physical characteristics of the fresh produce are not important as opposed to the fresh produce market.

1.3 Next steps and opportunities

Figure 6 shows some of the key opportunities and threats for Australia to become a key supplier of fruit and vegetable ingredients. Domestic revenue from Australian fresh f&v products in frozen or shelf-stable form has declined in recent times due to fierce competition from imports. However, a key outcome of this project is the identification of opportunities to increase growth in Australian f&v demand that are likely to come from the supply of a wide range of high value f&v ingredients. Currently, this opportunity is unrecognised within the Australian food industry, which does not manufacture premium f&v ingredients for applications in packaged food, beverages and nutraceuticals. This is especially so for ingredients outside shelf-stable and frozen categories. Chapter 1 includes a list of potential cornerstone customers for the hub and channels within Australia, although a more detailed market study is required to identify customers overseas.



Australian status (2017-18)

Opportunities	Threats
• Exports are increasing – processed fruit • Opportunity to diversify revenue and leverage momentum to Australian producers	• Imports: \$2.8B – increasing over increasing demand • Import countries: New Zealand, China, and USA • F&V industry declining – overseas competition • No apparent focus on manufacturing premium f&v ingredients for food (outside shelf-stable and frozen)

Figure 6. Opportunities and threats for the manufacturing of fruit and vegetable ingredients in Australia.

Analysis of the process needed to seize new opportunities to generate domestic and export revenues from fresh horticulture produce identified several gaps in market, product and consumer knowledge. Therefore, some of the key steps to progress a hub feasibility study may include the following strategies:

Market

- Effectively validating the domestic demand for Australian fruit and vegetable ingredients with greater level of granularity
- Further identifying key export markets for uptake of Australian f&v ingredients for beverages and packaged foods
- Defining the specific channels for selected value added ingredients into those markets, following preliminary ingredient prioritisation based on demands and strategic drive

Product

- Identify applications for Australian specialty f&v ingredients within existing commercial product pipelines
- Explore innovative formulations for beverages and packaged foods containing Australian f&v ingredients, especially those that leverage the health and wellbeing attributes of f&v ingredients demanded by the market

Consumer

- Understand in more detail the consumer trends (e.g., demographics) for products containing fruit and vegetable ingredients

2. Hub processing infrastructure and capital

A preliminary assessment was undertaken of the capital investment required for the infrastructure to establish a processing hub for the commercialisation of premium fruit and vegetable derived ingredients. This section covers the highlights of the financial information captured in Chapter 2.

The assumptions around this assessment were that the proposed hub will mainly focus on level 4 or specialist processing into key ingredients shown in Figure 7, including: whole material powders, fermented solids, fibre extracts, and non-fermented or fermented extracts in dried or liquid form as concentrates. Market segment examples of these type of products and their market growth dynamics in key local and export markets were defined in Chapter 1.

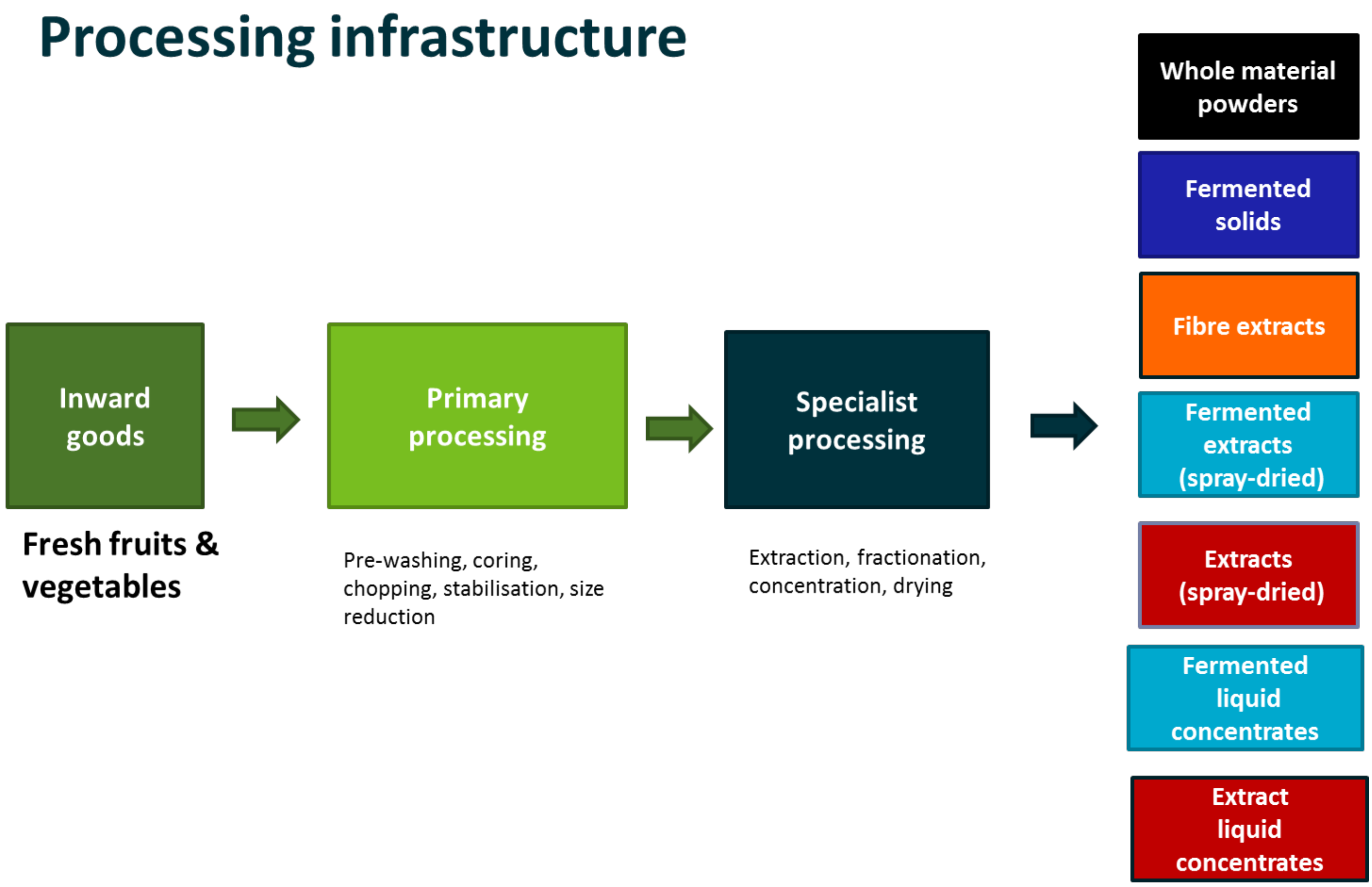


Figure 7. High level process flow diagram and generic ingredient options for the proposed fruit and vegetable manufacturing hub

The technologies considered for the hub are at mature stage of development and the equipment is commercially available.

2.1 Hub operation, infrastructure and processes

Given the further details required in terms of specific products to be produced in the hub and their markets, the current example assumes a feedstock push, rather than a market pull approach, assuming a processing capacity of 22,000 tonnes at maximum, based on typical equipment scales.

Table 1 summarises the infrastructure and operational costing for a regional hub example that processes up to 5 tonnes/h of fresh horticultural feedstock to produce specialist ingredients. The maximum capacity allowed for in the costing represents produce flows as generally managed by comparable, standard processing equipment. Assumptions for costing operational expenditure are covered in Tables 2 and 3. The timeframe to being fully operational assumes 1-2 years construction and commissioning from the third year. Even though it is envisioned that the hub will grow by adding processing modules with different technologies, a modular approach exercise is not included here. The income of the hub was estimated through the sale of specialty ingredients shown in Table 2, where the price was derived from market reports. In the case of less specialised products (whole vegetable powder and fibre) 25% of the market research price for non-wheat flours was assumed.

The annual revenue of the hub from the sale of the speciality ingredients was estimated at AUD 66.4M and the annual operating cost was estimated at AUD 45.8M. The equipment required in the hub to manufacture these ingredients was identified and costed as part of the capital investment.

Table 1. Indicative infrastructure and operational costing of a horticulture regional hub

Stage of Development	Parameter	Value
Construction and commissioning (Year 1 and 2)	**Building costs, services, infrastructure and working capital** **(incl. contingency of installed equipment costs 15%)**	AUD 24.8M*
Fully Operational (from Year 3)	**Maximum feedstock processing capacity**	22,000 tonnes
	Annual revenue	AUD 66.4M
	Annual operating cost	AUD 45.8M
	Net income (EBITDA)	AUD 20.6M

*assuming an initial period of 1 year for construction and up to 1.5 years for commissioning, depending on equipment selection

Using the study method of capital cost estimation with its ±30% error as a first approximation, the building costs, services infrastructure and working capital were estimated at AUD 24.8M and included a contingency of 15% of the installed equipment cost. Once fully operational, the total annual production costs were estimated at AUD 45.8M and included direct and fixed operating costs as well as contingency costs. Operating costs were estimated to include feedstock, utilities, consumables and labour, maintenance, and effluent treatment as direct costs. Other fixed costs were assumed to include indirect labour, plant overheads, insurance, laboratory costs and marketing of the hub. Approximately 72% of the operating cost of the hub is due to cost of feedstock material, while labour only accounted for 4% of the cost. The processing plant was assumed to operate for 40 weeks per year, 6 days per week and 3 shifts per day with 20 hours of production and 4-hours cleaning in place (CIP) cycle. The estimated net income of the venture before interest, tax, depreciation and amortisation was AUD 20.6M pa.

Table 2. Assumptions on product pricing and annual production

Products			
	t/year	AUD/t	Pricing
Whole vegetable powder (t/year)	435	26,299	25% of the average market research price for non-wheat flours
Fibre extract (t/year)	1463	26,299	25% of the average market research price for non-wheat flours
Solid fermented (t/year)	87	31,234	Pre/probiotic prices from market research
Fermented concentrate (t/year)	113	31,234	Pre/probiotic prices from market research
Fermented vegetable powder (t/year)	156	46,851	50% margin added to pre/probiotic prices from market research
Concentrated extract (t/year)	85	27,911	Average price of antioxidants/colours/flavours/proteins from market research
Extract powder (t/year)	13	41,867	50% margin added to average price of antioxidants/colours/flavours/proteins from market research

Table 3. Assumptions on operating capacity and capital costs

Operations	
Hours/day	20
Day/week	6
Weeks/year	40
Fruit and Vegetable produce processing rate (t/year)	22,000
Feed stock price ($/kg)	15
AUD:USD	1.3
Sales growth (% of plant capacity)	
Year 1	40
Year 2	60
Year 3	80
Year 4 – year 10	90
Year 11 Year 15	100
Operating expenditure	
Salary cost of operators ($)	50,000
Salary cost of supervisors ($)	80,000
Operator and supervisor on-cost (%)	40
Capital costs	
Lang factor for installed equipment cost	1.8
Capital cost contingency (% of installed equipment cost)	15
Services (Steam supply and distribution, electrical, auxiliary buildings) (% of fixed equipment cost)	12

Table 4. Indicative estimate of direct and indirect labour requirements to operate the hub

Direct labour	
Plant operators	18
Plant supervisors	3
Total direct labour	**21**
Indirect labour	
Plant overheads and administration (including General Manager)	4
Laboratory costs (including Quality Assurance)	5
Marketing and sales	5
Total indirect labour	**14**
Total labour	**35 (FTEs)**
Contractors	**13-18** Examples: Food technologists (2-3); Fruit and vegetable processors (3-5); Drivers (4-5); Other subcontractors (5)

It is anticipated that the operation of the plant would be managed by specialised food processing equipment operators and a plant supervisor per shift within an automated setting with interconnected equipment to a centralised control room (Table 4). Other plant staff, as well as staff in charge of purchasing, administration, management, sales, dispatch and logistics, are accounted as overheads costs.

2.2 Cash flow and profitability analysis

The projected cash flow of the hub was estimated based on the assumptions of sales income and expenditure over the life of the project, and initial capital expenditure. The profitability of the hub was assessed by projecting future cash flows and using the set of traditional financial parameters shown in Table 5 (see Chapter 2 for definitions). Estimates from the cash-flow and profitability analysis indicated a Net Present Value of AUD 93.1M over a 15-year life span with a 3-year payback period, indicative of good financial health across the period. Other financial profitability parameters below support a positive outcome from this investment.

Table 5. Profitability analysis for the hub infrastructure investment over a 15 year period

Net Present Value, NPV (AUD M) Cumulative cash flow less capital cost after discounted factor (10% discount rate)	**93.15**
Internal Rate of Return, IRR (%)[1]	**42%**
Payback Time, PBT (years) Without discounting	**3.0**
Return on Investment, ROI (%)[2] (without discounting, after interest payment)	**66%**

[1] IRR is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero

[2]ROI = (cumulative net cash flow/15 year)/total capital cost

2.3 Financial risk sensitivity methodology and forecasting

Chapter 2 also includes in this example the financial risk sensitivity methodology that enables evaluating considering multiple return scenarios. Following the infrastructure and operating costs assessment for the hub, a set of return-on-investment scenarios were modelled through a risk sensitivity analysis on profitability. The details of this work have been captured in Chapter 2.

The key variables considered for each scenario and each financial parameter are listed in Table 6. The analysis undertook over 5000 iterations using combinations of inputs of lower, expected and higher values of each risky variable and provided outputs for each financial criteria.

Table 6. Risk sensitivity analysis: effect of the possible ranges in target variables

	Low	Mean	High
Feedstock Price (AUD /tonne)	1200	1500	2000
Sales as a % of production			
Year 1	30	53	75
Year 2	45	63	80
Year 3	60	75	90
Year 4 – 10	70	85	100
Year 11 - 15	95	100	105
Product prices (AUD 000's/tonne)*			
Whole material (powder)	19.7	26.3	36.8
Fibre extract (powder)	21.0	26.3	39.5
Fermented (powder)	25.0	31.2	46.9
Fermented (liquid concentrate)	23.4	31.2	46.8
Fermented spray dried (powder)	37.5	46.9	70.3
Extract (liquid concentrate)	20.9	27.9	39.1
Spray dried extract (powder)	31.4	41.9	58.6

*Product prices: min – decrease by 25%; max increase by 40 or 50%

At this pre-feasibility stage of the hub, the sensitivity analysis of the estimated profitability parameters predict a positive financial health over a 15 year operating period. However, it must be emphasised that assumptions were made in order to estimate capital and operating costs (including cost of feedstock) as well as to estimate product sale volumes and prices. The sensitivity of the profitability of the proposed hub to individual risk variables is summarised in Table 7 including the net present value, the internal rate of return, the pay-back time and the return on investment.

Table 7. Indicative sensitivity analysis of the profitability criteria of the hub.

Parameter	Low	Medium	High
NPV (AUD, $M)	-98	77.9	254
IRR (%)[1]	-27.1	39	112
PBT (years)	1	3.1	6
ROI (%)[2]	-44	58	157

[1] IRR is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero

[2]ROI = (cumulative net cash flow/15 year)/total capital cost

A tornado plot may also be used to rank each variable by their level of influence on a certain operational criteria, here profitability, and assesses the expected range of the impact on profitability. The tornado plot in Figure 8 suggests that the volume and cost of some of the speciality products manufactured by the hub will, not unexpectedly, influence hub profitability. In this analysis, fibre extracts may have the greatest impact on hub profitability over the period examined, compared with that of other hub speciality products, powders and fermented extracts.

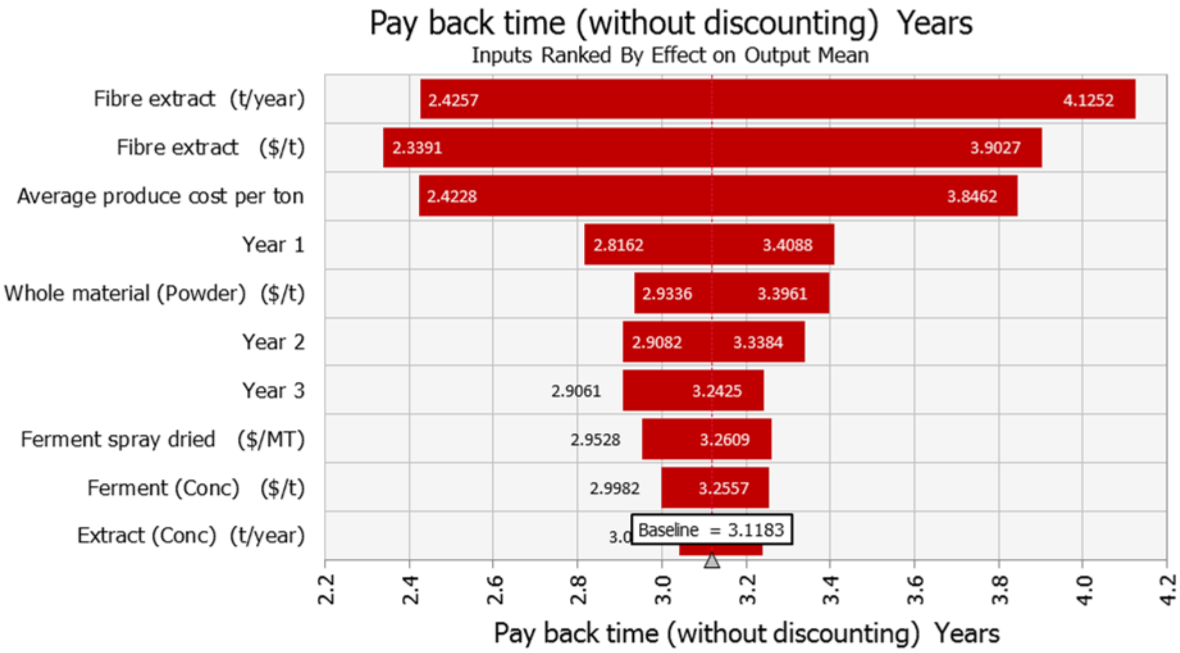


Figure 8. Sensitivity of hub profitability (as measured by pay back time) to changes in variables considered risky, including feedstock cost, the price and volumes of ingredients produced, and plant utilisation rate during Year 1, 2, 3 and 4-10. Extract (Conc) and Fermented (Conc) refer to extracted and fermented concentrates.

The data gathered here is anticipated to provide inputs for a decision tool to be implemented later in the feasibility study. The tool has been already developed by CSIRO and includes decentralised and centralised facility location optimisation tools. The suppliers' locations and feedstock inputs, candidate locations for intermediary processing facilities, and candidate locations for the hub, are included as inputs or output flows, while combining with other financial information. The output model will provide a map of logistics and more detailed information on the geographic and financial scenarios from the choice of specific ingredients and market demand information.

The economic evaluation and financial projections are based on assumptions and are only a guide and not definitive. While the authors believe that the figures presented are indicative of the projected financial performance of the hub, no guarantee, either expressed or implied, is provided for their accuracy. CSIRO is not a licensed financial advisory entity, and as such, further independent financial advice should be sought before any investment is made.

A similar methodology can be used to determine next steps in the actual feasibility study once specific products and their volume demand are determined.

2.4 Technologies for Industry 4.0

The hub will also comprise integrated technologies for Industry 4.0. Modern information and communication technologies like the cyber-physical system connecting growers to the hub and capturing logistic and production data, big data analytics and cloud computing, will help early detection of defects and production failures, thus enabling their prevention and increasing productivity, quality, and agility benefits that are anticipated to have significant competitive value. These technologies may be a critical component for the long term success of the hub, given the potential toll processing requirements based on various needs, diversity of raw materials processed, and range of finished products delivered to various markets. As such, the hub will also be represented virtually through digital plant models with sensor data and will be able to make decentralised decisions. A list of potential suppliers and developers of integrated technologies for Industry 4.0 (advanced manufacturing linking), some of who provide Internet of Things (IoT) platforms, as well as a case study, is included in Chapter 2. The equipment to be implemented is off the shelf scale equipment and will enable applying innovative proprietary technologies.

2.5 Next steps and recommendations

The current pre-feasibility study was carried out with a high level estimation using the study method of capital cost estimation, which provides a ±30% error as a first approximation for the building costs, services infrastructure and working capital. A more detailed feasibility study for the proposed hub will require a more accurate definition of the target markets to inform decisions around selection of the specific ingredients to be manufactured, to enable estimating volume demands and final product pricing.

As such, the availability of fresh fruit and vegetable feedstock in the region will be refined, according to a specific set of participants. By knowing the specific ingredients required for the B2B operation, the specific unit operations required along the primary and specialty processing steps will be more accurately defined. More specific details on feedstock and equipment will provide a more detailed approximation on equipment prices as well as direct and indirect costs. Estimates of income will also be more refined by establishing a more accurate set of pricing ranges for the specific potential products. A shortlist of products to be included in the manufacturing hub's planning pipeline for market delivery in the short and long term will improve the accuracy of these estimates.

3. Hub value-chain business models

Chapter 3 examines the company structures and business and operational models as options for a dedicated business venture with technical capability to manufacture specialty fruit and vegetable ingredients. The strategic vision of the venture may be described in the following example:

“The core business is to extract more value from fresh horticultural produce as premium ingredients for the food, beverage and nutraceutical industries, on behalf of shareholders, members or other stakeholders”

3.1 The venture

Traditional horticultural value adding is generally based on value-adding fresh produce to varying extents: by washing and packing, to the preparation of ready-to-cook or ready-to-eat products (levels 1, 2 or 3 processing, respectively) (Figure 9). A successful manufacturing venture will take value adding of fresh produce a step further to the extraction of oils, bioactives, proteins etc as a level 4 processing type business for the manufacture of fruit and vegetable ingredients (Figure 9). In this way, revenue for the new venture is proposed as generated from a core business that includes the production of value-added products leveraging proprietary technologies.

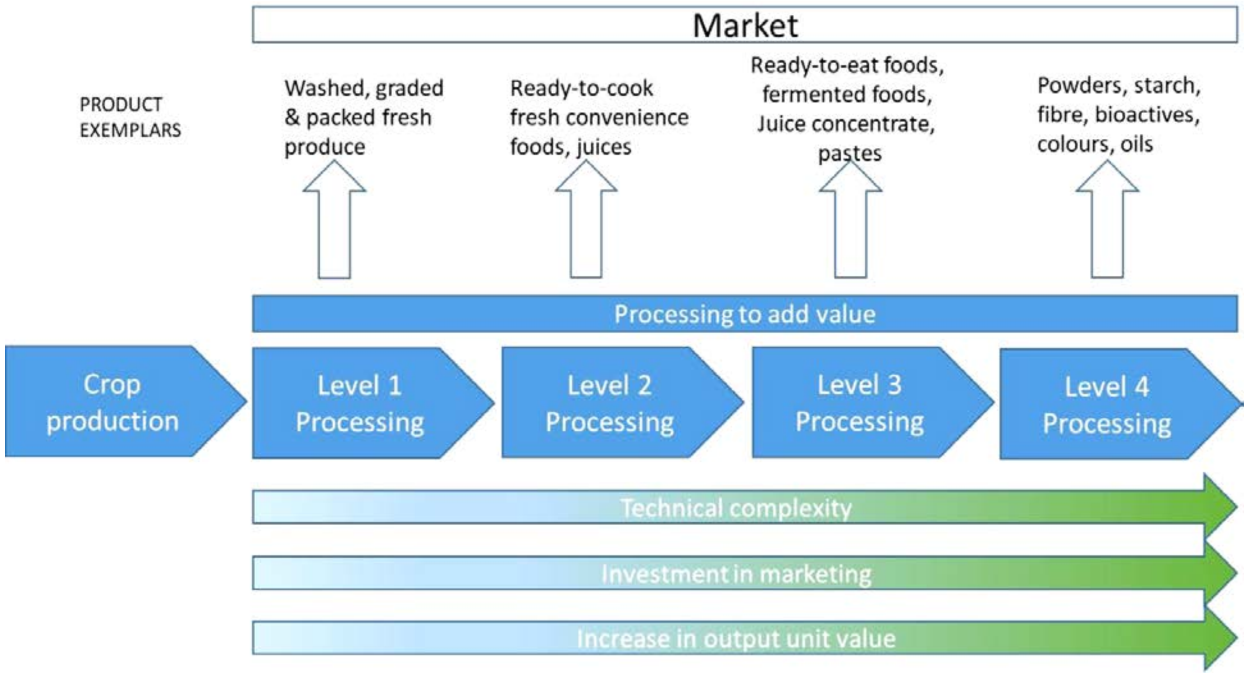


Figure 9. An indicative value chain for the vegetable industry. Prospects for value-adding feedstock streams by means of level 1 to level 4 processing, each with product exemplars as indicative outputs.

The core operations of the proposed manufacturing hub venture are listed in Figure 10, including (1) sourcing fresh produce from nearby suppliers, (2) aggregation of the fresh produce and potential stabilisation, (3) pre-processing of incoming produce, and (4) level 4 processing to manufacture fruit and vegetable ingredients. Subsequent parts of the core operations of the business include quality assurance, packaging, storage and sales. emonitoring across the chain can potentially be provided through Industry 4.0 information technology infrastructure.

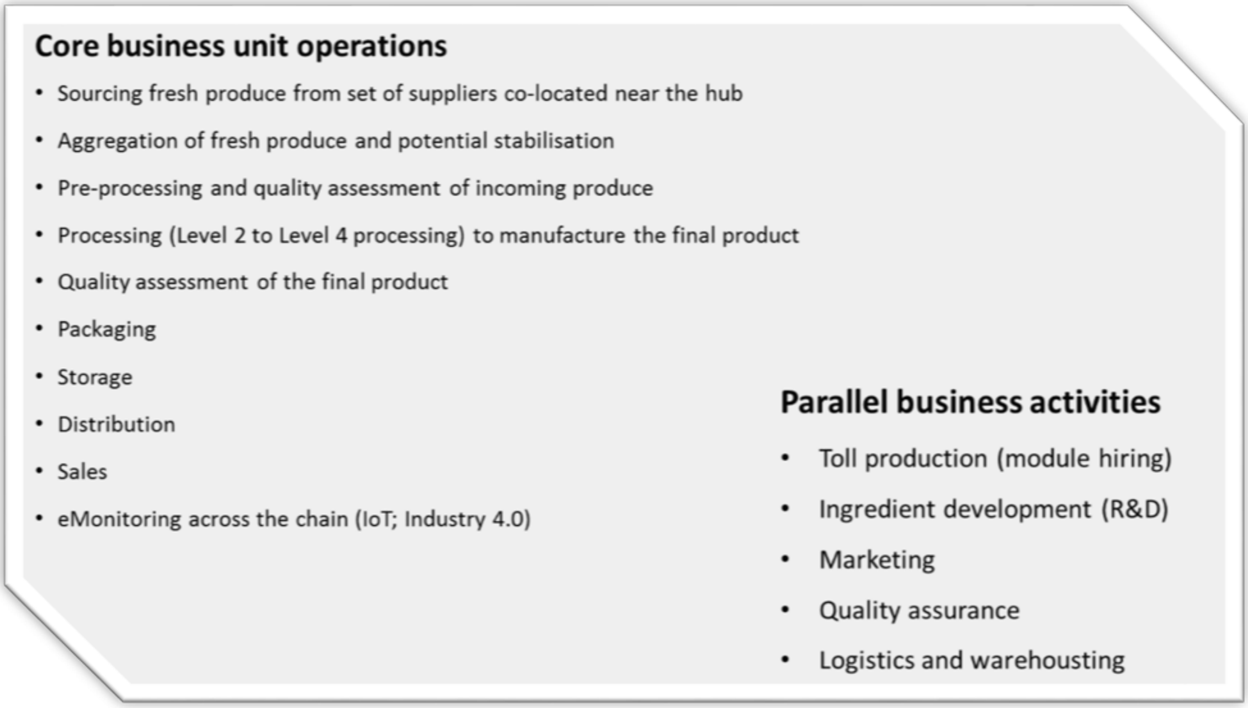


Figure 10. Core business unit operations and parallel business activities that define the hub's operational model.

There may be parallel business activities for the proposed venture in toll production for client companies who need access to specialised manufacturing modules to generate samples of innovative food products for market testing. In addition, toll processing facilities are often contracted when client companies do not have the capital infrastructure to enable commercial-scale manufacture. In this way, the commercial development of innovative ingredients, in particular, often is unable to progress due to the lack of available infrastructure. For example, the commercialisation of CSIRO patented encapsulation technology Micromax®, which provides the opportunity to stabilise oils and a means of adding liquid oil ingredients into various beverage or package food applications, required access to toll processing to determine the commercial feasibility of the technology as well as providing quantities of product for market testing purposes. A toll processing example is Hellay Australia, who offers contract manufacturing and packaging for the production of vitamins, functional ingredients, and specialty premixes.

The proposed manufacturing venture is based on agricultural feedstocks, and periodic downtime based on the seasonality of the feedstock is expected. This downtime, while facilitating equipment maintenance, also may enable the opportunity to commercially leverage the venture's excess capacity. Therefore, the seasonality of agriculture-based production may provide the opportunity to generate additional revenues by means of contract services to external parties.

The regional hub may also provide services to other client companies in the region on ingredient development (R&D), marketing and quality assurance, should this be assessed as a requirement for the region. Those service contracts are proposed to leverage the skills, capability and capacity of the venture/hub in commercial scale manufacturing, as well as supply chain management, quality assessment and reporting, quality certification, packaging (bulk or specialist packaging warehousing and storage), pre-processing of fresh produce, and logistics and distribution. The hub also brings opportunities to work in collaboration with CSIRO's Food Innovation Centre for pre-commercial development of target ingredients and novel background technologies to extract, concentrate, separate, stabilise and deliver such ingredients.

A recommendation of this report is that the proposed new business venture considers marketing the speciality ingredients on a business-to-business basis (B2B) rather than on a direct to consumer or retail basis (B2C). This is mainly because the venture can make use of longer sale cycles and longer term contracts offered by B2B sales, and often at a fixed price. This long term revenue may enable the new venture to make financial plans, thereby allowing future expenditure planning and returns to shareholders.

The proposed venture may be structured as either a centralised or decentralised operation. Having all manufacturing steps (from pre-processing to finishing) and warehousing in one location can reduce production cost per unit, while using the same equipment for different products. Centralisation can also improve efficiencies on raw material turnover and production scheduling. However, a decentralised company splits out its unit operations from within an overall production process or distributes entire production lines to different locations or regions. Drivers for decentralisation may include seasonal availability of feedstocks, availability of highly skilled personnel in specific location, and logistic and financial decisions on aggregations and pre-processing operation closer to fresh produce supply.

Chapter 3 illustrates the option of decentralisation with a case study example of GLK Foods, a US-based company producing sauerkraut from fresh cabbage. The company owns two factories in key growing regions; however, pre-processing (coring and chopping) in more distant cabbage-growing regions occurs by using mobile facilities to minimise transport costs.

3.2 Corporate structures of the venture

From a risk management perspective, the most suitable corporate structures for the proposed venture include that of a proprietary company, incorporated co-operative or join venture, defined in Chapter 3. From the perspective of the investors or members, an incorporated structure may provide risk management benefits. Specialist legal and tax advice should be sought when identifying an appropriate structure. Chapter 3 provides case studies of proprietary companies, co-operatives, and joint ventures as illustrations of the commercial sustainability and capacity to generate revenues of these types of corporate structures. For example, Norco Co-operative Limited is provided as an exemplar both of an enduring agribusiness co-operative as well as the value of the joint venture in the agriculture sector.

Norco is a 100% Australian farmer-owned dairy co-operative with 326 active members on 220 dairy farms in northern New South Wales and southeast Queensland. Norco actively manages its membership and only admits new members to match contract and other revenue opportunities. The Norco co-operative built the business over time by means of a series of strategic acquisitions to expand the footprint over which milk supply was aggregated. Those strategic transactions also included building value-adding and processing capability in new products (e.g., acquisition of ice cream manufacturing from other dairy co-operatives), a JV with a US manufacturer, and diversifying product offering by acquisition of agricultural businesses.

3.3 Assessment of risks

The risks involved in establishing a venture that manufactures new value-added vegetable-based ingredients were also considered.

The key areas of risk identified for the proposed fruit and vegetable ingredients venture are associated with the venture's initiation, financial and business execution risk, and market delivery and expectation. Chapter 3 considered that some of the risks identified may represent "stop-go" points in the decision by the investor to progress a commercial, value-adding venture. In particular, those risks may include: financial risk, market pull, market dynamics, differentiation, offtake agreements, and seasonality. A second deliverable within Chapter 3 is the set of recommended mitigation strategies to manage each identified risk, which are summarised in Table 5. The specifics of these risks and mitigation strategies will be further developed during the hub's feasibility stages.

Table 5. Key business risks and strategies to mitigate, manage or avoid those risks

Risk	**Key mitigation strategy**
Failure to launch	Robust business plan completed and verified
	Alignment between key venture participants
	Economic scale of production defined
	Market pull for final product confirmed
	Engagement with customers and suppliers established
Financial failure	Sound economic analysis to support the project completed and verified
	The detailed requirements of investors are met
Failure in business execution	Professional business managers are recruited and retained
	Clear timeframes for delivery of defined milestones are provided to managers
	Robust corporate governance established
	Culture of the business (board, management and staff) with the goals and expectations of owners, investors, and/or shareholders are aligned
	Formal contracts (eg offtake, supply, cooperative, JV etc) are secured
	Supply chain is protected
	Seasonality is managed with feedstock flexibility and/or feedstock- or application-flexible equipment
	Technically-skilled staff & managers are recruited; local staff trained/upskilled; ongoing budget provided
	Investment in market trend research & customer relationships is budgeted
Market Delivery/Expectation	Market trends actively monitored
	Investment in product quality and differentiation is ongoing
	Relevance and responsiveness to market dynamics and changing expectations into the business culture

3.4 Hub ownership models

A review of the ownership structure of companies suggests that a broad scope of arrangements and combination of arrangements can be set up for the venture: proprietary, public, co-operative, partnership control, leasing, regional, government (national or state), and employee ownership or employee stock ownership plans (ESOPs). The choice of ownership model for this project is anticipated to be one that delivers maximised returns, and, depending on the purpose for which the venture is established, sustainability over longer term. However, how various ownership models maximise returns depends on strategic vision of the enterprise, management and governance structure, the availability of finance, the treatment of surplus, regulation, and other factors.

A description of each ownership model is included in Chapter 3, by comparing the models across key features: business ownership, business control, asset ownership, cost control, management responsibility (e.g., operation, administration, services, sales, contracts and leasing), revenue management, and investment.

At this early stage of assessment, it is difficult to establish or even recommend an appropriate ownership arrangement of the hub without first identifying key investors and participants. Furthermore, decisions on the ownership model selection for return maximisation need to be combined with decisions on the strategic vision of the enterprise, the management and governance structure, the availability of finance, the treatment of surplus, regulation, and other factors. Participants in business ownership in any of the models reviewed are represented in Figure 11.

Value chain	Supply of fresh produce	Aggregation	Specialist processing	Finished product
Participants in value chain operation	Grower	Grower/aggregator Aggregator	Specialist processor	End-user Customer
Investors and/or Business owners	Grower, Grower/aggregator, Aggregator Specialist processor End-user, Customer Local and regional government State government Federal government Corporate investors (agribusiness, real estate, crowdsourcing, development banks) Private investors			

Figure 11. Potential roles of value chain participants or external investors in selected ownership models in a hub venture that manufactures specialty fruit and vegetable ingredients.

It is recommended that to facilitate the manufacturing hub venture, consideration be given to the motivation for investment and the investors' long-term goals and ambitions for the venture. The examples shown in cases studies may be used as guidance: the Dalby Biorefinery (proprietary or public ownership model), Norco (co-operative model), Biopharmaceuticals Australia (leasing model and state-owned entity) or Mackay Renewable Biocommodities Pilot Plant (anchor ownership model). Table 6 provides a summary of these case studies

Table 6. Comparative summary of ownership models

Case study	**Dalby Biorefinery**	**Norco**	**BPA**		**Mackay Renewable Biocommodities**
Ownership model	**Proprietary**	**Co-operative**	**Government**	**Leasing**	**Regional**
Business ownership	Subsidiary of United Petroleum Pty Ltd	100% Australian farmer-owned by 326 members	Government fully owns BPA as a Proprietary company. One government shareholder.	Government owns infrastructure	Queensland University of Technology (QUT) as anchor institute
Business control	Owner (United Petroleum)	Members have control through a representative Board and professional managers	Government delegates control to professional managers	Business control is delegated to professional management company that negotiated lease with specialist manufacturer	Queensland University of Technology (QUT)
Asset ownership	United Petroleum	Members	Government owns infrastructure and some equipment	Government owns infrastructure and some equipment	Queensland University of Technology (QUT),
Cost control	United Petroleum	Members, or by means of professional managers appointed by Board	Corporate executive team (rather than public servants) are responsible for economic decision-making	Specialist manufacturer operates the facility	University employees as professional managers
Management responsibility	United Petroleum i s responsible for strategic and operational decisions	Members, by means of professional managers appointed by Board	Corporate executive team (rather than public servants) are responsible for economic decision-making	Specialist manufacturer operates the facility	University employees as professional managers
Revenue management	United Petroleum retains all revenue	Members have both direct and indirect financial benefits including income distribution and cost reductions	Government benefit i s intangible: achievement of strategic goals	Specialist manufacturer pays rent to investors, while retaining net revenues.	University provides operational funding to supplement contract revenues
Investment	No external investors	Limited access to external investment	No external investors	No external investors	No external investors

The number of potential investors and the investment of quantum per investor need to be defined at project outset. The extent of legal ownership of the venture required/desired by the investor, as well as the level of control of the business, needs to be determined.

The role of governments that may invest in the project at initiation or during expansion phases must also be established as well as and their ownership position in the venture. The level of return on investment must be determined and agreed in the case of multiple owners/investors. Furthermore, the need for future financing must also be considered in the return on investment equation.

While this chapter has outlined various ownership models, from corporate, co-operative to alternative structures, further detail is required to determine the optimal ownership model for this project. Specialist legal, financial and tax advice will be required.

3.5 Hub governance models

Chapter 3 also includes the governance frameworks and practices associated with options for businesses operating for the specific ownership models mentioned above.

There are defined structures within a business to support good governance and risk management. The composition of boards and number of board members, as well as the structure and composition of board oversight committees, underpin the governance culture within a business. Many boards have a composition largely representative of the company's owners or investors. However, companies tend to include a small number of external directors to bring independence of thought, additional relevant skills and experience, and reduce conflicts of interest to board deliberations on behalf of all investors and stakeholders (Figure 12).

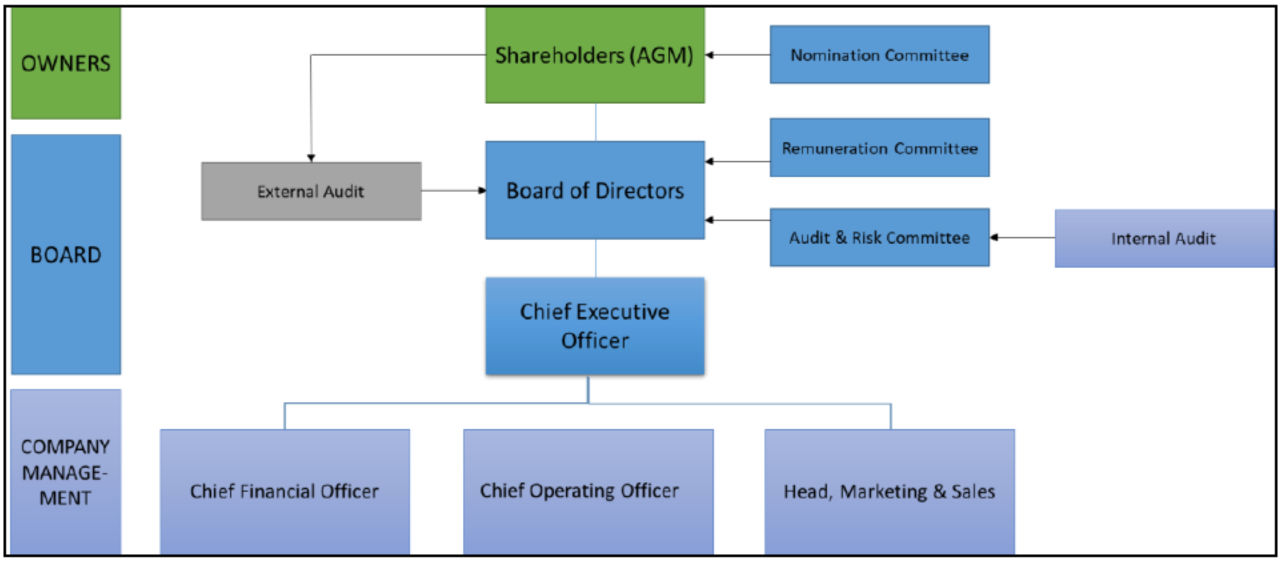


Figure 12. Indicative governance structure of a company or co-operative.

A strong governance framework and practices need to be established at the outset of the venture, to protect owners' assets and to deliver long-term business sustainability. The ideal governance structure will have an element, at least, of independent oversight, provide mechanisms for owners to have input into strategic decision-making, and to receive financial and performance reporting from business operations.

In addition, engagement of professional management is essential to impart flexible and responsive business practices or "plasticity in business structure" to commercial hub operations. From the establishment of the commercial venture, both the ownership and framework within which management operated need to be clear in terms of objectives and timeframe of execution. The reporting structure similarly needs to be defined at the outset of the venture: the CEO reported to the shareholders through the Board.

The creation of sustainable long-term value on behalf of all owners and shareholders is considered the ultimate measurement of successful corporate governance.

3.6 Hub competitiveness analysis

Chapter 3 examined the long-term competitiveness of the hub in the international context, including product differentiation opportunities to ensure competitiveness. At this current pre-feasibility stage, Chapter 3 lists the key metrics of sectorial competitiveness on a high level context.

Even though Australia has a high global competitiveness ranking, its ranking has slipped over recent years as that of other nations improved. Australia has shown a decline in economic performance, and government and business efficiency. Furthermore, key Australian fruit and vegetable export markets such as APAC and the UAE are intensely competitive and price-driven. Improving the competitiveness of a hub that delivers specialty ingredients in such environment will require a sectorial approach. Sectorial competitiveness of the venture includes addressing key metrics on branding, provenance and traceability, supply chain control, veracity of product specifications, critical scale of production, industrial R&D strength, transparency and stability, access to the Asian market, and support infrastructure.

3.7 Next steps and opportunities

Further work is needed to refine the decision on company structure, based on, at least: (a) the availability of a keystone participant from within or outside the horticulture sector, (b) the level of interest from a number of aspiring growers as co-investors in a company or as members of a cooperative, and (c) the level of interest of a specialist processor or customer as a joint venture partner.

A detailed financial model evaluating the decision-making on the optimal business configuration, as well as the cost-effectiveness of subcontracting operational units (such as specialist processing, marketing, packaging, etc.) needs to be carried out during detailed feasibility study. The venture needs to consider whether the skills and capabilities needed for each unit of operation, may be developed in-house, provided to the business by means of a sub-contractor, accessed by means of a collaboration such as a joint venture or partnership, or by acquisition.

As mentioned, a more detailed feasibility assessment will determine a specific set of fruit and vegetable ingredients for key national and export markets. In doing so, more concrete measures to mitigate risks as well as drivers for competitiveness on a specific Australian region can be established to inform regional strategies.

4. Regional benefits provided by the hub

Chapter 4 provides an economic impact analysis for the proposed establishment of a horticultural food-processing hub in regions across Australia. A case study of Gippsland, Victoria is provided as an example.

This activity aimed to capture the spillover effects of the regional food manufacturing hub. The economic impact case study covers three main components: 1) direct capital expenditure on its creation, 2) current expenditure on the operation of the hub, primarily on wages and salaries as well as farm incomes and 3) the flow-on effects of both areas of expenditure on the wider economy. The evaluation focused on the impact on a single particular region, but also the expected effects that are generated at a national level. Gippsland in the state of Victoria was studied as a representative region of Australia, taking up 21% of Australia's fresh produce production and 9.1% of Victoria's production.

The proposed hub would have five main impacts on regional income: the initial capital expenditure (equipment, building and construction costs etc.), the ongoing income that would flow to farmers supplying produce, additional operating costs (labour, maintenance, hub marketing, laboratory costs, water, electricity, packaging etc.), expansion of farming to supply the hub by including new entrants, and multiplier effects that would flow across the general Gippsland community. The analysis of regional benefits based on the Gippsland case study are anticipated to be relevant to other horticulture regions, and potentially other agricultural regions more generally, within Australia.

4.1 Impact of direct expenditure

Estimates of the capital expenditure required to build and operate the hub were divided into those expenditures concentrated in Gippsland and those expended elsewhere. The Australian Bureau of Statistics Input-Output tables were used to apportion capital and operating expenditure to Gippsland and elsewhere in Australia.

In the capital cost phase, for instance, it is anticipated most of the equipment would be purchased from other parts of Australia or from overseas. Installation and building costs would mostly be concentrated in the region. Deducting the equipment costs from the total capital costs leaves AUD 14.2M, the bulk of which may be undertaken in the region.

The bulk of operating costs would be incurred in the region, showing that typically approximately 46% of inputs are in the form of (local) agricultural-related inputs and 20.5% include compensation of (local) employees. In addition, while transport and wholesale trade are important, around one-half of this expenditure would be incurred outside of the region.

4.2 Indirect economic effects on the region

The indirect production effect for these supplying industries is known as a *multiplier*, where each dollar spent on the output of one industry leads to output increases in other industries. For example, expenditure on food processing requires inputs of produce, energy, communication services and so on. A multiplier of up to 2.0, acceptable to the Australian Treasury for use in economic assessment, was converted to a total value of about AUD 28m in the capital expenditure phase (AUD 14M x 2.0) and then from zero up to AUD 74M per annum (AUD 37M x 2.0), when the hub operates at full capacity. Overall the annual impact of the hub on the Gippsland regional area is estimated to be around AUD 74M per annum or around 1.5 to 2.0% of the Gross Regional Product of the region. This in itself has the potential to make a significant contribution to the economy of the region, although it must be noted that the contribution to the country as a whole may be far less. That said, if successful, the Gippsland case study will be applicable to other locations, which means that the contribution of value-adding fresh agricultural or horticultural produce to a national benefit might be significantly enhanced.

Depending on the final corporate structure of the proposed hub, profits generated from the hub may flow to regional shareholders (i.e. growers), and then multiply through local communities. Another impact not measured by the multiplier effect, is the potential increase in entrepreneurial activity in the region that such a hub is likely to create. Such a hub may stimulate the creation of new micro and small enterprises, which may generate further employment opportunities, particularly for the young, and disadvantaged.

4.3 Employment

In terms of employment, the proposed hub may create a range of jobs including plant operators, plant supervisors, food technologists, administration, finance and marketing personal, fruit and vegetable processors, drivers, and other subcontractors. Some of these skills are in short supply in the region (i.e. food technologists), however in many cases, members of the existing local workforce could readily retrain to fill operational positions. As shown earlier and in Chapter 4, 35 workers would represent direct labour (operators, plant supervisors, administration and general management, laboratory and quality assurance, marketing and sales). Labour outsourced as contractors would represent an additional 13-18 positions associated with transport work, food technology research providers, drivers and others. Furthermore, the local economy of Gippsland would gain additional employment of an estimated 50 people from the flow-on effects of income generated and spent from and by the hub. These jobs would be spread over a range of industries, including the horticultural, retail, transport, and services sector more generally.

4.4 Next steps

Further detailed studies will be required to understand the social and community benefits in the region as a results of the hub's creation as well as the nature of upskilling achieved or increase in construction jobs. A more detailed feasibility study will also evaluate the attraction of specific collateral businesses to the region, through exemplars on particular case studies.

Key findings

- There are a myriad of opportunities to value add to existing horticultural crops to generate commodity and specialist ingredients for the food markets both nationally and internationally. We have identified the major markets and determined the growth potential for specialty horticultural ingredients both in Australia and in major Australian export destinations in Asia-Pacific. Specialty ingredients showed higher price per volume.
- The analysis of the opportunity is based on the existing horticultural production in the region used as case study. The case for horticultural produce that is grown-for-purpose for value-adding is discussed.
- Value-adding of horticultural produce is considered an initiative with potentially national application. The proposed hub may be located in any region or regions of Australia that are positioned to provide sufficient fresh produce as feedstock to be commercially viable.
- A preliminary capital infrastructure and operating cost assessment for the hub was built as an example by considering the unit operations to manufacture the above-mentioned ingredients in a hub receiving up to 22,000 tonnes pa. The example predicted good financial health for the hub over a 15 year period.
- A strategy for business to business (B2B) market positioning is recommended for clearer financial planning and stakeholder forecasting for the hub venture. The project shortlisted a set of potential ownership arrangements, including a proprietary company or public limited company, co-operative ownership, partnership contract, anchor, leasing, and government- or employee-owned models.
- The major business risks for the hub venture were identified and analysed. Some key risks that were highlighted, include: (a) failure to launch, (b) financial failure, (c) failure in business execution, and (d) failure in market delivery or in meeting market expectations. Strategies to manage, mitigate or avoid the identified risks were outlined.
- An economic impact analysis for the proposed establishment of a processing hub in horticultural food producing regions across Australia reflected on the flow-on benefits to the wider economy, both regional and national. Economic benefits may include diversification of grower revenues, sustainable employment in a new manufacturing sector, at least, and creation of new export markets for Australian products.

Next steps

The next steps in this project are to refine assumptions, extend the analysis and build the necessary commercial relationships to enable the manufacture of market-ready, value-added food and ingredients from fresh horticultural produce.

Therefore, the recommended next steps are:

- Feedstocks: extended analysis of horticultural feedstocks available to a candidate regional hub and portfolios of potential manufactured products that may be derived from those feedstocks;
- Engagement with potential specialty f&v ingredient customers, investors, and other stakeholders to refine a commercial product portfolio;
- Product definition and performance metrics, undertaken with customer input;
- Market data: extended market analysis of target product candidates;
- Economic modelling: refine existing models based on new production scenarios and products;
- Regional benefit: based on refined production and financial models; and
- Business model for hub operation: based on stakeholder input.

The implementation timeline includes a construction and commission phase, followed by the hub operation on a commercial footing. Conservatively, our estimate is that 2 years is required to secure a commercial contract for each new product.

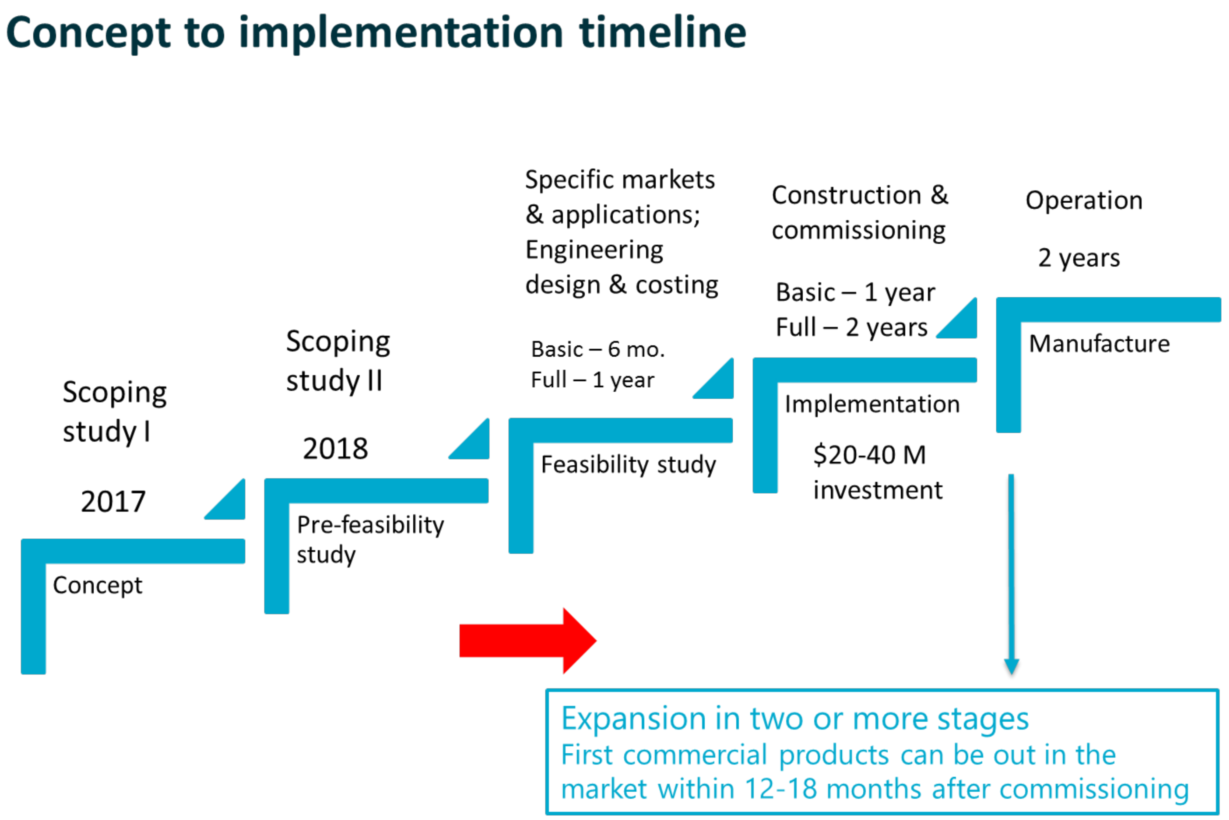


Figure 13. Concept to implementation timeline for a food manufacturing hub. The red arrow indicates the current stage of development of the hub concept after this pre-feasibility study. As staged approach will need to be considered for the Feasibility study.

Glossary

B2B	Business to business model in which a business supplies a goods to another business.
B2C	Business to Consumer model in which a business supplies final product directly to retailers or directly to consumers.
Bioactive	Substance or compound having positive effect on human health, beyond basic nutrition (e.g. enzymes, vitamins, antioxidants). The bioactive compound may be considered a nutraceutical ingredient.
Commodity Ingredient	Bulk, high volume, low value products.
Concentrate	Liquid food resulting from the water removal by evaporation
Dietary Supplement	A product that contains one or more nutrients or bioactive ingredients such as vitamins or amino acids that are intended to supplement one's diet or address a deficiency.
Fibre extract	Product resulting from the extraction and separation of dietary fibres from fresh produce (such as vegetables), transformed into a powder and added to a food or beverage.
Fermented product	Food (eg milk) undergoing a fermentation process following the addition of yeast or bacterial cultures to preserve or add nutraceutical value (eg yogurt).
Functional food	Food with nutraceutical (health-driven) attributes
Nutraceutical	Bioactive ingredient offering health benefits beyond basic nutrition (e.g., antioxidants, vitamins, or enzymes).
Prebiotic	A non-digestible food ingredient (similar to fibre) that promotes the growth of beneficial microorganisms in the intestines for gut health.
Probiotic	A product containing microorganisms such as *Lactobacillus* to maintain or restore beneficial bacteria to the digestive tract.
Specialty ingredient	Low volume, high value ingredient, usually requiring high degree of specialised processing. Examples include bioactives, colours and flavours (see examples in Figure 2a).
Spray dried product	A powder that results from the removal of most of the water content from the original product using evaporation technologies.

Feedback from the Industry Steering Committee

Following recommendations from Hort Innovation, an Industry Steering Committee has been formed to support uptake of the concept in various grower clusters across the country. The following members of the Industry Steering Committee are now in possession of the report:

- Dr. Nicola Watts, East Gippsland Food Cluster
- Dr. Steve Lapidge, Director Food Innovation Taskforce, Primary Industries and Regions South Australia – PIRSA
- Dr. Georgina Davis, Queensland Farmers Federation
- Dr. Steve Tiley, Hort360 Innovation Coach, Growcom

Acknowledgements

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Feasibility options for an innovative food manufacturing hub

Chapter 1. Market opportunity for value added fruit and vegetable ingredients

Contributors: CSIRO and Monash Food Innovation Centre

Citation
Deane J, Andres M, Juliano P, Achariya A, et al. (2018) Market opportunity for value added horticultural products. CSIRO, Australia.

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Contents

Executive summary

Major opportunities abound for premium Australian fruit and vegetable (f&v) ingredients, particularly in Australia's key agriculture and food export markets of Asia Pacific (APAC) and the Middle East. F&v ingredients are commonly utilised in the beverages, packaged foods (e.g. baby foods, baked goods, confectionery, savoury snacks ready meals, breakfast cereals, etc.), and nutraceutical categories. High growth is expected in these categories in several countries.

Consumer health and wellness trends are expected to raise the profile and demand for f&v ingredients in both local and international markets, as horticulture products are valued for nutritional and health benefits and the perception of such these ingredients as 'natural'. This is creating opportunities for growth through new and innovative products. Australia for example is one of the most lucrative markets for naturally healthy foods and plant-based products[5].

More than 1500 new products were launched in Australia between 2015-2016 with vegetables as ingredients. Of these products, 5% were fresh or frozen vegetables and the other 95% were dips, spreads, dairy, bakery, ready meals, beverages, pet food, and others, which brings enormous potential for f&v ingredients.

The Gippsland region is a prime example of a region well positioned to grasp this opportunity. Its advantageous climate conditions, availability of agriculture land and proximity to consumers, transport infrastructure and local food manufacturers makes it a good candidate for processing horticulture products into higher value produce.

Key highlights

Current state of industry in Australia

- Exports of processed fruit and vegetables are a key source of revenue for many local f&v processors, accounting for 49.2% of revenue and under 27% of the total volume produced. The value of exports has increased strongly over the past five years as larger players have aimed to serve the growing populations and incomes of the growing middle class in Asia and the Middle East[1].
- Revenue of Australian processing f&v has declined in recent times due to fierce competition from overseas[1]. *Opportunities to increase growth are likely to come from increasing scale of production, or a mix of high value products and ingredients.*
- *Currently, the Australian food industry does not focus on manufacturing premium f&v ingredients for applications in packaged food, beverages and nutraceuticals.* This is especially so for ingredients outside shelf-stable and frozen categories.
- Australia is a lucrative $41B market for packaged foods containing premium f&v ingredients. F&v ingredient consumption has an estimated growth of 6%. Other growing source of revenue include beverages.

Forecast on fruit and vegetable ingredients in APAC and the UAE

- High growth in some of Australia's major export markets is expected for the use of f&v as ingredients, into products such as packaged foods, beverages, and nutraceuticals. For example, a

$157B (16.8m ton) f&v ingredient market was estimated for a $610B packaged food market. This is particularly in China, India, Indonesia and United Arab Emirates.

- Forecasts show that China, Indonesia, India and the UAE are expected to achieve significant growth in demand for selected ingredients which can be derived or replaced by f&v ingredients between 2017-2021 (estimated at 15%, 49%, 28% and 33%, respectively).
- Nutraceuticals is a rapidly growing market, particularly in Asia-Pacific countries. High growth is expected in nutraceutical beverages in Indonesia, India, Australia and UAE in the coming five years.
- Ingredients sourced from fruits (particularly super fruits), vegetables, plant-based oils and wholegrains that are rich in natural sources of specific nutrients, such as antioxidant, vitamins, etc, are becoming sought after.

Estimated market

- Australia grows sufficient fresh produce (8.72M tonnes fresh f&v) to fulfil its own f&v premium ingredient supply.
- The current demand for f&v ingredients in selected export markets is enormous. To indicate the scale of opportunity, using high level estimates of current market sizes in selected countries and fresh produce available in Australia, Australia has the potential to supply Australian grown fruit and vegetable ingredients which account for 0.2% to 35% of selected ingredient markets
- Like other regions, Gippsland's current availability of fresh produce could satisfy a very small fraction of the demand for selected f&v ingredients in selected export markets.

Opportunities for a premium ingredient manufacturing hub

- There are numerous companies with a manufacturing presence in Australia, and Victoria, which could be potential hub customers or users.
- Gippsland meets numerous criteria which make it suitable for a food hub. This includes ideal conditions to grow key produce, such as potatoes, cabbages, sweet corn, tomatoes, onions, broccoli, carrots, beans, apples, and cauliflowers. Gippsland is ideally located to key grower and processor communities and infrastructure including key ports for export. Further, it has the potential to supply between 0.001-0.33% of the specialty ingredients market, and 0.05-0.45% of the commodity ingredient demand in local and selected export markets.

Knowledge gaps

Several gaps in Market, Product and Consumer knowledge were discussed and identified in two Knowledge Mapping sessions based on the information captured.

- **Market:** Even though a list of Australian food manufacturers that could buy and use f&v ingredients on their products is included in this report, further interviews are required to effectively validate local demand. There is a myriad of food manufacturers in Australia's key export markets that can be potential buyers of f&v ingredients for beverages and packaged foods. Further research is required on these companies and the specific channels (e.g. online sale platforms) for selected value added ingredients markets based on specific ingredient selection.
- **Product:** The opportunities to include specialty f&v ingredients into existing product pipelines require further refinement. There is an abundance of opportunities to create innovative formulations of beverages and packaged foods containing f&v ingredients and match with existing or grown-for-purpose raw materials. For example, a variety of fermented food ingredients from f&v can be formulated to suit a number of product categories.

- **Consumer:** Even though the food processing hub will operate on a business to business mode by supplying industries utilising fruit and vegetable ingredients to food manufacturing companies in APAC, consumer trends (e.g., demographics) on products manufactured by such companies required further understanding.

Scope of this report

This activity focused on exploring the national and export market opportunities for ingredients that use, or could be substituted by, premium fruit and vegetable ingredients. Covers information drawn from a range of market reports, industry sources and guidance provided through Knowledge Mapping sessions run by The Monash Food Innovation Centre, and will include:

a) key trends impacting consumption of food, beverages and nutraceuticals with particular focus on the Health and Wellness trend impacting f&v ingredients;
b) the market for packaged foods, beverages and nutraceuticals containing fruit and vegetable ingredients in Australia and selected key export markets including China, India, Indonesia, Japan, Singapore, South Korea, Taiwan, New Zealand, and the United Arab Emirates (UAE);
c) the market size and growth for specialty ingredients and commodity ingredients in Australia and selected key export markets;
d) the scale of opportunity for a regional hub and Australia in general taking into consideration raw materials from the Gippsland region and Australia wide;
e) potential hub clients, hub users, and potential competitors; and
f) two market exemplars using key produce from the Gippsland region, broccoli and carrots

1 Premium fruit and vegetable product ingredients

Premium fruit and vegetable (f&v) ingredients include those which can be extracted from fruits and vegetables that can be used to add value to products including processed foods, beverages and nutraceuticals. While shelf stable and frozen f&v products are of interest, the focus of this study is on a variety of ingredients applicable to a broader range of packaged food, beverages and other nutraceutical products. Categories of fruit and vegetable ingredients have been classified into two groups: (a) commodity ingredients, and (b) specialty ingredients. Table 1 shows the ingredients listed under each group selected from Euromonitor's market categorisation.

Table 1. Categories identified for specialty and commodity fruit and vegetable ingredients*

Commodity ingredients	Specialty ingredients
Fruit	Botanicals
Fruit Juice	Carotenoids
Vegetable	Colours and flavours
Potato products	Other flours (not cereal)
	Polysaccharides and Oligosaccharides
	Preservatives/Antioxidants
	Proteins

*Euromonitor database classification

This ingredient selection was based on opportunities to create high value health driven commodity and specialty ingredients from fruit and vegetable sources. These can be used to partially substitute existing ingredients with a broader nutritional balance of fibre, protein, and antioxidants such as phytonutrients.

1.1 Products utilising fruit and vegetable ingredients

According to the Euromonitor database, f&v ingredients are predominantly utilised in Food, Beverage and Other Nutraceutical categories. As shown in Table 2, within Food, the categories used to describe the ingredient applications include Packaged Food and Meal Replacements, within Beverages, the categories includes alcoholic, hot and soft drinks. Fruit and vegetable ingredients are predominantly consumed in packaged food and is therefore a major focus of this report. Packaged food categories (applicable to f&v ingredients) are outlined in Table 2.

The use of f&v ingredients in beverages and other nutraceutical products, such as vitamins and dietary supplements, will also be considered.

Table 2. Food and Beverage market categories defined by Euromonitor

Beverages	Food
Soft Drinks Functional Bottled Water, Cola Carbonates, Low Calorie Cola, Carbonates, Non-Cola Carbonates, Regular Cola Carbonates, Lemonade/Lime, Ginger Ale, Tonic Water/Other Bitters, Orange Carbonates, Liquid Concentrates, Powder Concentrates **Hot Drinks** Fruit/Herbal Tea, Green Tea, Instant Tea, Other Tea, Flavoured Powder Drinks, Malt-based Hot Drinks, Other Plant-based Hot Drinks	**Packaged food** Baby Food (Excl. Milk Formula), Baked Goods, Breakfast Cereals, Confectionery, Sour Milk Products, Yoghurt and Flavoured Milk Drinks, Ice Cream and Frozen Desserts, Processed Fruit and Vegetables, Processed Meat and Seafood, Ready Meals, Rice, Pasta and Noodles, Sauces, Dressings, Soup and Condiments, Savoury Snacks, Spreads, Sweet Biscuits, Snack Bars and Fruit Snacks
Alcoholic Drinks Beer, Non/Low Alcohol Beer, Stout, Cider/Perry, RTDs, Spirit-based RTDs, Brandy, Cognac, English Gin, Vodka, Cream-based Liqueurs, Whiskies, Other Spirits, Wine	**Meal Replacement**

2 Fruit and vegetable ingredients in Australia

2.1 Fruit and vegetable processing industry

Industry revenue for f&v processing in Australia has declined in recent years and is forecast to continue to decline at an annualised 0.6% rate over the five years through 2022-23, to $5.4 billion[1]. This is mainly due to the industry continuing to struggle with low-cost imports from countries where economies of scale are much larger and labour costs are much lower.

Businesses in this industry primarily process, bottle, can, preserve, quick-freeze and quick-dry fruit and vegetables. The industry includes dehydrated vegetable products, soups, sauces, pickles, mixed meat and vegetable products, and non-milk based baby foods. Major segments are shown in Figure 1[1]. Frozen or shelf stable fruit and vegetables make up 45.1% of the market value and under 27% of the volume, and undergo minimal processing and are therefore easy to substitute.

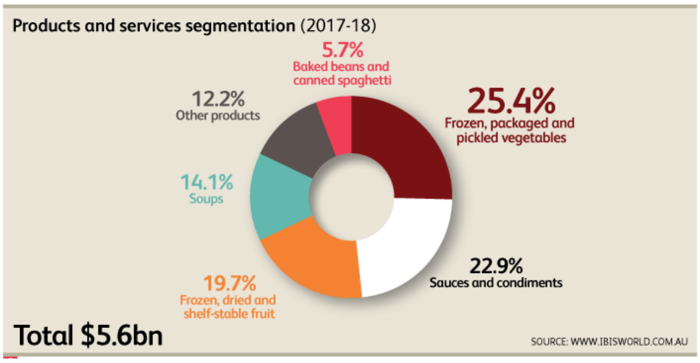

Figure 1. Product segments for fruit and vegetable processed products in Australia based on $5.6B revenue.

Exports of processed fruit and vegetables are a key source of revenue for many local processors, accounting for 49.2% of revenue as shown in Figure 2. The value of exports has increased strongly over the past five years as larger players have aimed to serve the growing population and incomes of the middle class in Asia and the Middle East[1].

Imports have surged as a share of domestic demand over the past five years. An erratic supply of key inputs due to unfavourable weather conditions later in 2017, combined with high costs, has contributed to supermarkets sourcing processed goods from overseas. Industry players have been compelled to reduce Australian prices to maintain market share. This has reduced revenue and squeezed profit margins. Lower profitability has forced f&v industry exits, offshore relocations and the consolidation of processing facilities[1].

Australia imports $2.8B worth of processed f&v ingredients. The biggest importers are New Zealand, China and United States, mostly due to cost advantages and the economies of scale which can be achieved in these countries.

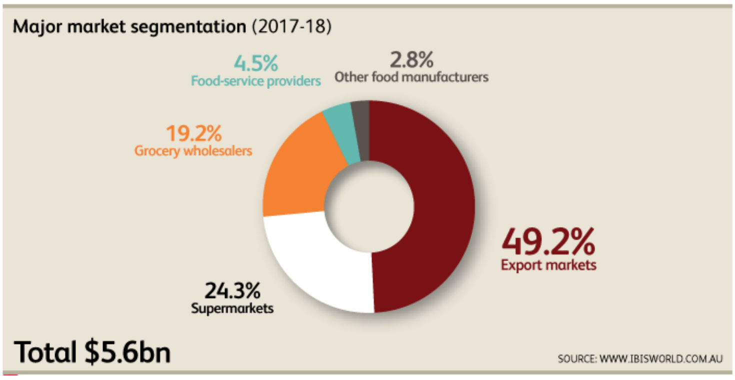

Figure 2. Customer market segments of fruit and vegetable products consumed in Australia based on $5.6B revenue

2.2 Opportunities for Australian fruit & vegetable ingredients

2.2.1 EXPORT MARKETS

Australian provenance in target export markets is becoming a big opportunity as the perceived high quality of Australian processed fruit and vegetables has contributed to sustained demand growth from export markets[1]. Preferences for food provenance however tend to vary depending on the type of product and the country of consumption e.g. countries with consumers who have biosecurity or food safety concerns. For example, most consumer preference studies with regard to local offerings show that fresh f&v is where the local label exerts most traction, followed by dairy, and meat & seafood[1].

Given the bulk of industry exports consists of processed fruit[1], and there is a growing demand for packaged food, including 'western style' food in key markets, there are likely to be export opportunities for a broader product mix. Many of the local food manufacturers in Australia, including those using f&v ingredients, have begun to grow their international footprints. Multinationals manufacturing in Australia are already leveraging product sales across multiple geographies. Some of these multinationals have acquired local food manufacturers and used their multinational distribution footprint to grow their market share in other countries e.g. this year Coca Cola has launched fruit and vegetable based products from its acquisition of SPC into China. Some of these companies are summarised in the Appendix (Table A3).

2.2.2 AUSTRALIA

Australians are embracing foods with a higher content of plant based products in-line with the health and wellness trend discussed in the next section. Australasia tops per capita expenditure on naturally healthy products within packaged food and beverage10. In 2016, Australia ranked first in plant-based product sales, particularly savoury snacks and ice cream, due to the large demand for free-from and organic products, the large number of millennials, the growing share of vegetarians and vegans, and rapidly rising demand for sports protein and weight management products[2]. More than 1500 new products were launched in Australia between 2015-2016 with vegetables as ingredients. Of these products, 5% were fresh or frozen vegetables and the other 95% were dips, spreads, dairy, bakery, ready meals, beverages, pet food, and others[3.] Out of 284 products launched in Australia in 2014 with active health claims, 135 included vegetables as healthy ingredients (excluding vegetables such as garlic as flavours, thickener or dry legumes).

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[1] Does Local Still Matter? Yes, But With Caveats, Euromonitor, 2016
[2] Plant based protein assessing demand for sustainable alternatives, Euromonitor, 2017
[3] McTavish-West, 2016

3 Trends shaping the horticulture sector and value added ingredients

3.1 Megatrends in food and agriculture

The sustainability of the horticulture industry is set to be shaped by various megatrends expected to broadly impact the food and agriculture sector,[4]. Some of the pros and cons of these trends have been outlined in Figure 3. The horticultural industry will likely be positively impacted by the Health and Wellness trend (H&W), as horticulture products are valued for nutritional and health benefits and the perception of these ingredients as 'natural'. The health benefit is provided by individual components in fruit and vegetables that can be used to market ingredients in bulk or specialty form for specific and holistic health related outcomes.

	Pros	Cons
A less predictable planet	• Australia has strong R&D capability to help tackle resource constraints and climate and biosecurity risks. • Agriculture land scarcity, makes alternative sources of protein to meat more viable.	• Climate change adversely impacts essential agriculture inputs, particularly water, especially in a dry continent like Australia. • Biosecurity threats could hinder some of Australia's comparative advantages.
Health & Wellness	• Horticulture products valued for nutritional and health benefits. Especially products perceived as more 'natural'. • Health benefit claims can used to market products for specific and holistic health outcomes.	• Fresh food further weakens perception and demand for packaged products especially those perceived as overly processed or with too many ingredients.
Choosy Customers	• Premium products can be targeted to specific preferences. • Customers more likely to look for things beyond ingredient list – green credentials, provenance etc.	• Customer changing preferences/diets can quickly make products and supporting technology obsolete. • Customers less willing to spend money on things they don't value, or on commodity products.
One world	• Opportunity to diversity customer base where there is growth and innovation potential. • Globalisation in the food and beverages industry e.g. Chinese, Japanese and Korean culinary influences spread in the west and vice versa.	• Cheaper production and greater scale of producers from outside Australia continues to create price competition. • Lack of continual investment in R&D and innovation in agriculture and food could put Australia behind. • Geopolitical instability can disrupt supply chains.
Smarter food chains	• Food provenance technology to help market product. • Digital agriculture to improve yield and efficiency. • Extracting high value ingredients improves farm viability.	• Smarter food chains could erode Australia's differentiating factors as other countries improve their credentials.
Social and demographic shifts	• Growing wealth and education levels creates opportunity for premium priced higher value products. • Ageing population investing in preventative health. • Rise in single households which creates demand for alternatives to cooking from scratch. • Hectic lifestyles increases demand for convenience foods.	• Packaged food and beverages has reached maturity in some countries, meaning innovation is usually required to achieve category growth, e.g. Japan and South Korea. • Declining or stagnating populations and economies, particularly in developed countries lowers opportunity for growth categories.

Figure 3: Megatrends set to shape the food and agriculture sector and suggested pros and cons.

3.2 Trends impacting food, beverage and nutraceutical products

Trends shaping the food, beverage and nutraceutical sectors (and associated ingredients) have been mapped out across some of the aforementioned megatrends in Figure 4. The most crucial of these trends is the growing demand for healthier and more 'natural' ingredients as consumers grapple with increasing health concerns and choosy customer and social and demographic shifts yield smarter consumers who want convenient but healthy product options. This is driving the nutraceutical market as well as H&W products in food and beverages categories. The horticulture industry is well positioned for this trend, as

[4] Food & Agribusiness Roadmap, CSIRO, 2017.

ingredients from plant based sources are in demand, and there is growth in examples of investment and innovation in plant based ingredients.

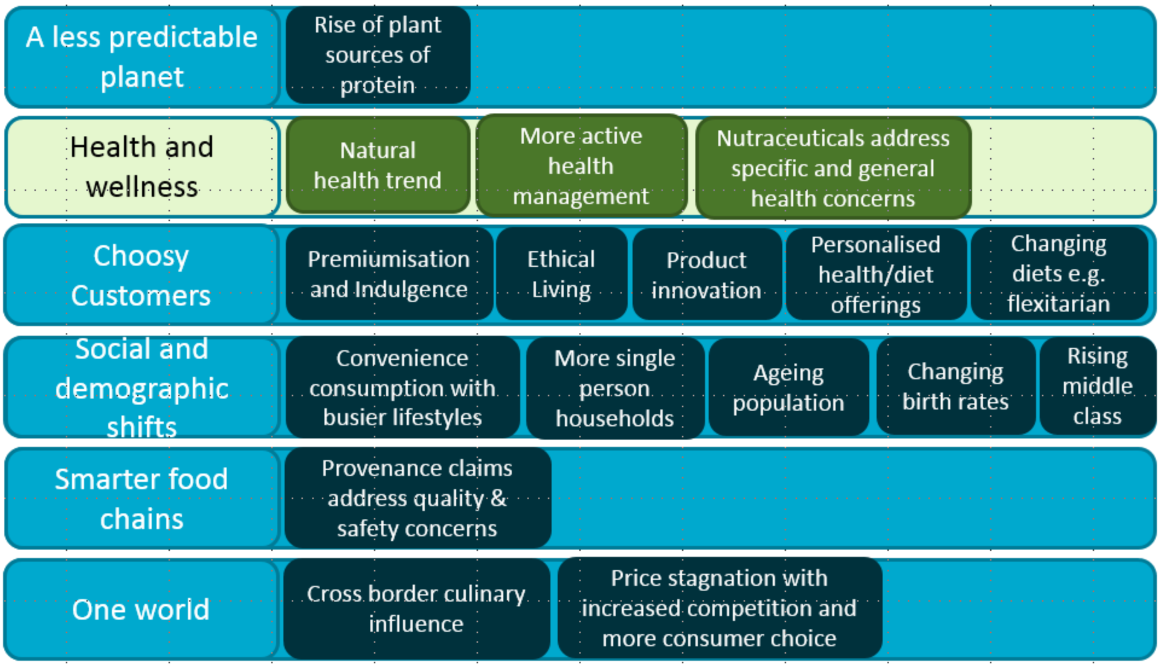

Figure 4. Megatrends and potential impact for horticulture food processing

3.2.1 NATURAL HEALTH TREND

Consumers are looking for minimally processed or unprocessed products, in line with the clean label trend, with natural ingredients, limited or no artificial colourings or preservatives and with ingredients rich in natural sources of nutrition. According to Euromonitor International's Global Consumer Trends Survey 2016, food attributes leaning towards "All Natural" are the most desired attributes which have been increasing in desirability over the past few years. Ingredients rich in natural sources of health driven components including fruit (particularly super fruits), vegetables, and although out of the scope of this study, tea herbs are very popular[5]. This has translated to higher sales of products containing f&v ingredients. Between 2013 and 2016, 50,000 new products were launched globally with vegetables as ingredients, that were not part of the 'fruit and vegetable' category[6].

Within the $707B H&W global market, naturally healthy packaged food and beverages is the largest segment ($249.5B), with fortified/functional foods closely following ($247B)[7]. Fortified/functional products showed the fastest growth in absolute value terms over the 2011-2016 period, which links with the increasing interest in good nutrition as a way to support healthy living. However, in developed countries data shows a massive trend towards the use of natural ingredients that underpins the success of the naturally healthy offering, which is expected to grow the fastest in the coming years. This trend is also closely followed by emerging countries such as Brazil or China[7].

[5] Euromonitor, 2016
[6] McTavish-West, 2016; Source: InnovaDatabase
[7] Healthy Ageing Opportunities, Euromonitor, 2017

Health and Wellness product strategies and positioning

A common current strategy by food, beverage and supplement companies is to provide more value-added food products with significant health claims that are priced at a premium. With the increasing materials and processing costs, this strategy can create margin pressure relief for major food and beverage companies. Premium pricing has become more acceptable as more consumers become wealthier and educated about their health and take a more active role in health management. A premium price is easier to justify when a consumer fully understands the proposed health benefit of the product[8]. Furthermore, the ageing population is investing in preventative health.

Health benefit claims can be used to market products for specific and holistic health outcomes. While General Wellbeing and Weight Management are the largest categories with health claims, more targeted health positioning is used to attract specific consumers. Ageing populations for example have driven some of these, particularly Bone and Joint Health ($15.7B), Cardiovascular Health ($8.2B), Vision Health ($5.4B), and Brain Health and Memory ($4.6B)[7].

Ingredients sourced from fruits (particularly super fruits), vegetables, plant-based oils and wholegrains that are rich in natural sources of specific nutrients, such as antioxidants, vitamins, etc, are becoming sought after. As it will be discussed later, Australian grown sweet potato, carrot, kale, spinach, broccoli, beetroot, pumpkin, are ideal examples for these applications.

Investment strategies

Many investors are interested in exploiting plant-based, natural and organic related businesses as consumers focus on pro planet, pro health and pro animal consumption increases. With the investments from venture capital entities and major corporations increasing, plant-based foodstuffs will progressively raise their profile in the shopping aisle[9]. The plant-based food and beverage private equity firm PowerplantVentures for example announced the closing of a USD42 million fund to invest in emerging plant-centric businesses.

The Naturally Healthy (NH) market segment is highly fragmented and major players use acquisition to widen their portfolios. ADM (Archer Daniels Midland) acquired WILD Flavors in 2014 (botanical extracts and health-conscious food and beverage ingredients), and the company has since acquired further add-ons to this division all of which have interests in natural, organic, non-GMO and/or gluten-free ingredients.

Markets in Asia Pacific and Australasia

In 2016, Asia Pacific accounted for over one third of the global NH market sales and it is also forecast to post the largest value growth over 2016-2021 due to the strong presence of tea beverages[5]. Australasia tops per capita expenditure on NH products at USD148 in 2016[5].

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[8] Nutraceuticals: Global Markets, BCC Research, 2017

[9] Ancient Wisdom & Botanical Acquisitions, Euromonitor, 2017

4 Market and growth

4.1 Packaged foods and associated ingredients in selected countries

Packaged Food is the major end-use for ingredients, including f&v ingredients, and is experiencing rapid growth in value and volume in some of the selected countries for this study[10]. Globally packaged food was worth USD2,182B in 2017, and APAC accounted for USD620B of this market, Australasia accounted for USD40B, and the UAE USD18B[10]. APAC is expected to account for 52% of global packaged food value growth by 2022, accounting for at least 15% of the global growth in each packaged food category[11].

Of these export destinations, India, the United Arab Emirates (UAE), Indonesia and China are expected to experience the strongest growth in packaged food in volume terms between 2017 and 2021 as shown in Table 3.

Similarly to Packaged Food, f&v ingredients within packaged food is expected to achieve the strongest growth in India, the United Arab Emirates (UAE), Indonesia and China (Table 3). In these countries most categories of selected ingredients within packaged food are experiencing high growth.

The largest of these markets for packaged food, and therefore f&v ingredients, include China, Japan, India, and Indonesia.

Table 3. Volume growth in packaged food and fruit and vegetable ingredients by country

Country	Packaged Food 2017 market size (USD Billions)	Packaged Food volume growth 2017-21	Selected fruit and vegetable ingredient volume growth 2017-2021	Ingredient categories with high growth over 10% (volume growth 2017-2021)
China	**$250**	**11%**	**15%**	**Potato products; Antioxidants, Proteins, Vegetables, Fruit, Other Flours, Colours, Fruit Juice, Flavours**
Australia	$41	7%	6%	Carotenoids, Botanicals, Potato Products, Preservatives/Antioxidants
Japan	**$180**	**-1%**	**1%**	**n/a**
South Korea	$23	-3%	5%	Other Flours, Potato Products
Indonesia	**$27**	**22%**	**28%**	**All categories growing over 16%**
India	$66	33%	49%	All categories growing over 19%
Singapore	**$2**	**5%**	**9%**	**Potato Products, Colours**
New Zealand	$7	7%	6%	Botanicals, Other Flours
UAE	**$5**	**26%**	**33%**	**All categories growing over 23%**
Taiwan	$9	5%	6%	Preservatives/Antioxidants

[10] Euromonitor, 2018
[11] Shifting Market Frontiers in Asian Century, Euromonitor, 2017

The size of packaged food categories across selected countries in 2017 and their expected value growth to 2022 is shown in Figure 5. In these countries the largest expected growth categories include Dairy Products (Sour Milk Products, Yoghurt, Flavoured Milk), Baked Goods, Baby Food (Excluding milk formula), Savoury Snacks and Breakfast Cereals. These categories are expected to have a CAGR of over 6% between 2017 and 2022. The largest categories in 2017 included Rice, Pasta and Noodles ($76B) and Baked Goods ($66B).

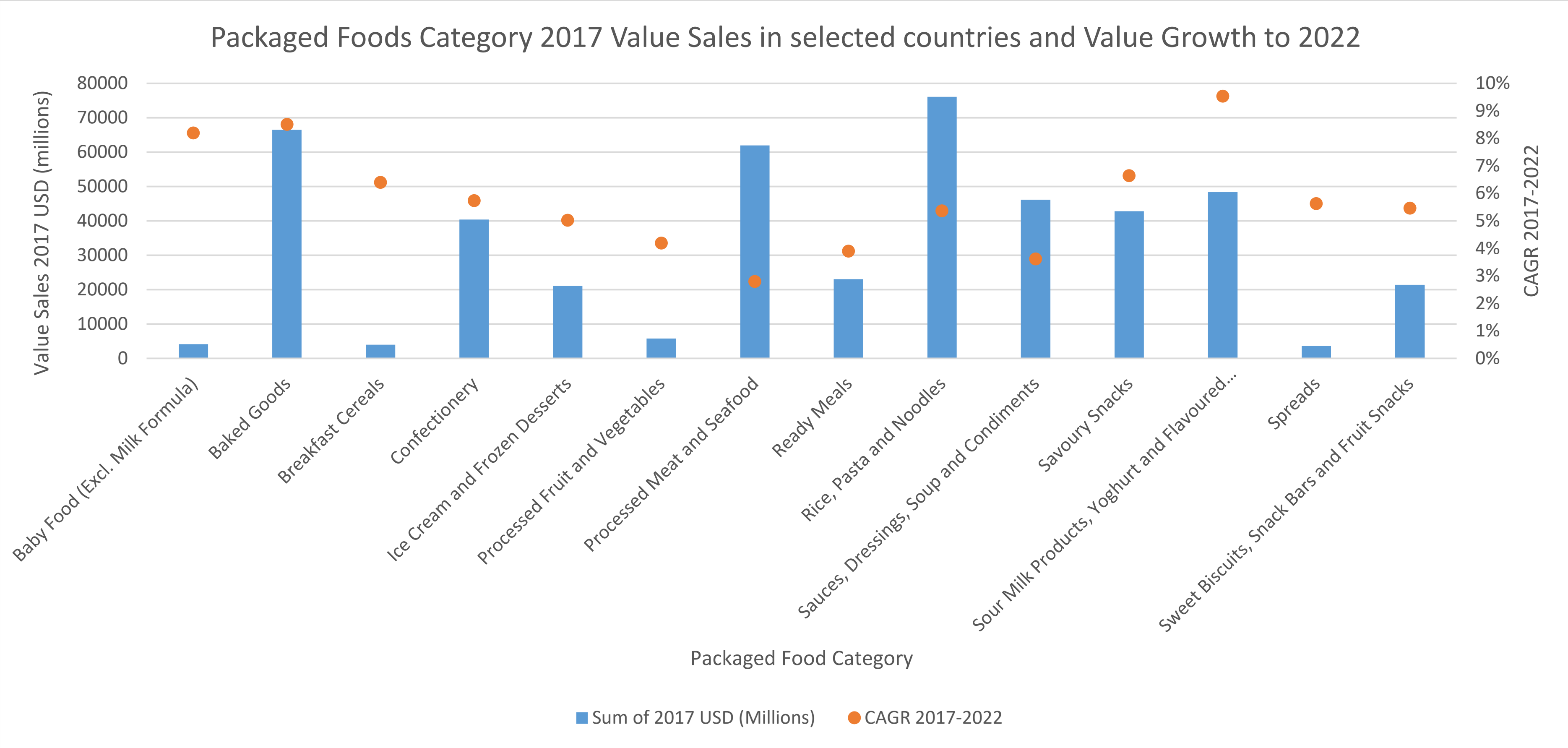


Figure 5. Packaged Foods Categories in selected countries, which includes fruit and vegetable ingredients. Countries include China, India, Indonesia, South Korea, Singapore, Taiwan, Australia, NZ, and UAE.

4.2 Beverages in selected countries

The impact of the health and wellness trend is evident in beverages with high growth expected in selected countries for beverages which are more naturally healthy or those which are functional or fortified with beneficial ingredients. A number of selected countries are expected to have high growth in fortified beverages between 2017 and 2022 (Figure 6), CAGRs of these countries for this period include Indonesia (7%), India (7%), Australia (6%), UAE (6%), China (5%) and South Korea (5%)[10].

Naturally Healthy beverages however will show some of the largest pockets of growth in beverages in selected countries, and is one of the fastest growing categories in H&W food and beverages overall[10]. Selected countries are all expected to achieve growth, many of which are expecting a CAGR of over 5% between 2017-2022 including India (18%), South Korea (9%), China (7%), Australia (7%) and Indonesia (6%). The largest of the selected markets are by far China ($38B) and Japan ($24B).

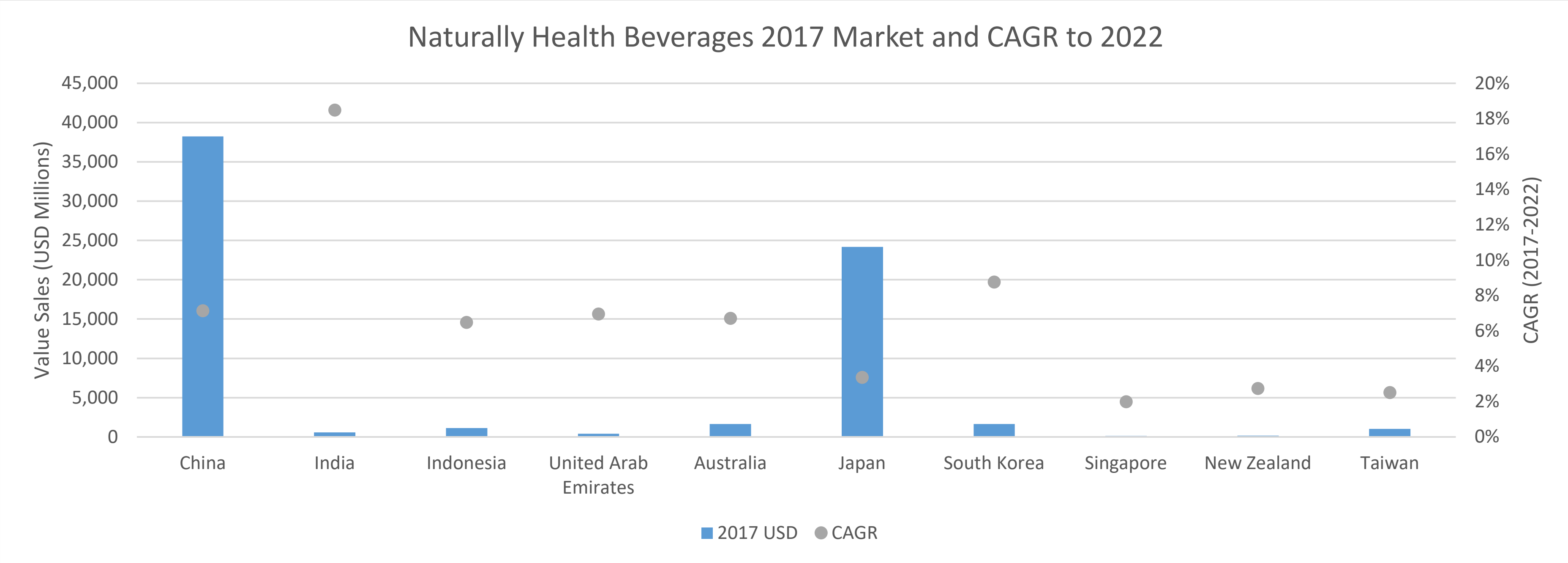


Figure 6. Naturally healthy beverages in Australia and key Australian agricultural export countries.

4.3 Ingredient consumption within food and beverage categories

While Packaged Food is the major category utilising selected ingredients, the Beverages category also accounts for a high proportion of selected ingredient consumption. The selected ingredients sub-category encompasses ingredients which can be derived or supplemented by f&v ingredients and includes a range of botanicals, colours, flavours, etc as detailed in Table 4. It shows where selected ingredients consumed in Asia Pacific are distributed into food and beverage products. The biggest end-use categories for each ingredients consumption is also shown. The proportion which goes into vitamins and dietary supplements is unknown.

Many of the food/beverage categories could be relevant targets for f&v ingredients based on the distribution of selected ingredients shown in Table 4. For Packaged Foods the, Sauces, Dressings & Condiments is the most popular category for these ingredients, followed by Dairy, Processed Fruit and Vegetables and Savoury Snacks.

Table 4. Ingredient proportion consumption for Packaged Food and Beverage categories in Asia Pacific in 2017.

Category	Beverages (%)*	Packaged Food (%)*	Biggest Food/Beverage Categories by proportion distribution of ingredient (excluding dietary supplements categories)
Specialty ingredients			
Botanicals	52	40	Soft Drinks (40%), Dairy (34%), Hot Drinks (11%), Ice Cream and Frozen Desserts (4%)
Carotenoids	66	34	Soft Drinks (66%), Ice Cream and Frozen Desserts (12%), Sweet Biscuits, Snack Bars and Fruit Snacks (8%)
Colours	57	20	Soft Drinks (56%), Confectionery (2%), Sweet Biscuits, Snack Bars and Fruit Snack (2%), Savoury Snacks (2%),
Flavour Enhancers	n/a	100	Sauces, Dressings and Condiments (94%), Rice, Pasta and Noodles (4%), Savoury Snacks (1.5%)
Flavours	54	36	Alcoholic Drinks (31%), Soft Drinks (22%), Dairy (13%), Sauces, Dressings & Condiments (6%)
Other Flours	4	96	Rice, Pasta and Noodles (74%), Savoury Snacks (11%), Hot Drinks (4.4%), Confectionery (3%), Baked Goods (3%)
Polysaccharides and Oligosaccharides	16	82	Savoury Snacks (32%), Rice, Pasta and Noodles (14%), Soft Drinks (10%), Dairy (10%), Sweet Biscuits, Snack Bars and Fruit Snacks (7%)
Preservatives/Antioxidants	9	65	Baked Goods (46%), Ready Meals (9%), Soft Drinks (8%), Processed Meat & Seafood (5%)
Probiotic Cultures	n/a	57	Dairy (57%)
Proteins	9	87	Dairy (32%), Processed Meat and Seafood (15%), Rice, Pasta and Noodles (11%)
Commodity ingredients			
Fruit	7	93	Processed Fruit and Vegetables (20%), Baked Goods (14%), Sauces, Dressings and Condiments (13%), Dairy (4%)
Fruit Juice	93	7	Soft Drinks (50%), Alcoholic Drinks (42%), Dairy (4%), Processed Fruit and Vegetables (2.5%)
Vegetables	n/a	100	Sauces, Dressings and Condiments (57%), Processed Fruit and Vegetables (17%), Rice, Pasta and Noodles (8%)
Potato Products	n/a	100	Processed Fruit and Vegetables (72%), Savoury Snacks (26%)

Total volumes exclude vitamin and dietary supplements. The remaining proportion of ingredients not shown are distributed into Personal Care, Home Care, and Pet Care products.

4.4 Nutraceutical ingredients

Nutraceutical ingredients are active ingredients that offer health benefits beyond basic nutrition and can be included to value add products as such as dietary supplements. These ingredients can be added into beverages or packaged food to make "functional" beverages or food products. Dietary supplements may include vitamins, natural colours, and herbs (as single herbs or mixtures), and other botanicals, amino acids, and dietary substances presented in as tablets, capsules, softgels, gelcaps, liquids, and powders. The global nutraceutical market has grown exponentially in the last few years, and growth is expected to continue at a CAGR of 7.5% until 2021 to reach a $285B market[12]. From a product perspective, functional beverages dominated the global nutraceutical market in 2015 with a 36.0% share, followed by functional food with 32.5% and dietary supplements with 31.5% (Table 5).

Market data reported in the above sections on Packaged Food and Beverages have excluded Dietary supplements. However, it is worth noting that there is an overlap between databases describing Functional Beverages and Food (BCC research) and Packaged Food and Beverages (Euromonitor).

Table 5. Global nutraceutical market by product type (through 2021; $ billions; Nutraceuticals: Global Markets, BCC Research, 2017)

Product	2015	2016	2021	CAGR% 2016-2021
Functional beverages	66.6	71.5	105.5	8.1
Functional food	60.1	64.6	92.3	7.4
Dietary supplements	58.3	62.6	87.2	6.9
Total	185.0	198.7	285.0	7.5

4.4.1 DIETARY SUPPLEMENT INGREDIENTS

The market for dietary supplement ingredients in the United States and Europe in 2015 was a combined $10.13 billion in industry turnover. Europe and North America represents about 34% of the global nutraceutical market. Revenue is expected to grow at a 9.5% CAGR from 2015 to 2020[13]. Immunity, general health and wellness, digestive health, women's health, eye health, and sports health are the leading therapeutic areas in terms of projected growth in this markets (Figure 7).

[12] Nutraceuticals: Global Markets, BCC Research, 2017
[13] US and European Dietary Supplement Ingredients Market Analysis, Frost & Sullivan, 2016

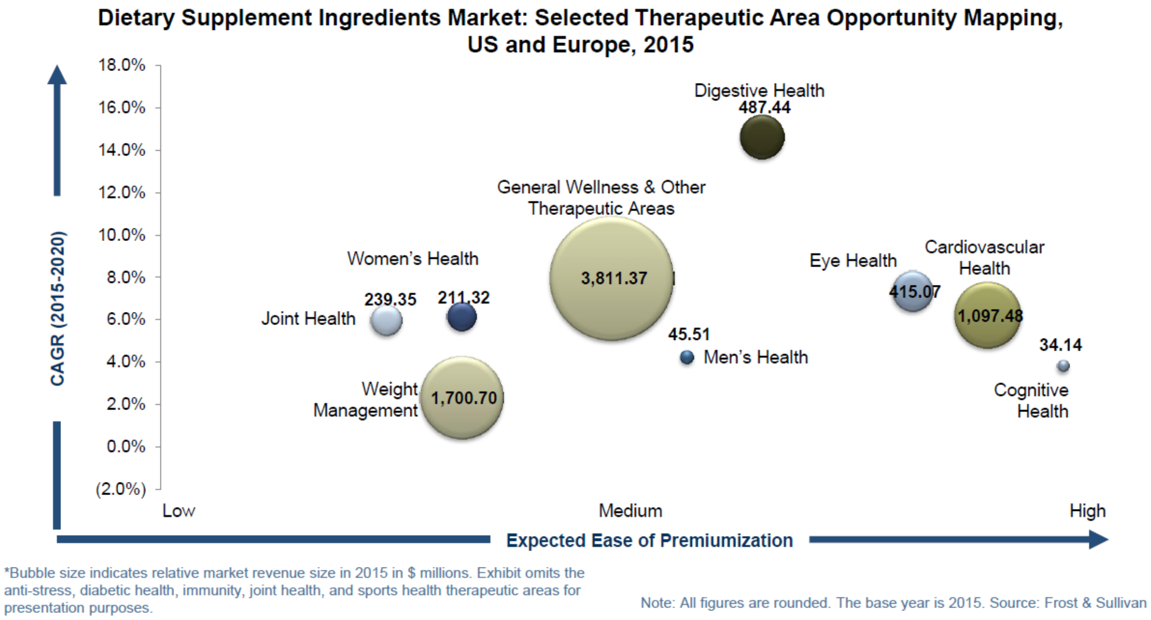


Figure 7. Growth and expected ease of price augmentation (i.e., premiumization) of dietary supplement ingredients segments

4.5 Digestive health ingredients

The Digestive Health Food and Drinks category includes probiotics, prebiotics and food enzymes such as fermented fruit and vegetables such as sauerkraut or kimchi, which could be prepared in ingredient form. The market was worth $25.9B in 2015 and will reach $37.6 billion by 2020, growing at a CAGR of 7.77%[14]. Asia-Pacific (APAC) led the global digestive health food and drinks market in terms of value in 2015 (Figure 8).

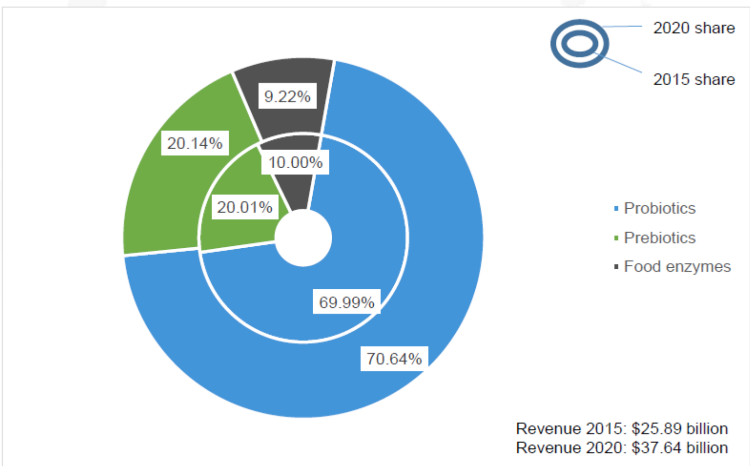


Figure 8. Growth in digestive health ingredients from 2015 to 2020

Market research by BCC Research values the global market for probiotics at $31.8 billion in 2014, projected to reach $50.0 billion in 2020, growing at a CAGR of 8.0% from 2015 through 2020. The market is led by probiotics in the food and beverages industry, which accounted for almost 73% of

[14] Global Digestive Health Food and Drinks Market 2017-2021, 2017

the global market in 2015 and is expected to maintain its leading position throughout the forecast period[15]. Probiotic cultures could be added to fruit and vegetable ingredients for value addition.

Growing demand for meat products such as sausages, pickles, and probiotic–based cereals are driving this market.

4.5.1 PREBIOTIC AND PROBIOTIC INGREDIENTS

The global prebiotic ingredients market was worth $1.35 billion in 2016, and is expected to register a CAGR of 5.4% from 2016 to 2021[16]. The APAC region dominates this market, with China accounting for 19.2% of this market and the Rest of Asia 15.9%.

The total probiotics ingredient market was valued at €1.31 billion in 2016 and is expected to reach €1.82 billion by the end of 2021, based on a CAGR of 6.8%[17].

[15] The Probiotics Market, BCC Research, 2016
[16] Global Prebiotic Ingredients Market Overview Forecast to 2021, Frost & Sullivan, 2017
[17] Global Probiotic Ingredients Market Overview, Forecast to 2021, Frost & Sullivan, 2017

5 Estimated Market Opportunity

The market for f&v ingredients which could be targeted has been estimated using both supply and demand factors. The supply has been estimated by using both Australia wide supply of fresh produce and, as a regional example, the Gippsland area supply. Demand for ingredients has been estimated using the market for ingredients in packaged food from selected countries. The actual demand is larger if beverages and other nutraceuticals such as vitamins and dietary supplements are included.

5.1 Australia-wide market opportunity

The purpose of this section is to establish a connection between supply of Australian fresh f&v produce and the achievable demand for f&v. Numbers highlighted here are rough estimates and further refining and adaptation to the specific possibilities of growing for purpose or current regional produce is required. Refining of the specific demand for specific ingredients under the categories listed is required. Section 5.1.1 considers the Australian supply and the achievable demand for f&v ingredients in Australian and overseas target markets. Section 5.1.2 takes the example of Gippsland in terms of fruit and vegetable supply while considering the achievable demands for f&v ingredients in Australia and key overseas markets.

5.1.1 MARKET IN SELECTED EXPORT COUNTRIES AND AUSTRALIA

The achievable demand for each selected ingredient has been calculated individually using the current supply of fresh Australian produce in Table 6. The current market for selected commodity and specialty ingredients in target Australian export markets has been used to calculate this demand, as well as the estimated total amount of fresh produce grown in Australia that could potentially be transformed into target Australian specialty or commodity ingredients. The achievable demand for each ingredient is calculated by the content of specific target components to be extracted, separated or value added. The achievable target market fraction in most cases is between 10-35% of the total demand for each f&v ingredient (Table 6). However, Antioxidants & Botanicals and Colours & Flavours manufactured with all suitable and available Australian fresh produce would only satisfy 3.4% and 0.2% of the total global target market demand respectively.

Based on reported values, Australian fresh produce supply could be enough to produce f&v ingredients to satisfy its own local ingredient demand. This is valid except for Colours & Flavours where Australia's fresh produce could only supply up to 19.7% of Australia's total demand for colour and flavour ingredients.

Table 6. Estimated achievable demand fraction of the Australian and overseas target markets based on available fresh fruit and vegetables in Australia

Ingredient/Product	Global f&v ingredient demand 2017 (Total available market, tonnes)*	Expected Growth (%) 2017-2021	Achievable target market fraction (%)	Achievable demand (Total obtainable market, million USD)	Achievable demand (Total obtainable market, tonnes)	Estimated price per produce (USD)	Content in produce (%, wet basis)	Current supply of fresh produce in Australia (tonnes, wet basis)
Antioxidants and botanicals (incl. carotenoids)	242,641	3	3.4	179 - 2,854	8,155	22,000 - 350,000	0.1	8,154,995
Colours and flavours	1,832,448	4	0.2	99 - 354	3,541	28,000 - 100,000	0.05	7,081,117
Other flours	798,405	15	35.2	22,756	280,937	81,000	15	1,872,915
Polysaccharides and Oligosaccharides	1,944,075	18	15.8	24,634	307,923	80,000	3.75	8,211,291
Proteins	512,117	20	10.2	2,162	52,106	41,500	2	2,605,288
Digestive health (pre/probiotic)	261,256	N/A	29.9	2,892	78,159	37,000	15	521,058
Fruit (dried)	2,559,959	15	35.2	30,668	902,005	34,000	15	6,013,364
Fruit Juice	1,033,442	11	23.3	192	240,535	800	40	601,336
Vegetable (dried)	5,642,359	13	10.1	25,115	569,494	44,100	30	1,898,315
Potato products (frozen)	2,007,260	24	27.9	1,457	560,566	2,600	40	1,401,415
Grand Total	**16,833,962**	**14**	-	**154,379 - 157,309**	-	-	-	-

**Assumptions: Ingredient demand is from Packaged Foods in China, India, Indonesia, South Korea, Singapore, Taiwan, Australia, NZ, and UAE. All raw material available is assumed to be utilised to produce a specific ingredient. Value quantification was calculated from price estimates on selected ingredients assuming bulk sales. Botanicals include phytochemicals and plant extracts; Flours are substituted by vegetable/fruit powders; Polysaccharides and oligosaccharides include insoluble fibre; Differentiated fruit juices with ingredients; Total fruit and vegetable production for Australia in 2017 is 8,211,291 tonnes.*

5.1.2 GIPPSLAND REGION MARKET OPPORTUNITY

Gippsland has the potential to supply between 0.001-0.33% of the specialty ingredients market, and 0.05-0.45% of the commodity ingredient demand in local and selected export markets (Table 7). This is with the exception of Other Flours and Potato products, with the potential to satisfy 2.56% and 2.17% of the Packaged Food ingredients demand respectively. Table 7 calculations assume supply of fresh fruit and vegetables in the region only, selected for the production of specific specialty or commodity ingredients.

Table 7. Estimated achievable demand fraction of the Australian and overseas target markets based on available fresh fruit and vegetables in Australia

Ingredient/Product	Global f&v ingredient demand 2017 (Total available market, tonnes)*	Expected Growth (%) 2017-2021	Achievable target market fraction (%)	Achievable demand (Total obtainable market, million USD)	Achievable demand (Total obtainable market, tonnes)	Estimated price per produce (USD)	Content in produce (%, wet basis)	Current supply of fresh produce in Australia (tonnes, wet basis)
Antioxidants and botanicals (incl. carotenoids)	242,641	- 3	0.04	1,958 - 31,150	89	22,000 - 350,000	0.1	88,528
Colours and flavours	1,832,448	4	0.00	755 - 9450	27	28,000 - 100,000	0.05	53,926
Other flours	798,405	15	2.56	1,656,564	20,451	81,000	15	136,343
Polysaccharides and Oligosaccharides	1,944,075	18	0.30	466,667	5,833	80,000	3.75	155,556
Proteins	512,117	20	0.33	69,895	1,684	41,500	2	84,211
Digestive health (pre/probiotic)	261,256	N/A	8.93	863,334	23,333	37,000	15	155,556
Fruit (dried)	2,559,959	15	0.05	47,233	1,389	34,000	15	9,261
Fruit Juice	1,033,442	11	0.45	3,705	4,631	800	50	9,261

Ingredient/Product	Global f&v ingredient demand 2017 (Total available market, tonnes)*	Expected Growth (%) 2017-2021	Achievable target market fraction (%)	Achievable demand (Total obtainable market, million USD)	Achievable demand (Total obtainable market, tonnes)	Estimated price per produce (USD)	Content in produce (%, wet basis)	Current supply of fresh produce in Australia (tonnes, wet basis)
Vegetable (dried)	5,642,359	13	0.36	884,923	20,066	44,100	30	66,888
Potato products (frozen)	2,007,260	24	2.17	113,445	43,633	2,600	40	109,081
Grand Total	**16,833,962**	**14**	**-**	**-**	**-**	**-**	**-**	**-**

Assumptions: Ingredient demand for Packaged Foods in countries including China, India, Indonesia, South Korea, Singapore, Taiwan, Australia, NZ, and UAE. All raw material available is assumed to be utilised to produce a specific ingredient. Botanicals include phytochemicals and plant extracts; Flours are substituted by vegetable/fruit powders; Polysaccharides and oligosaccharides include insoluble fibre; Differentiated fruit juices with ingredients; Total fruit and vegetable production for Gippsland in 2017 is 155,556 tonnes.

6 Opportunity for regional food manufacturing hubs

Food manufacturing hubs are expected to be geographically positioned in key agricultural regions of Australia where fruit and vegetables are grown (Figure 9). This will facilitate further value addition while providing opportunities to local producers, food manufacturers or innovators to access the hub. The amount of raw materials available in the region however has the potential to limit the production volume of premium ingredients, and therefore its market reach or total obtainable market.

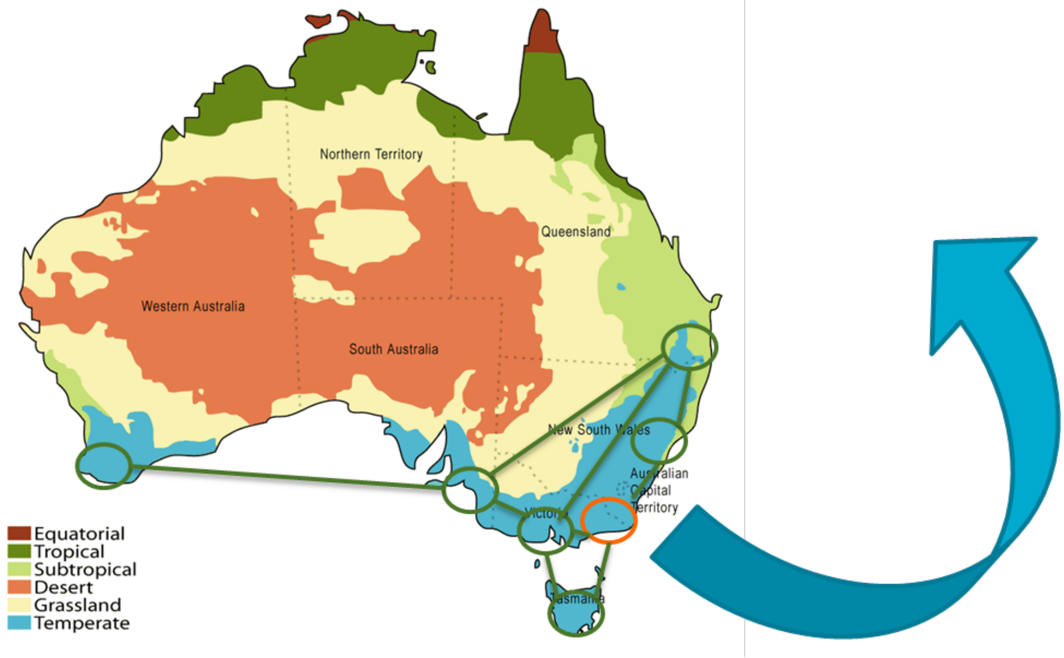


Figure 9. Australia's candidate regions for the establishment of food manufacturing hubs and premium f&v ingredient export platforms. Gippsland is demarked as centralised hub region for the case study[18].

6.1 Australia's fruit and vegetable production perspective

In 2017, Australia produced 8.2 million tonnes of fruit and vegetables (ABS 2018). Half of its production is dedicated to grapes (21.6%), grapes for wine production (19.7%) and potatoes (13.7%) (see Table A1 in Appendix). Another third of the production included tomatoes, oranges, bananas, apples, carrots, onions, melons, grapes for all other uses and mandarins. An estimated 15% of the volume of Australia's fruit and vegetables (1.1 million tonnes) is made up of 26 crops, such as pumpkins, sweet corn, broccoli and berries which carry significant potential nutritional and health components and therefore may be suitable for high value premium ingredient manufacturing.

More than 25% of fruit, vegetable & nut production in Australia is currently under-utilised due to either being out of retail specification, surplus from over-production, or as by-product of a primary production or

[18] Australian Bureau of Statistics, Regions of fruit and vegetable production

processing system. This creates opportunities for conversion of underutilised biomass into value added specialty and commodity ingredients.

6.2 Case study - Gippsland

Victoria represents 21% of Australia’s raw material production with 1.70 million tons of raw fruit and vegetable raw materials being produced. Gippsland produces 9.1% of Victoria’s production or 155 thousand tonnes of fresh fruit and vegetables. A significant number manufacturers of packaged food are located in Victoria, which makes the area amenable for potential clients of a food processing hub. Manufacturers and growers currently focus on mainly on commodity types products and have limited capacity or know-how to produce specialty fruit and vegetable ingredients but are willing to consider diversifying into alternative product lines. The region therefore has access to a community prepared to value add to fruit and vegetables in various ways.

The region is also known for its high rainfall and temperate climate that is ideal for growing certain varieties specific to the region (see a list in Table A2 in the Appendix). The ten top crops grown within the region, which make up 97% of the volume of all crops grown, include potatoes, cabbages, sweet corn, tomatoes, onions, broccoli, carrots, beans, apples, and cauliflowers. In particular, potatoes, cabbages, and sweet corn take up 43%, 16%, 10% of all fruit and vegetable production in the region, respectively. The specific nutraceutical components in some of these raw materials, create opportunities for specialised value added ingredients.

The region brings opportunities to grow for purpose, thereby increasing use of underutilised land, as well as recovering food loss in the form of by-products from harvest, packing and processing operations.

The proximity to ports and availability of other transport routes provides a suitable case for a food manufacturing hub to be located in the region.

Being close to the capital cities of Melbourne and Canberra also brings substantial benefits such as local R&D expertise, consumer and business communities, suppliers and skilled labour.

7 Potential hub users and/or competitors and hub clients

Fruit and vegetable product or ingredient manufacturers may be interested in making use of the hub to make their own ingredients or purchase ingredients. These are most likely to be beverage or packaged food companies who may either be participant owners of the hub or use some of its facilities through toll processing or outsourcing schemes. Other hub users may potentially include innovators or new product developers outsourcing the hub to launch their product concepts to the market, or individual growers, or grower cooperatives using the hub to innovate on their fresh produce.

Multinational or large companies have a large portfolio of packaged food and beverages, which can potentially use fruit and vegetable ingredients. Some of these companies have a fruit and vegetable product portfolio and capability to either manufacture their own ingredients or outsource ingredient manufacturing.

Table A3 in the Appendix includes a list of local food and beverage companies that may use the hub for fruit and vegetable ingredients, most of whom have a manufacturing presence in Australia.

8 Case study on broccoli and carrot derived ingredients

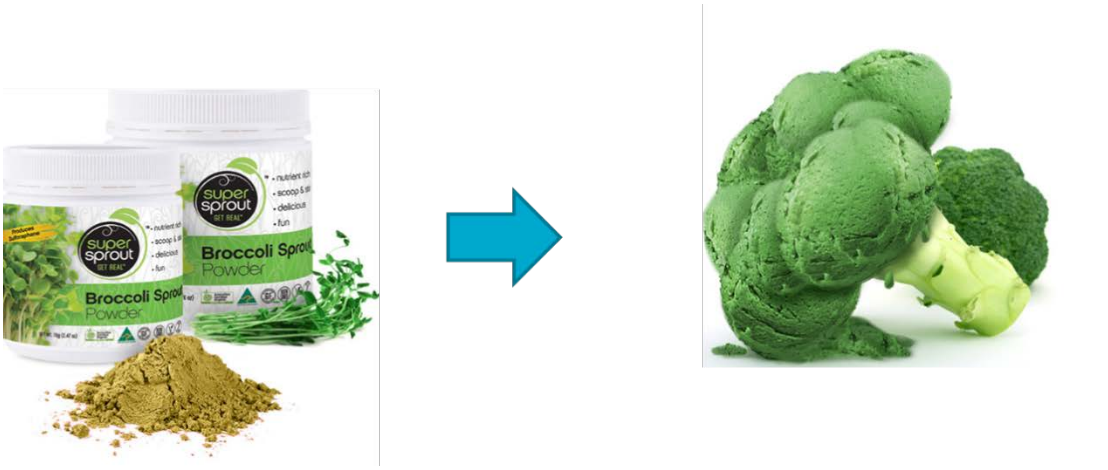
8.1 Broccoli ingredients

Broccoli ranks number seven in Australia in terms of raw vegetable production. Broccoli is a high source of nutrients including carotenoids, chlorophyll, vitamins A and C, phenolics, plant sterols and glucosinolates. Other health driven compounds include tocopherols (alpha and gamma) and carotenoids (lutein and beta-carotene). Among the glucosinolates, glucoraphanin can produce sulphoraphane which has been shown to have nutraceutical properties including protection from oxidative stress and inhibition of tumour growth. Other health claims include its potential to protect from cardiovascular and neurodegenerative diseases such as stomach cancer. There are significant quantities of broccoli-type stem produced, which merits investigating potential for converting into value-added commodity and specialty ingredients.

There are business to business opportunities in supplements, sports nutrition, ready meals (puree/pulp), baby foods, or branded dried powders sold in pouches or encapsulated powders into nutrient dense snacks (McTavish-West 2015). Other opportunities include blending with other ingredients including beetroot, kale, cauliflower, berry, among other powders. Figure 10 shows an example of a commercial Australian broccoli sprout powder.

Between 2012-2014, there have been 15 new products containing broccoli powder launched in Australia and 827 globally[19]. Same packaged product examples include dietary supplements (e.g., BioCeuticals), tablets (e.g. Nature's Way), baby purees in pouches (e.g., Rafferty's garden), and vegetable patties (e.g., Colonial Farm). Today, 25% of juice drinks now contain vegetables[20]. One example includes the Nosh Raw Veggie Smoothie in the United Kingdom, which includes broccoli, parsley, avocado and peach ingredients.

The availability for drying in Victoria is limited in scale and capacity, and commercial drying facilities are located mainly in Tasmania (freeze-drying), in Queensland (refractance window drying) or in New South Wales, limiting localised manufacturing of broccoli or broccoli derived powders. The establishment of a food processing hub with commercial capacity will facilitate regional manufacturing of such powders.



[19] MacTavish-West 2015; Innova Database 2017
[20] MacTavish-West 2016

Figure 10. Australian broccoli sprout powder (https://aus.supersprout.co/product/broccoli-sprout/)

8.2 Carrot ingredients

Carrot ranks as the number eight fruit and vegetable produced in Australia in terms of raw material production. Carrots are a source of fibre, potassium, vitamins B6, C and K (10% reference daily intake per carrot) and a good source of vitamin A from beta-carotene (25% reference daily intake per carrot). Other key components include sugars, carotenoids, flavonols, polyacetylenes, and terpenoids, which also carry out nutritional or health components. Like other fruits and vegetables, carrots provide an opportunity for natural, clear label ingredients enabling health property claims for antioxidant activity or digestive, immune or eye health. Carrot ingredients can also provide orange or purple colour, sweetness and flavour. Table 8 provides examples of key commodity and specialty ingredients that can be made from carrots, many of which are manufactured overseas (e.g., China, Poland) but not in Australia (Mactavish-West, 2016) and some examples of its application are shown in Figure 9. For example, the Korean Seoulmik Happy Yogurt LoveYou includes apple and carrot flavours. A detailed market study is required to estimate the demand for such ingredients in local and overseas markets according to raw material availability.

Table 8. Ingredients from carrots (Mactavish-West, 2016)

Commodity	Specialty
Juice concentrate (aseptic)	Colour - Extract - colour - Natural violet anthocyanin colour - Colour organic
Dried carrots - Rolled dried flakes - Vacuum dried - Freeze dried	Oleoresin (concentrate/ powder)
Quick cook, puffed	Seed oil
Pickled, brine	Fibre
Canned	Powder (spray dried) - non-organic - organic
Frozen carrots	Fermented powders
Juice concentrate (frozen) - non-organic - organic	
Pulp, puree	
Carrot nutrient dense snacks	

Figure 11. Options for carrot functional ingredients (courtesy of McTavish-West and activzcomplete; https://activzcomplete.com/powders/vegetable/carrot-juice-powder-20-servings/)

8.3 Knowledge mapping and information gaps

Two knowledge mapping sessions were carried out at the Monash Food Innovation Centre in January 2018 with project participants and other external participants interested in fruit and vegetable ingredient manufacturing. Through systematic hypothesis formulation the gaps in Market, Product and Consumer knowledge were discussed and identified based on information presented. The information captured into this report covered some of the gaps identified. This report is not intended to cover all broad and specific aspects of market analysis and further detailed market research is required to understand market niches and consumer opportunities for fruit and vegetable ingredients. Some gaps in knowledge not covered in this report but mentioned are the knowledge mapping session are discussed below.

8.3.1 MARKET

The details on the specific domestic and global markets for f&v ingredients is yet to be determined. In particular, details in terms of points of difference between markets across Asia Pacific are required for informed decision making.

Identification of most suitable channels for sale of value added ingredients (e.g., online sales) requires further consideration. Chapter 2 recommends a Business-to-Business (B2B) strategy of selling specialty f&v ingredients to manufacturers of beverages, packaged foods and nutraceutical products. Following this approach, questions were raised during the first session on the role of e-commerce sales channels in China, particularly for B2B deals (e.g., opportunity to use the Alibaba platform offer for China export).

More specific information is required on markets for f&v ingredients targeted to specific packaged food categories (e.g., infant formula). Other country specific segments require further insights to identify the market space for f&v ingredients in ageing populations, younger generations, as well as gender splits, among other key trending segments. A potential segment requiring investigation is the use of f&v ingredients in traditional foods in the Indian market.

Specific country data on functional and nutraceutical ingredients and the market opportunity for these ingredients needs further research.

Declining markets such as Japan & Singapore may be considered as an opportunity if differentiated products are identified.

Even though fermented f&v products exist, opportunities for high value fermented f&v ingredients including food stock, country of origin, volume and price are yet to be determined.

Further research in provenance is required to understand the price differential that Australian origin can bring and credentials for “clean, green” connected to country of origin. This requires to at least identify the Asia Pacific food manufacturer markets interested in Australian sourced products and their different price points.

8.3.2 PRODUCTS

Further refining, through industry engagement and interviews is required to engage local manufacturers to include f&v ingredients into their future product pipeline.

There is an abundance of opportunities to create innovative formulations of beverages and packaged foods containing f&v ingredients. For example, a variety of fermented food ingredients from f&v can be formulated to suit a number of product categories. Other innovative formats for vitamins & dietary supplements and their final product uses may exist and requires further exploration.

Specific product prototypes for nutrient dense, fresher, healthier “free from”, or shelf stable products need to be developed. The health or related claims to market these f&v ingredient added products need to be understood in each target country. Furthermore, product development requires identifying “premium gifting opportunities” and understand the scope and cultural occasion to target.

In formulating these products it is important to evaluate what are Australian competitors (e.g. NZ) doing that Australia is not, to target consumers in the f&v space.

Further raw material selection is required for specific ingredients, including opportunities for growing for purpose, value add from fresh first or second grand produce, and possibilities of creating ingredients from by-products from Level 2 processing such as juicing (e.g., apple pomace) or drying (e.g., off-cuts).

One particular opportunity for Gippsland that requires further investigation is the addition of f&v ingredients in dairy products. Development and scrutiny of specialty f&v ingredients as 'inclusions' in a dairy product can be a next step for industrial integration of horticulture and dairy. The same could apply for horticulture and meat.

8.3.3 CONSUMER

Further refining of the consumer definition of "healthy" and "premium" in Asia pacific markets is required in the context of f&v ingredients into consumer products.

Market research on specific current consumption of specific processed f&v consumed across APAC countries is required. Product differentiation based on consumer preference and price points in markets across APAC will also be required.

Demographic changes in target markets over the next 5-10 years, including the new trends in f&v consumption from Millennials (Gen Y) needs further research. Even though it is clear that opportunities for nutraceuticals are increasing globally across segments further data is needed to show trends in Asia Pacific markets in different life stages, e.g., ageing populations.

Once the importance of provenance in target countries is validated, consumer preference for Australian sourced f&v ingredients needs to be compared against other similar markets like New Zealand and Canada.

Within packaged food, and given the opportunities for using f&v ingredients in snack products, preference for new snack categories needs evaluation.

Another aspect for differentiation is the opportunity and appeal of biodegradable packaging, to carry f&v ingredients, in view of the increasing use of plastic packaging in APAC countries.

9 Appendix

Table A1. Total production of fruit and vegetables in Australia

Produce	Production (t)	Production fraction %
Grapes	1,772,911	21.59
Grapes for wine productions	1,618,286	19.71
Potatoes	1,130,175	13.76
Tomatoes	405,167	4.93
Oranges	398,610	4.85
Bananas	354,241	4.31
Apples	308,298	3.75
Carrots	299,612	3.65
Onions	264,547	3.22
Melons	239,146	2.91
Grapes for all other uses	154,625	1.88
Mandarins	125,233	1.53
Pears	104,928	1.28
Pumpkins	94,482	1.15
Cabbages	87,500	1.07
Sweet corn	86,559	1.05
Olives	75,084	0.91
Pineapples	71,782	0.87
Avocados	67,600	0.82
Cauliflowers	66,868	0.81
Broccoli	54,479	0.66
Mushrooms	50,388	0.61
Peaches	48,957	0.60
Strawberries	48,401	0.59
Mangoes	42,515	0.52
Lemons	37,490	0.46
Capsicums	36,793	0.45
Beans (french and runner incl)	35,602	0.43
Nectarines	31,851	0.39

Table A1. Total production of fruit and vegetables in Australia

Produce	Production (t)	Production fraction %
Green peas	19,811	0.24
Cherries	18,374	0.22
Plums	17,992	0.22
Limes	9,297	0.11
Apricots	8,700	0.11
Grapefruits	8,192	0.10
Brussel sprouts	7,906	0.10
Blueberries	6,810	0.08
Kiwifruit	2,082	0.03
TOTAL	**8,211,291**	**100.00**

Table A2. Total production of fruit and vegetables in Gippsland

Produce	Gippsland	
	Production (t)	**Producers**
Potatoes	67,028	56
Cabbages	25,478	5
Sweet Corn	15,432	12
Tomatoes	14,896	4
Onions	6,627	7
Broccoli	5,854	14
Carrots	5,205	4
Beans (including French and runner)	4,799	18
Apples	2,928	8
Cauliflowers	2,775	4
Capsicums (excluding chillies) -	2,417	4
Lemons	797	7
Grapes	466	8
Green peas	429	12
Pumpkins	289	7
Olives	99.5	10
Avocados	9.37	3
Peaches	8.67	4

Table A2. Total production of fruit and vegetables in Gippsland

Produce	Gippsland	
	Tonnes	**Producers**
Plums	5.29	6
Pears	3.82	7
Nectarines	2.50	3
Blueberries	1.56	4
Cherries	1.50	3
Apricots	0.96	3
Oranges	0.59	3
Strawberries	0.44	3
Brussels sprouts	0.43	1
Grape Fruits	0.43	4
Mandarins	0.22	3
Limes	0.17	3
Total	**155,556**	**228**

Table A3. Potential users or clients of the food hub

Companies	Categories	Locations
Simplot Australia Pty Ltd	Packaged Food - Processed Fruit & Veg	***Headquartered*** – Mentone, Victoria ***Manufacturing locations*** – NSW (Kelso, Bathurst), Victoria (Echuca, Pakenham) and Tasmania (Devonport, Ulverstone)
Heinz Co Australia	Packaged Food - beans and pasta, soups, sauces and dressings, vegetables, baby food, chicken, desserts, and ready meals	***Headquartered*** – Southbank, Victoria ***Manufacturing*** – Four manufacturing facilities
SPC Ardmona LTF (Parent: CCL)	Packaged Food - Processed Fruit & Veg, sauces, condiments, fruit snacks, ingredients, soups, ready meals	***Headquartered*** – Hawthorne East, Victoria ***Manufacturing*** – Goulburn Valley, Victoria ***National Distribution Centre*** - Shepparton
McCain Foods (Australia)	Packaged Food – Frozen Foods such as fries, pizza, veg, fruit and frozen meals	***Headquartered*** – Wendouree, Victoria ***Manufacturing*** – Ballarat, Victoria, Lisarow, NSW and Smithton, Tasmania
Wesfarmers Ltd	Processed Fruit & Veg	
Entyce Food Ingredients	• Ingredients (supply and product dvt) – Bakery ingredients, fruit and vegetable products in various grades, sizes, and origins, as well as in IQF, dried, dehydrated, puree, juice, aseptic, and powdered forms etc, grains, seeds, herbs etc • Packaged Food - Processed Fruit & Veg, sauces, condiments, dairy etc, processed meat	***Headquartered*** – Knoxfield, Victoria ***Distribution*** - Australia
Logan Farm	Packaged Food – Frozen Vegetable products (beans, peas, spinach, potato products, carrots etc)	***Headquartered*** - Southport, Qld ***Processing*** – NZ south island
OOB Organic	Packaged Food (Organic) – Frozen Fruit Desserts and Ice Cream, Smoothie Mixes, Frozen Berries,	***Headquartered*** - NZ ***Farm*** – Omaha, NZ north island
Patties Foods (Pacific Equity Partners)	Packaged Food - Ready Meals e.g. pies and frozen meals, Ice cream and frozen desserts	***Headquartered*** – Mentone, VIC ***Manufacturing*** – Bairnsdale, VIC
Nestle Australia (Nestle S.A.)	• Packaged Food – Breakfast Cereals, Confectionary, Processed Fruit & Veg, Rice, Pasta & Noodles, Baby Food • Beverages – Powdered Hot Drinks, Coffee Pods	***Headquartered*** – Rhodes, NSW ***Manufacturing*** – Gympie, QLD; Smithtown, NSW; Blacktown, NSW;

	• Baking Ingredients • Meal Replacement	Wahgunyah, VIC; Tongala, VIC; Broadford, VIC; Campbellfield, VIC ***Health Sciences*** – Mulgrave, VIC
Unilever	• Packaged Food – Ice Cream & Frozen Desserts, Processed Fruit & Veg, Edible oils, Snacks, Meals, Soups, Spreads • Beverages – Tea	***Headquartered*** – Sydney, NSW. ***Manufacturing*** - Various
Parmalat Australia (Parmalat Australia Pty Ltd)	• Packaged Food – Dairy (milk, cream, yoghurt, cheese etc), Ice Cream and Frozen Desserts • Beverage – Juices	***Headquartered*** – South Brisbane ***Manufacturing*** - Various
Lion	• Packaged Food – Dairy (milk, yoghurt, cream, cheese), Ice Cream and Frozen Desserts (pouring custard) • Beverages – Alcohol, Juice	***Headquartered*** – Sydney, Dairy & Drinks (Docklands, Vic), Alcohol (Auckland) ***Manufacturing*** - Various
Kelloggs	Packaged Food – Breakfast Cereals, Snacks	***Headquartered*** – Pagewood, NSW; Ferntree Gully, VIC ***Manufacturing*** – N/A
Sanitarium Health Food (Australian Health and Nutrition Association)	• Packaged Food – Breakfast Cereal, Spreads, Snacks • Beverages – Soymilk, almond milk, coconut milk	***Headquartered –*** Berkeley Vale, NSW; Auckland, NZ ***Manufacturing*** – Berkeley Vale and Cooranbond, NSW; Carmel, WA; Brisbane, QLD; Christchurch and Auckland, NZ ***Exports -*** China
Nutricia Australia	Fortified/Functional Packaged Food	
George Weston Foods	Packaged Food – Baked Goods, Processed Meat & Seafood;	***Headquartered –*** North Ryde, NSW; Port Melbourne, VIC; Auckland, NZ. ***Manufacturing*** – Victoria; New Zealand
Jalna Dairy Foods	Packaged Food – Dairy (Yoghurt)	***Headquartered –*** Thomastown, VIC. ***Manufacturing*** – Victoria
Goodman Fielder (Wilmar International and First Pacific)	• Packaged Food – Dairy, Baked Goods, Processed Meat & Seafood, Sauces, Condiments & Dressings, Edible Oils, Spreads • Ingredients – Baking	***Headquartered –*** North Ryde, NSW; ***Manufacturing*** – Over 40 plants in Australia, NZ, PNG, Fiji and New Caledonia ***Other Markets*** - APAC
Aspen Pharmacare Australia Pty Ltd	Fortified/Functional Packaged Food	***Headquartered*** - St Leonards, NSW
Bead Foods Pty Ltd (Chobani)	Packaged Food – Dairy, Desserts, Soups	***Headquartered*** - Dandenong, VIC ***Manufacturing -*** Victoria
A2 Dairy Products Australia Pty Ltd	Packaged Food – Dairy	***Headquartered –*** North Sydney, NSW ***Manufacturing*** – N/A.

Murray Goulburn Co-operative Co Ltd	Packaged Food - Dairy	***Headquartered –*** South Bank, VIC. ***Manufacturing*** – Victoria
Hansells Foods Australia Pty Ltd	Packaged Food – Snacks, Desserts, Soups	***Headquartered –*** Auckland, NZ.
Vitaco Health Australia Pty Ltd/Vitaco Holdings	• Packaged Food – Snacks, Cereal, Sauces, Processed Seafood • Supplements and Sports Nutrition	***Headquartered*** – North Ryde, NSW; ***Manufacturing*** – 3 facilities across Aus and NZ
Tempo Foods	• Packaged Food – Dairy (Yoghurt, Milk, Cream, Cheese), Ice Cream and Frozen Desserts • Beverage – Juice	***Headquartered*** – Mordialloc, VIC; ***Manufacturing*** – Gippsland, VIC;
Fonterra Brands (Australia) Pty Ltd	• Packaged Food – Dairy (Milk, Cream, Cheese, Yoghurt, Butter), Ice Cream & Frozen Desserts • Ingredients - Milk Powder, whey protein concentrate	***Headquartered*** – Auckland, NZ; Mount Waverly, VIC; ***Manufacturing*** - Victoria
Body Science International Pty Ltd	• Fortified/Functional Packaged Food • Protein Powders	***Headquartered*** – Gold Coast, QLD; ***Manufacturing*** – N/A
Black Swan Foods	Packaged Food – Snacks, Dairy (Yoghurts)	***Headquartered*** – Clayton South, VIC; ***Manufacturing*** - Victoria
Bellamy's Australia Ltd	Packaged Food – Baby Food	***Headquartered*** – Launceston, TAS; ***Manufacturing*** – N/A
Tamar Valley Dairy Pty Ltd (Fonterra Parent)	Packaged Food - Dairy	***Headquartered*** – Invermay, TAS; ***Manufacturing*** – Australia?
Mondelez International	• Packaged Food – Confectionary, Snacks, • Ingredients – Baking	***Headquartered*** – South Melbourne, VIC; ***Manufacturing*** - Suttontown (South Australia), Ringwood and Scoresby (Victoria), Claremont (Tasmania) and Dunedin (South Island, New Zealand).
Mars Inc	Packaged Food - Confectionary	***Headquartered*** – Wodonga, VIC; ***Manufacturing*** – N/A
PepsiCo Inc	• Packaged Food • Beverages – Soft Drinks	***Headquartered*** – Sydney, NSW; ***Manufacturing*** – N/A

Saputo Inc	Packaged Food - Dairy	***Headquartered*** – South Melbourne, VIC; ***Manufacturing*** - Victoria
General Mills Inc	• Packaged Food – Pasta, Rice & Noodles, Snacks, Desserts, Ready Meals, Sauces & Condiments • Ingredients – Baking	***Headquartered*** – Melbourne, VIC; ***Manufacturing*** – N/A
Arnott's Biscuits (Campbell Soup Co)	Packaged Food - Snacks	***Headquartered*** – Strathfield, NSW; ***Manufacturing*** - Australia
Swisse Wellness Group	Vitamins and Dietary Supplements	***Headquartered*** – Collingwood, VIC; ***Manufacturing*** - Australia
Blackmores	Vitamins and Dietary Supplements	***Headquartered*** – Warriewood, NSW; ***Manufacturing*** - Australia

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Feasibility options for an innovative food manufacturing hub

Chapter 2. Hub Processing Infrastructure and Capital Scenario Modelling and Forecasting

Participants: CSIRO

Authors: Kirthi De Silva, Peerasak Sanguansri, Filip Janakievski, Pablo Juliano

Citation

De Silva K, Sanguansri P, Janakievski F, Juliano P (2018) Feasibility options for an innovative food manufacturing hub. Hub processing infrastructure and capital, scenario modelling and forecasting. CSIRO, Australia.

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Executive summary

A preliminary assessment of the capital investment required for the infrastructure to establish a processing facility (hub) for the commercialisation of premium fruit and vegetable derived ingredients from Chapter 1 was undertaken. These ingredients include concentrates or powders, which are made of either whole fruit or vegetables fractions, non-fermented or previously fermented. The hub will be designed to process up to 22,000 tons of fresh horticultural feedstock annually (or up to 5 tons/h maximum capacity) to produce the targeted ingredients. The preliminary estimate on annual revenue of the hub from the sale of the targeted ingredients was $66.4M and the annual operating cost was estimated at $45.8M.

The equipment required in the hub to manufacture these ingredients was identified and costed as part of the capital investment. Using the study method of capital cost estimation with its ±30% error as a first approximation, the building costs, services infrastructure and working capital were estimated at $24.8M and included a contingency of 15% of the installed equipment cost. Total annual production costs were estimated at $45.8M and included direct and fixed operating costs as well as contingency costs. Operating costs included feedstock, utilities, consumables and labour, maintenance, effluent treatment as direct costs. Other fixed costs were assumed to include indirect labour, plant overheads, insurance, laboratory costs and marketing of the hub. The estimated net income of the venture before interest, tax, depreciation and amortisation was $20.6M pa.

An estimated cash-flow and profitability analysis indicated a Net Present Value of $93.1M over a 15-year life span with a 3 year payback period. Other financial profitability parameters also indicate good financial health for the hub across the 15 year period. These included a Discounted Total Capital of $22.5M with a Net Return Rate of 27%, Internal Rate of Return of 42% and Return on Investment of 66%.

The infrastructure investment costs for the hub were used to model the profitability criteria through a risk sensitivity analysis. A range of price points of the feedstock (i.e., fresh produce), price points of the specialty ingredients (final products), and scenarios on incremental utilisation of the hub were used in the analysis. All scenarios predicted good financial health for the hub over the 15 year period. The greatest risk sensitivity found, in terms of variability on return-on-investment seen upon changing production parameters, was due to variations on fibre extract powder production volume and price, followed by price of fresh produce used as feed.

Background

In response to an imminent need for regional diversification in the Australian Horticultural industry, there is an opportunity to establish a food manufacturing hub to drive job creation and innovation for regional economic growth. The concept of a regional manufacturing hub opens up not only the opportunity to bring 'smart specialisation' into the region, but also an opportunity to focus state resources to strategically grow the agribusiness sector through value addition. The needs for existing horticulture food clusters such as the East Gippsland Food Cluster are similarly being addressed, to value-add regional produce, attract investment to the region, and support better returns to growers while developing new capabilities through 'smart specialisation'.

As a result, a collaboration framework has been developed between the East Gippsland Food Cluster, the Latrobe Valley Authority, Corelli Consulting, Swinburne University, the Monash Food Innovation Centre (Monash FIC) and CSIRO to support and progress the concept of a food manufacturing hub for Gippsland focused on horticulture products.

This report includes the contributions by all parties to a pre-feasibility study, which provides a high level assessment for the establishment of an innovation manufacturing hub with smart specialisation for modular food processing and integrated technologies with the objective of achieving Industry 4.0. The initial stage of the project considers the value addition to horticultural products. The project was be led by CSIRO in collaboration with Corelli Consulting, Swinburne University, and the Monash Food Innovation Centre (FIC).

This consortium is aware that innovative enterprises often create successful new product or technology concepts, yet often fail to bring these products to the market, due to the high risks involved in capital investment for food processing infrastructure. Many commercial clients of CSIRO's Food Innovation Centre have also faced the same challenge despite an early investment into R&D.

The activities summarised below define the scope and key deliverables of the pre-feasibility study with the goal of progressing the development of a regional food manufacturing hub based on primary produce, generating commercial returns for growers, and deploying innovative technologies. The food manufacturing hub concept is applicable within the context of most horticultural regions across Australia.

The economic evaluation and financial projections are based on assumptions and are only a guide and not definitive. While the authors believe that the figures presented are indicative of the projected financial performance of the hub, no guarantee, either express or implied, is provided for their accuracy. CSIRO is not a licensed financial advisory entity, and as such, it is recommended that independent financial advice be sought before any investment.

1 Economic analysis of the hub

1.1 Hub operation

The food processing hub will operate by sourcing feedstock from growers in the region who can supply fresh fruit and vegetables. The infrastructure identified for the hub is based on technologies that are commercially available and capable of transforming the fresh feedstock into specialised food ingredients. The hub will mainly focus on level 4 processing or specialist processing into key ingredients shown in Figure 1 including: whole material powders, fermented solids, fibre extracts, and non-fermented or fermented extracts in dried or liquid form as concentrates. Market segment examples of these products and their market growth dynamics in key local and export markets were previously defined in Chapter 1. The parallels between both market and production terminologies are shown with examples in Table 1.

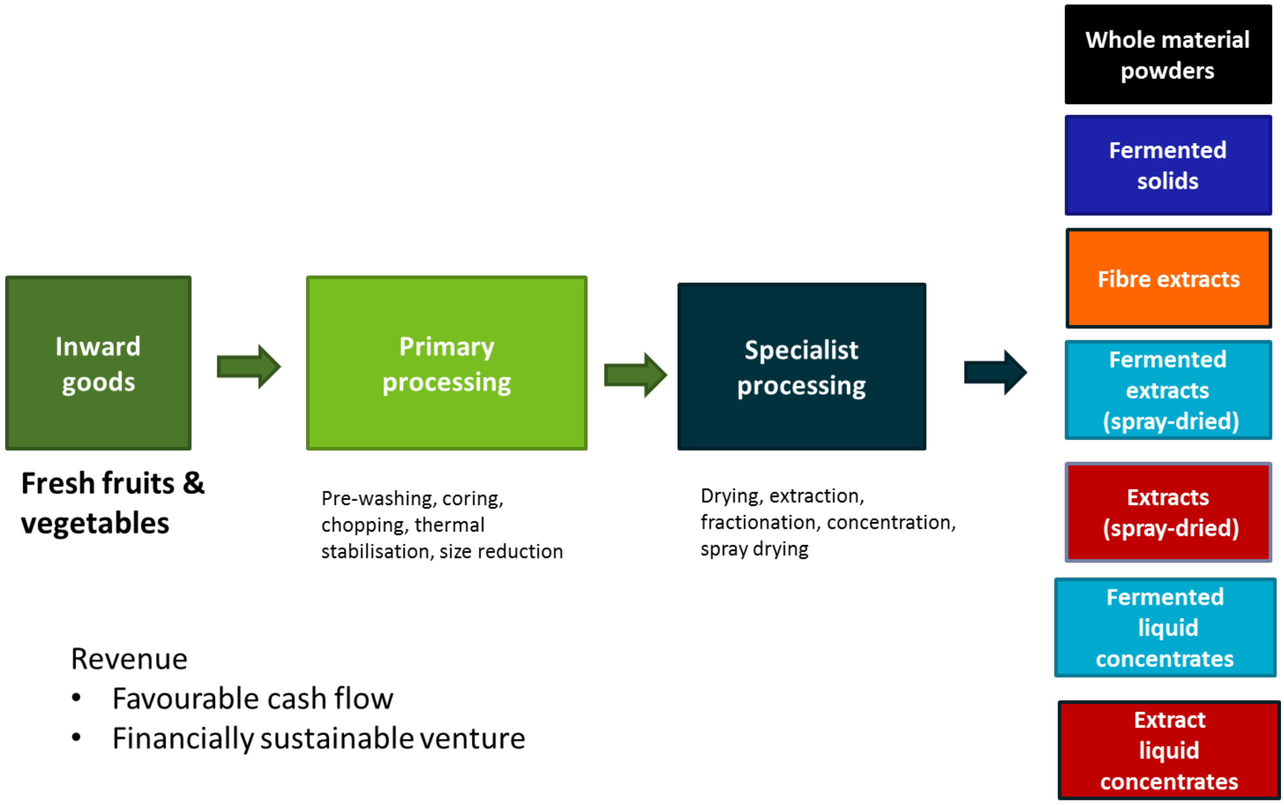


Figure 1. High level hub process flow diagram

Table 1. Correlation between market demand and manufactured product opportunity

Specialty ingredients (market demand - Euromonitor)	**Products manufactured by the hub**	**Examples**
Antioxidants and botanicals (incl. carotenoids) Colours and flavours	Extracts (concentrates or spray dried powders; non-fermented)	Beta-carotene, polyphenols, grape skin extract powder, fruit and vegetable concentrates, natural flavouring concentrates
Other flours	Whole material solids (powders)	Broccoli powder, carrot powder
Polysaccharides and oligosaccharides	Solid extracts and fibre powders	Fibre, pectin, cellulose gel, modified food starch, oligosaccharide powders
Proteins	Extract powders (spray dried)	Broccoli, asparagus, lentil, soybean, pea protein powder
Digestive health (pre/probiotic)	Fermented concentrates or powders with or without live cultures	Kimchi dried mix, sauerkraut powder, other fermented concentrate mixes including berries, coconut and/or other fruits or vegetables, fibre

2 Hub infrastructure and processes

This section will outline the assumptions underpinning the modelling for the infrastructure and materials processing within the hub facility. The economic evaluation and financial projections are based on assumptions and are only a guide and not definitive. While the authors believe that the figures presented are indicative of the projected financial performance of the hub, no guarantee, either express or implied, is provided for their accuracy. CSIRO is not a licensed financial advisory entity, and as such, it is recommended that independent financial advice be sought before any investment.

The hub will have a core processing infrastructure (unit operations) that is capable of employing processes that are already developed to transform horticulture feedstock to produce ingredients for local and export markets that secure financial sustainability through the project lifetime (further information in Chapter 3). In addition, research & development of new innovative processes based on the core unit operations to manufacture new ingredients from existing and new horticulture products may be carried out by research providers such as CSIRO or Universities using their laboratory and pilot facilities to define the final process, product specifications and manufacturing conditions will be scaled up and commercialised in the hub.

The hub may also comprise integrated technologies for Industry 4.0. Modern information and communication technologies like cyber-physical system, big data analytics and cloud computing, may help early detection of defects and production failures, thus enabling their prevention and increasing productivity, quality, and agility benefits that have significant competitive value. A high level description of the smart specialisation components for this high level study is included in the Appendix. The supply chain logistic and processing infrastructure will include connectivity devices. The identification of such devices is out of scope in the current study and should be considered in the next stages of feasibility.

The hub is assumed to process up to 22,000 tonnes per year of selected fruit and vegetables (4.6 tonnes/h, Table 2) and market the specialist products generated, from the outset of operation. Manufacturing of ingredients will occur in modules equipped with unit operations intended to manufacture powders or concentrates.

As shown in the diagram in Figure 2, an inward goods reception area will be dedicated for fresh produce as feedstock including facilities with storage and refrigeration (e.g., cool rooms). In primary the processing area product sanitation, enzymatic and microbial stabilisation (blanching & or other methods of stabilisation) and size reduction will be carried out.

The stabilised and size reduced feedstock is assumed to be further processed as follows (Figure 2):

1. Approximately 20% will be subjected to the *solid drying process*. The energy efficient water removal drying method should be designed to maintain product specifications and quality, followed by further size reduction and packaging into bulk bags as whole material powder ingredients.
2. Approximately 65% will be used for *extraction of bioactive components* in the liquid phase followed by *separation of the extracts* from the insoluble fibre fraction.
    - Extracted bio-compounds will be used as an ingredient or further fractionated through separation processes into specific target compounds. Both these products can be concentrated and pasteurised to create refrigerated liquid concentrates as ingredients.
    - The insoluble fibre components which is the co-product stream from this process will be *dried* followed by size reduction to make fibre extracts in powdered form and could be further blended with the whole powders in response to market demand for higher fibre powders.
3. Approximately 10% will be *fermented and pasteurised* to obtain fermented liquid concentrates. These concentrates can also be *spray dried* to manufacture fermented powders.
4. Approximately 5% will be used to produce *fermented ingredients* from sized reduced fruit and vegetables.

The hub will also have the capability to manufacture combination of ingredients, e.g., fermented extracts with enhanced insoluble fibre content as the market for innovative products develop.

The different fresh fruit and vegetable feedstocks will be stored segregated under refrigeration until utilised. Processing of the material will be determined by the demand for specific ingredients and the quality specifications. It is also assumed most of the ingredients may consist of a combination of different fruit and vegetable material blended to achieve the required specifications of the ingredient market. The hub may also have the capability to produce ingredients based on single specific horticulture feedstock, e.g., ingredients based on carrots alone.

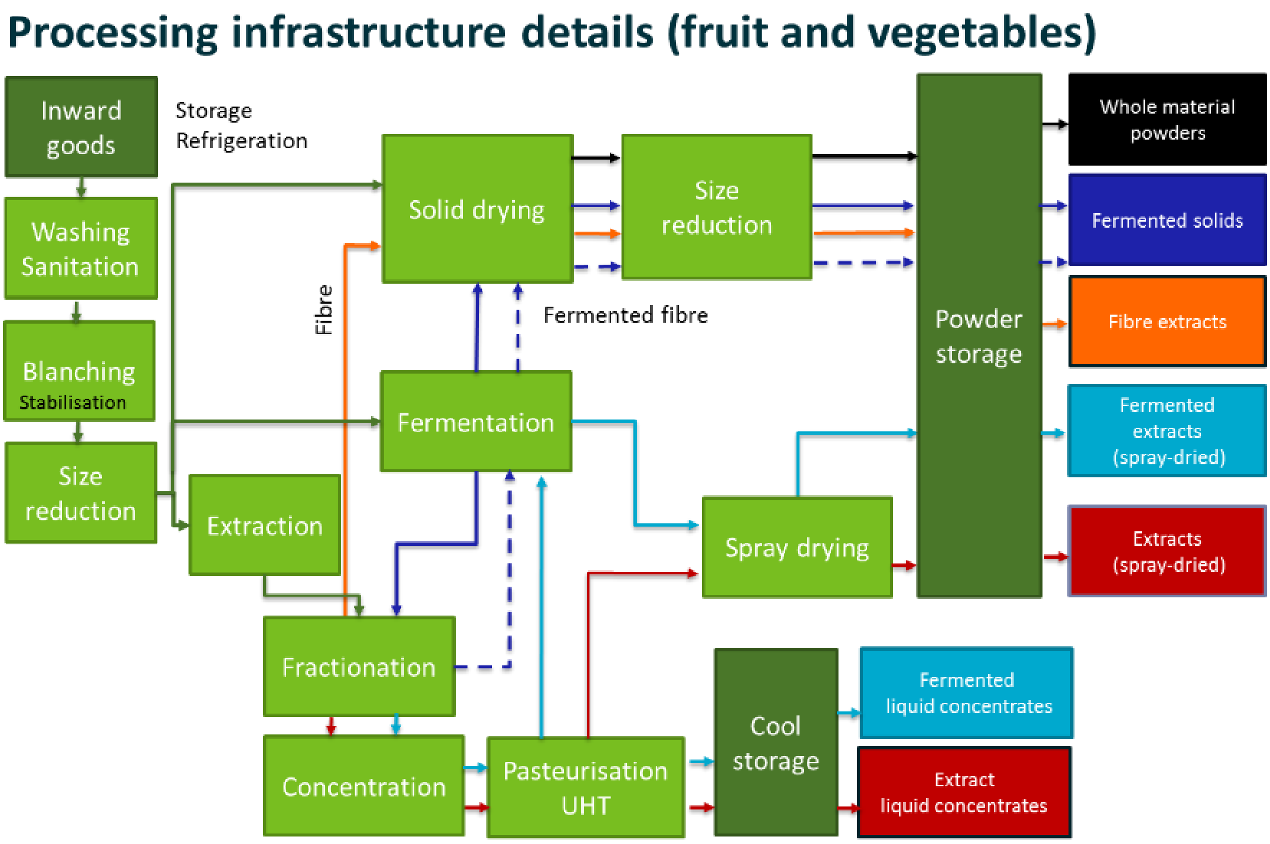


Figure 2. Unit operations recommended as part of the hub infrastructure

Table 2 shows indicative flow rates for each final product post fractionation, fermentation steps, and pasteurisation/UHT or drying steps. The capacity requirements for each unit operation outlined in Figure 2 was calculated based on a mass balance. Assumptions underpinning these estimates are that the processing plant operates for 40 weeks per year, 6 days per week and 3 shifts per day with 20 hours of production and 4-hours cleaning in place (CIP) cycle. These assumptions were used to calculate the annual production volumes for each target ingredient by assuming a 5% loss of solid material (Table 2).

Table 2. Indicative inputs into various product operations and output flow rates of target products

Material flows	Flow or production rate (kg/h)	Annual production (t/year)
Total f&v semi-finished product input to make:	4,583	22,000
Whole material powder	917	4,400
Fermented solids	183	880
Fermented concentrate	367	1,760

Extract concentrate	3,117	14,960
Total f&v ingredient output of:	516	2,352
Whole material powders	95	435
Fermented solids	19	87
Fibre extracts (powder)	321	1,463
Fermented extracts (spray dried)	34.32	156
Extracts (spray dried)	2.76	13
Fermented liquid concentrates	24.75	113
Extract liquid concentrates	18.72	85

2.1 Capital costs

2.1.1 ASSUMPTIONS AND METHODOLOGY

A pre-feasibility study to assess the viability of a food processing hub was carried out using the study method which is a chemical/process engineering economic cost estimation methodology to provide a ±30% range of accuracy on capital costs estimates (Couper, 2003, Saravacos, 2002, Peters, 1991).

The indicative equipment cost was estimated for the preliminary pre-feasibility evaluation using empirical methods with cost charts showing equipment cost against capacity (Brennan, 1998, Maroulis, 2007, Peters, 1991, Ulrich, 1984). Capacity adjustments for equipment cost was made using the relationship which allows an estimation of the cost of equipment if the cost of a particular capacity is known (Maroulis, 2007, Ulrich, 1984):

$$C = C_0\,(A/A_0)^n$$

where, C is equipment cost at capacity A and C_0 is cost at known capacity A_0 and *n* is the scale index which varies with the type of equipment and ranges between 0.5 and 1.0 and often taken as 0.6 (also known as the six-tenths rule, Peters, 1991). Considering the effect of inflation on the timing of the known cost and the difference in the material of construction, the following equation was used to estimate the equipment cost:

$$f_i f_m C$$

where, f_i and f_m are factors that take into consideration the impact of inflation and material of construction, respectively, on the cost of equipment (Maroulis, 2007, Ulrich, 1984).

The installed equipment cost was estimated by multiplying the estimated equipment cost by the Lang factor (Couper, 2003, Maroulis, 2007, Saravacos, 2002, Backhurst, 1981, Brennan, 1998). The Lang factor takes into account the costs associated with installation of the equipment and includes cost of instrumentation and control, electrical, piping and engineering. The Lang factor in food processing plants with instrumentation and process control is reported to vary from 1.5 to 2.5 (Saravacos, 2002) and is lower than in chemical plants due to the higher cost of equipment due to the use of stainless steel and less piping compared to chemical plants.

2.1.2 ESTIMATED CAPITAL COST OF THE HUB

The cost of the equipment selected for the unit operations shown in Figure 2 was estimated at $8.8M (Table 3). The equipment could be purchased all together as a single large investment or staged with the manufacturing of whole fruit and vegetable powders as a start and further unit operations added as the hub is established and the customer base developed. Table A1 in the appendix provides further details on the equipment used to estimate the total equipment costs.

The total installed equipment cost was estimated at $15.8M. This cost was estimated using a Lang factor of 1.8 (Maroulis, 2007) as the processes to produce ingredients are less complicated compared to other packaged food manufacturing operations such as dairy processing. Contingency for cost escalation was estimated at 15% of installed equipment cost and amounted to $2.37M, bringing the total estimated fixed equipment cost to $18.2M (Table 3). The working capital, i.e., the initial capital required to pay for the operation of the hub, was estimated at 10% of fixed equipment cost to cover the cost of raw materials and supplies carried as stock, finished and semifinished products, operating expenses and, accounts receivable and payable.

The building within which the equipment and the processing and storage areas were installed was proposed at 2,000 m^2 and the building cost was estimated at $1,300/$m^2$ (BMT, 2018).

Therefore, the total capital cost was estimated at $24.8M. The model assumes the land for the hub is provided by the statutory authorities or already owned, depending on the chosen ownership and business models.

Table 3. Indicative capital costs for the food processing hub ($ millions, AUD)

Total equipment cost	**8.78**
Installed equipment cost	15.80
Contingency (15% of installed equipment cost)	2.37
Fixed equipment cost	18.20
Services (Steam supply and distribution, electrical, auxiliary buildings, 12% of fixed equipment cost)	2.18
Building cost	2.60
Working capital (10% of fixed equipment cost)	1.82
Total capital cost (A$M)	**24.8**

2.2 Operating costs

2.2.1 ASSUMPTIONS AND METHODOLOGY

The operating costs of the venture were categorised into direct (variable and non-variable) and fixed costs. Direct variable costs (Table 4) include the cost of fresh produce as feedstock as well as running costs for water, electricity, and steam consumption. The average cost of the feedstock was assumed to be $1.5/kg. Other running costs include costs of packaging, cleaning in place (CIP) and chemicals for plant operation. Direct non-variable costs included in Table 4, generally consist of labour, maintenance, effluent treatment and, costs for replacement of consumables of separation and purification technology, e.g., membranes. Fixed costs estimated in this evaluation (Table 5) include indirect labour (25% of direct labour cost), plant overheads (25% of direct labour cost), insurance (3% of capital cost), and laboratory costs for quality assurance (20% of direct labour cost). Cost for marketing (B2B) of the hub was estimated at 1% of sales, assuming an initial set of cornerstone customers are aligned at the time of establishment of the hub. Maintenance costs was estimated at 5% of equipment cost. Effluent treatment was estimated at $300,000 per year after taking into consideration all biomass will be transformed into speciality ingredients, hence effluent streams will be minimal. In this model it assumed that costs of feedstock transport is included in the produce price. Other assumptions on product pricing and annual production, as well as operating capacity and capital costs are included in Tables A2 and A3 in the Appendix, respectively.

2.2.2 ESTIMATED OPERATING COST OF THE HUB

The total fixed and direct operating costs were estimated at $39.8M (Table 8). A $5.97M contingency comprising 15% of all (fixed and direct) costs was allowed for additional personnel and other activities not foreseen at this stage in this pre-feasibility study, making the estimated Total Production Cost $45.7M per annum.

Table 6 provides details of the breakdown of the required labour for the operation of the hub. The plant will include six specialised food processing equipment operators and a plant supervisor per shift within an automated setting with interconnected equipment to a centralised control room. The labour cost was taken as $50,000/ year and an additional 40% as on-cost and the cost of supervisor was taken as $80,000/year with an additional 40% on-cost. Other plant staff as well as staff in charge of purchasing, administration, management, sales, dispatch and logistics are accounted as overheads costs (Tables 5 and 6).

Other direct labour overheads include management, administration, quality assurance and marketing personnel (Table 6). Other indirect labour such as food technologists, fruit and vegetable processors or drivers can be subcontracted or outsourced according to labour demand and any additional staff will be covered through contingency costs at this pre-feasibility stage. The cost of training staff on a continual basis is assumed to be included within the contingency costs.

The most significant contributor to the cost of production (COP) is the cost of fresh produced used as the feedstock at 72%. The next highest cost was contingency at 13% followed by the cost of steam and labour, each at 3%.

Table 4. Estimated annual direct production costs of the hub.

Cost items (unit)	**Cost (A$M)**
Direct variable costs	
Input produce	33.00
Water	0.03
Energy (electricity)	0.19
Steam	1.44
Packaging and handling cost	0.01
Cleaning in place (CIP)	0.06
Chemicals	0.003
Total direct variable cost (A$M)	**34.82**
Direct non-variable costs	
Labour – operators for 3 shifts	1.26
Labour – supervisors for 3 shifts	0.34
Membrane replacement	0.13
Maintenance (% of equipment cost)	0.44
Effluent treatment	0.30

Total direct non-variable cost (A$M)	**2.47**
Total direct cost (A$M)	**37.3**

Table 5. Estimated annual fixed production costs of the hub

	Percentage	**Fixed cost (A$M)**
Indirect labour (% of direct labour)	25	0.28
Plant overheads (% of direct labour)	25	0.60
Insurance (% of capital cost)	3	0.74
Laboratory cost (% of direct labour)	20	0.35
Hub Marketing (% of sales)	1	0.45
Total fixed cost		2.52

Table 6. Estimate of direct and indirect labour requirements to operate the hub

Direct labour	
Plant operators	18
Plant supervisors	3
Total direct labour	**21**
Indirect labour	
Plant overheads and administration (including General Manager)	4
Laboratory costs (including Quality Assurance)	5
Marketing and sales	5
Total indirect labour	**11**
Total labour	**35 (FTEs)**
Contractors	Examples
	Food technologists (2-3)
	Fruit and vegetable processors (3-5)
	Drivers (4-5)
	Other subcontractors (5)

2.3 Income, expenditure and net income of the hub

The fruit and vegetable ingredient price and the actual demand for specific ingredients in the local and international market will determine the venture's income and the business cash flow. The revenue (Table 7) was assumed to be generated from specialty ingredient sales and assumptions were made on the range of market prices provided in the Euromonitor report. Unit prices were extracted from bulk market prices on antioxidants, colours, flavours, protein, oligosaccharides, prebiotics or probiotics, or other flours guided by the ingredient equivalence description in Table 1. Fibre prices were assumed to have similar pricing to flours. In most cases, 65-75% of the lower end of the range of the market research price provided by Euromonitor was taken as a conservative estimate of the sales price achieved by the hub in estimating the sales income.

Based on specialty ingredient sales utilising the total available fruit and vegetable fresh produce as feedstock (22,000 tpa), the annual sales income of the venture at full operational capacity is estimated at $66.4M. The estimated annual net revenue before interest, tax, depreciation and amortisation (EBITDA) and making an allowance for contingencies of 15% of direct and fixed cost was $20.6M (Table 8).

Table 7. Estimated annual sales income of the hub at full operational capacity, based on the discounted lower end of the ingredient process reported by Euromonitor.

Specialty ingredient	Ingredient sales (t/year)[1]	Price per ton (A$)[1]	Annual sales (A$M/year)[2]
Whole material powders	435	26,299	11.4
Fermented solids	87	31,234	2.7
Fibre extracts (powder)	1,463	26,299	38.5
Fermented extracts (spray dried)	156	46,851	7.3
Extracts (spray dried)	13	41,867	0.53
Fermented liquid concentrates	113	31,234	3.5
Extract liquid concentrates	85	27,911	2.4
Total income			**66.4**

[1]obtained from Chapter 1 (Table 6)

[2]calculated value

Table 8. Net income of the venture

Cost item	Cost (A$M)
Total direct cost (see Table 4)	37.3
Total fixed cost (see Table 5)	2.5
Contingency (15 % of total direct and fixed cost)	6.0
Total production cost (total fixed and direct cost, plus contingency)	**45.8**
Total Income	**66.4**
Net income	**20.6**

It should be noted the hub is capable of operating under several different business and ownership models as discussed in the Chapter 3. As the business and the ownership model of the hub is not decided at this pre-feasibility stage, there is adequate margin to adopt a range of ownership models including toll processing. This is because we have assumed the lower end of the ingredient sales price range and further discounted this price to estimate the venture’s sales income.

3 Cash flow and profitability analysis

3.1.1 ASSUMPTIONS AND METHODOLOGY USED IN PROFITABILITY ANALYSIS

The projected cash flow of the hub was estimated based on the assumptions of sales income and expenditure over the life of the project, and initial capital expenditure.

The profitability of the hub was assessed projecting future cash flows and using the following criteria:

Net present Value (NPV)

NPV is the sum of the future cash flows over the life of the project converted to present day equivalents using a discount factor which takes into account the cost of capital (e.g., weighted average of the costs of debt and equity and a factor for risk). The NPV corresponds to the net return after allowing for the cost of capital and recovery of the investment. A positive NPV represents a positive net return of future cash flows from the projects in present year dollars.

Net return Rate (NRR)

NRR is a profitability measure where NPV is compared to the original investment discounted to the same point as NPV. Because the discount rate covers the cost of capital of the project, NRR represents the net return on the project. The equation used to calculate NRR was:

NRR = ((NPV/DTC)*100/project life

where, DTC = discounted total capital or investment

Internal Rate of return (IRR)

IRR also known as the Discounted Cash Flow rate of Return is the rate of return which makes the sum of the cash flows discounted to the present day sum to zero. It also represents zero profitability and it indicates the maximum value the cost of capital can rise for the project to break even.

Payback time (PBT)

PBT represents the number of years for the cumulative net cash flow to sum to zero (i.e., the time taken for the net cash flow to equal the initial investment). PBT provides an estimate of the risk period of the project and provides an estimate of the time required to recover the initial investment.

Return on investment (ROI)

ROI is the return on capital employed after meeting all expenses, including interest over the life of the project. Depreciation is not taken into account in this calculation.

3.1.2 ECONOMIC ANALYSIS OF THE HUB

The cash flow and profitability analysis of the hub was carried out by estimating annual production costs and income over the 15 year life of project. This study assumed the sales volume to increase across the first 10 years of the project as shown in Table 9. In other words, the spare capacity for ingredient production was assumed to decrease from 60 to 10% underutilisation within the first 10 years of operation, with the sales revenue increasing from 40% to 90% by year 10. Once feedstock and specific ingredient are defined in a feasibility study, a staged approach with incremental investment in capital infrastructure will be considered.

The net present value (NPV) and the discounted total capital of the hub was estimated using a discount factor of 10%, which is higher than the current combined rates of interest and inflation and was taken as estimate of the cost of capital. Return on investment (ROI) was estimated on the net cash flow after allowing for interest at a rate of 6% and assuming all the capital was borrowed.

The cash flow analysis (Table 10) shows the cumulative sales revenue, expenditure, net cash flow and interest. Further details on these calculations can be found in the Appendix (Table A2). The cash flow indicates the hub will reach positive cash flow in just over 3 years at the assumed gradual increase in sales. The net present value (NPV) of the hub over the life of the project was estimated at $93M for an investment of $24.8M. The estimated financial parameters of profitability (Table 11) indicates positive outcomes over the 15 year project life resulting from a positive NPV) and NRR of $93M and 27%, respectively. A 42% IRR, 3.1 year PBT and 66% ROI are all healthy financial indicators estimated at this preliminary pre-feasibility stage for a low risk capital investment on a hub. The cash flow calculations on assessing the economic feasibility of the hub do not include equipment depreciation since the initial capital investment is taken as a negative cash flow item in year 0, the year the equipment is installed.

The estimated economic feasibility of the hub seems attractive due to many reasons and include (a) the fresh produce feed is transformed into many high value ingredients, (b) all the feedstock is transformed into ingredients, i.e., the amount of waste produced by the technology employed by the hub is minimal, compared to other food processes where a significant proportion of the feedstock may be a waste stream that incurs additional cost to further process and dispose, (c) the production of the range of ingredients is based on employing common unit operations, hence the utilisation of the equipment is high, (d) the operating cost of the hub is relatively low where the feedstock is the most significant COP of the hub accounting for over 70% of the operating costs.

Even though this study assumed incremental sales across the 15 year project period (Table 9), a multi-stage project implementation approach must be considered for planning and funding purposes once a clearer selection is made on target ingredients to manufacture. For example, one approach may include having a first stage where the hub is set up to manufacture powders only by purchasing a dryer and equipment for other related unit operations, comprising, for example, an estimated $11.2M initial capital investment, including building cost, services and working capital. A second stage of investment would expand production by including other modules and/or unit operations such as equipment for extraction, fractionation, fermentation, liquid pasteurisation and sterilisation and spray drying, nearing $13.6M of additional capital and installation costs. The multi-staged approach may also result in lower operating cost and lower income stream at the early stages, although the modelling for this approach has not yet been undertaken. Table 9 shows the initial plant utilisation, raw material requirements and related portion of the national and international fruit and vegetable ingredient market reach ranging from 0.16 up to 0.39% of the Australian local and key export markets.

Table 9. Plant utilisation assumption across initial 15 years

	Sales as a % of plant utilisation	**Raw material demand (tons)**	**Market demand portion (%, dry f&v powders consumption)***
Year 1	40.00	8,800	0.16
Year 2	60.00	13,200	0.23
Year 3	80.00	17,600	0.31
Year 4 -Year 10	90.00	19,800	0.35
Year 11 -Year 15	100.00	22,000	0.39

*Source: Chapter 1 (assumption: 8.6M demand baseline fruit and vegetable ingredient demand excluding fruit and vegetable juices and whole dried fruits and vegetables; annual growth in demand not included)

Table 10. Cash flow analysis across a 15-year operation

	A$M
Capital investment	**(24.77)**
Cumulative sales revenue	**869.78**
Cumulative total expenditure before interest	**(603.16)**
Cumulative variable cost	(438.74)
Cumulative non-variable direct cost	(36.99)
Cumulative fixed cost	(127.44)
Cumulative net cash flow	241.84
Cumulative Interest (6% of total capital cost)	(23.78)
Cumulative net cash flow after interest	**221.04**

Table 11. Profitability analysis for the hub infrastructure investment over a 15 year period

Net Present Value, NPV (A$M) Cumulative cash flow less capital cost after discounted factor (10% discount rate)	**$93.15**
Discounted Total Capital, DTC (A$M) After 10% discount rate	$22.52
Net Return Rate, NRR (%) (NPV/15 year)/DTC	**27%**
Internal Rate of Return, IRR (%)[1]	**42%**
Payback Time, PBT (years) Without discounting	**3.0**
Return on Investment, ROI (%)[2] (without discounting, after interest payment)	**66%**

[1] IRR is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero

[2]ROI = (cumulative net cash flow/15 year)/total capital cost

4 Risk sensitivity analysis

The sensitivity of the profitability criteria to risks associated with any changes in the assumptions used in the profitability analysis was conducted using risk estimating software (@Risk, Palisade Corporation, Version 7.5.1).

Sensitivity of the profitability criteria was analysed using a triangular probability distribution, with the risky variables at three levels (minimum expected, average, and maximum expected) (Figure 3). The simulation calculation which uses an iterative method, utilises this distribution to determine the minimum, mean and maximum expected value for the profitability criteria.

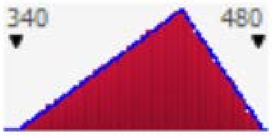


Figure 3 Example of a triangular probability function to estimate likelihood of expected values in an analysis. In this particular case, the minimum expected value = 340, the mean or most likely expected value 420 and maximum expected value = 480.

The software performed 5000 iterations using combinations of inputs of lower, expected and higher values of each risky variable and provided outputs for each financial criteria. The software provides a distribution of all outputs represented in probability and Tornado plots showing effect of inputs variables ranked by effect on the output mean.

The impact on the profitability of the hub was considered by changing the risky variables as detailed in Table 12

Table 12. The range of values used for the triangular probability distribution in the risk sensitivity analysis

	Low	Mean	High	
Feedstock Price ($/ton)	1200	1500	2000	
Sales as a % of production				
Year 1	30	53	75	
Year 2	45	63	80	
Year 3	60	75	90	
Year 4 – 10	70	85	100	
Year 11 - 15	95	100	105	
Product prices ($000's/ton)				
Whole material (powder)	19.7	26.3	36.8	Decrease by 25%; increase by 40%
Fibre extract (powder)	21.0	26.3	39.5	Decrease by 20%; increase by 50%

Fermented (powder)	25.0	31.2	46.9	Decrease by 20%; increase by 50%
Fermented (liquid concentrate)	23.4	31.2	46.8	Decrease by 25%; increase by 50%
Fermented spray dried (powder)	37.5	46.9	70.3	Decrease by 20%; increase by 50%
Extract (liquid concentrate)	20.9	27.9	39.1	Decrease by 25%; increase by 40%
Spray dried extract (powder)	31.4	41.9	58.6	Decrease by 25%; increase by 40%

The sensitivity analysis (Figure 3) shows with over a 90% probability that the NPV will be positive with a mean of $77.9M within the range of the risky variables tested. Table 13 summarises the 90% confidence intervals for all other profitability parameters within the range of variables tested. The probability of the venture achieving a negative NPV and a NRR of <0% was 6.8%, an IRR of <0% was 2%, a PBT of greater than 4 years was 20% and a ROI of <0% was 2.3%. The analysis also indicated that the probability of the venture achieving a NPV of >$30M was 80% and >$78M was 49%, an IRR >33% was 60% and a ROI of >33% was 79%. At this pre-feasibility stage of the hub and based on the assumptions made in estimating capital and operating costs (including cost of feedstock), product sales volumes and prices, the sensitivity analysis of estimated profitability parameters predict a positive financial health over a 15 year operating period.

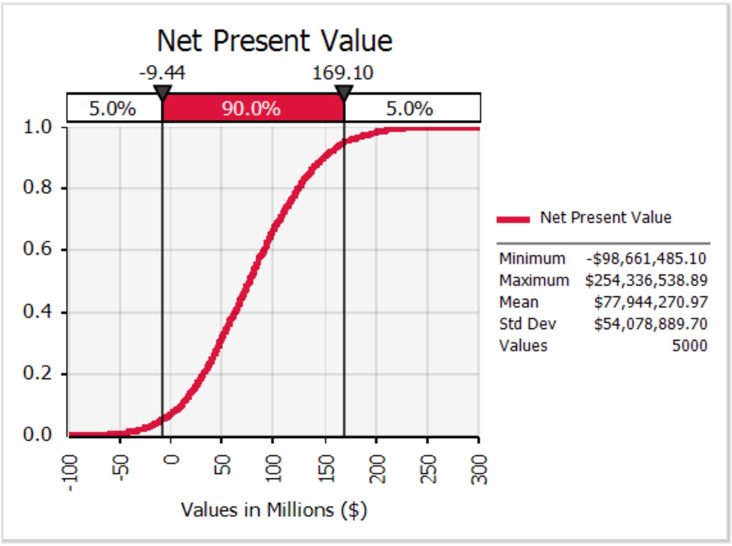
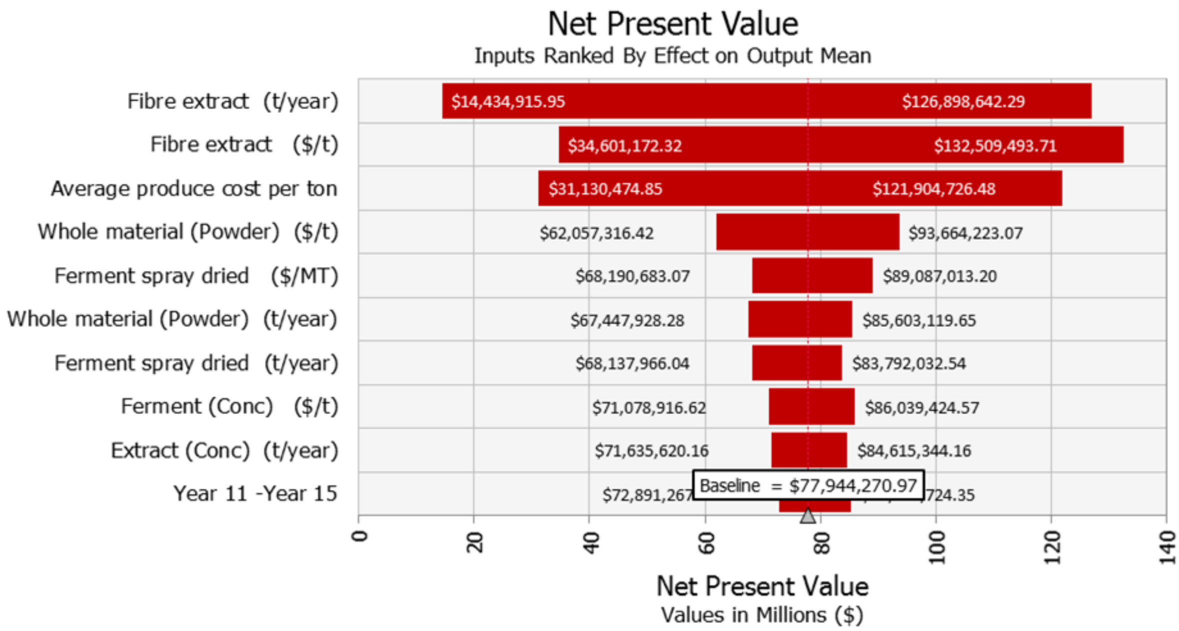


Figure 4. Indicative sensitivity analysis; cumulative probability plot of Net Present Value NPV has a probability of 90% to range between $-9.44 and $169M with a mean of $77.9M.

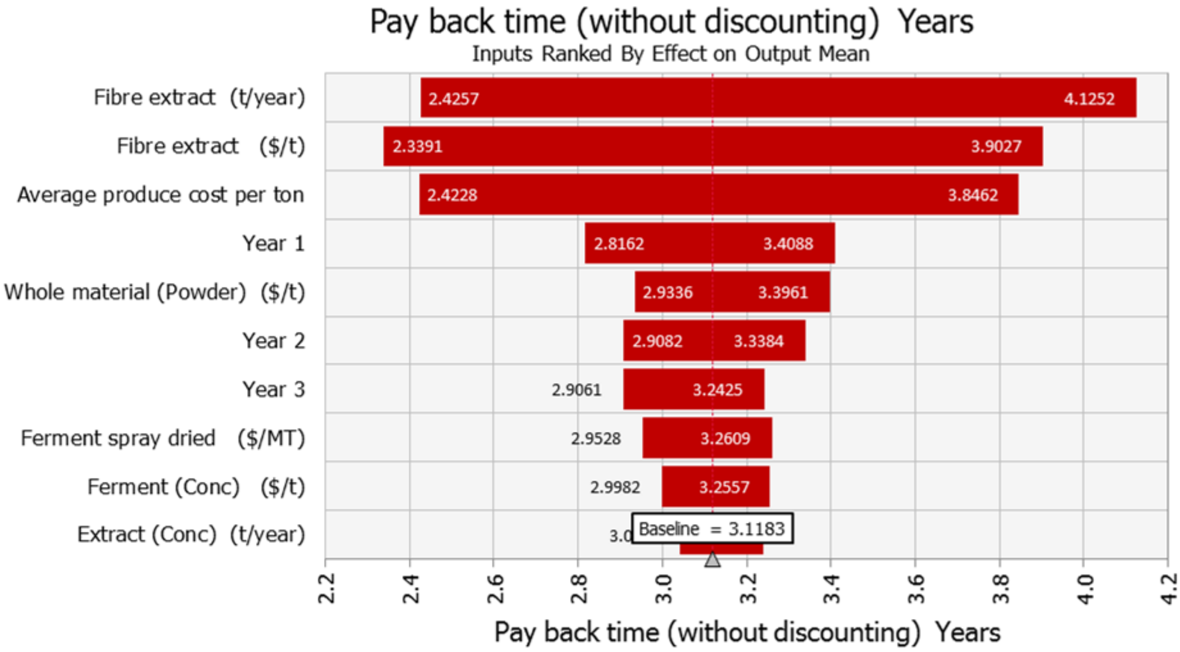
Table 13. Indicative sensitivity analysis of the profitability criteria of the hub.

Parameter	Low	Medium	High
NPV (AUD, $M)	-98	77.9	254
NRR (%)	-29.2	23.1	75.3
IRR (%)	-27.1	39	112
PBT (years)	1	3.1	6
ROI (%)	-44	58	157

Further sensitivity of the inputs and outputs of the risky variables impacting the financial performance of the hub are shown in the tornado plots in Figure 4. The tornado plots ranks the variables having the highest influence on the selected profitability criteria and the expected range of the criteria based on the range of the risky input variable. The tornado plots in Figure 4 show the greatest sensitivity impacting NPV (4a) and payback time (4b) investigated within the range of values considered for the risky variables was the quantity of fibre extract ingredient produced and sold, the price achieved for the fibre extract and the average cost of the fresh feedstock. These three variables had a similar impact on the other profitability criteria. (Table A3 in Appendix).



(a)



(b)

Figure 5. Sensitivity of (a) NPV and (b) PBT to variations on variables considered risky including feedstock price, the price and volumes of ingredients produced, and plant utilisation rate during Year 1, 2, 3 and 4-10.

5. Final remarks

The assessment of the profitability criteria of the venture was based on the hub processing horticulture biomass into selected ingredients and marketing the ingredients to other food and beverage manufacturers to manufacture packaged goods using the ingredients (i.e., B2B). Another variation to this option is operating the hub as a specialist toll manufacturer processing horticulture feedstock for a wide range of industrial customers. Notably, the hub will have the capacity to operate utilising both of these models. Further information on business models will be provided in Chapter 3.

Another option available as the operating model of the hub is that primary processing and stabilisation is carried out at the suppliers' site, that is, this task is decentralised to occur at the growers or horticulture feedstock aggregator site. Pre-processing fresh produce at the suppliers' sites and transporting to the hub for further processing will improve transport logistics with volume reduction and minimise food loss.

The financial benefits of both toll processing and decentralisation must be validated on each specific case. The final ownership and operating model of the hub venture is need to be refined with the choice of specific market targets and types of ingredients produced for a specific region.

The current pre-feasibility study was carried out with a high level estimation using the study method of capital cost estimation, which provides a ±30% error as a first approximation for the building costs, services infrastructure and working capital. A hub's feasibility study will require a more accurate definition of the target markets to inform the specific ingredients to be manufactured, which will enable estimating volume demands and final product pricing. As such the availability of fresh fruit and vegetable feedstock in the region will be able to be narrowed down to a specific set of participants. By knowing the specific ingredients required for the B2B transaction, the specific unit operations required along the primary and specialty processing steps will be defined. In this case, costing will require a more detailed approximation of equipment prices as well as direct and indirect costs. Income will also be refined by understanding a set of pricing ranges for the specific products in the hubs manufacturing planning pipeline in the short and long term.

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6 Appendix

6.1 Additional tables including assumptions

Table A1. List of equipment considered for the hub plant

Equipment purpose	Equipment type
Inward refrigeration	Refrigeration units
Washing & sanitation	Belt washer
	Process vessel
Stabilisation	Blanching
	Heat exchanger
Size reduction	Cutting
	Grinder
Fermentation	Solid state fermenters
	Liquid fermenters
Extraction	Specialised grinder
	Agitated jacketed tanks
Fractionation	Coarse Filtration
	Decanter
	Membrane filtration systems (MF, UF, NF)
Concentration	Forward Osmosis system, Reverse osmosis system
Preservation	Pasteuriser
	UHT system
Solid drying	Vibratory conveyor dryer
	Tray dryer
	Drum dryer
Product size reduction	Milling
Liquid drying	Spray dryer
	Evaporator
Product refrigeration	Refrigeration units (2-4°C)
Powder Storage	Flour bins
Boiler	

Table A2. Assumptions on product pricing and annual production

Products			
	t/year	AUD/t	Pricing
Whole vegetable powder (t/year)	435	26,299	25% of the average market research price for non-wheat flours
Fibre extract (t/year)	1463	26,299	25% of the average market research price for non-wheat flours
Solid fermented (t/year)	87	31,234	Pre/probiotic prices from market research
Fermented concentrate (t/year)	113	31,234	Pre/probiotic prices from market research
Fermented vegetable powder (t/year)	156	46,851	50% margin added to pre/probiotic prices from market research
Concentrated extract (t/year)	85	27,911	Average price of antioxidants/colours/flavours/proteins from market research
Extract powder (t/year)	13	41,867	50% margin added to average price of antioxidants/colours/flavours/proteins from market research

Table A3. Assumptions on operating, capacity and capital costs

Operations	
Hours/day	20
Day/week	6
Weeks/year	40
Fruit and Vegetable produce processing rate (t/year)	22,000
Feed stock price ($/kg)	15
AUD:USD	1.3
Sales growth (% of plant capacity)	
Year 1	40
Year 2	60
Year 3	80
Year 4 – year 10	90
Year 11 Year 15	100
Operating expenditure	
Salary cost of operators ($)	50,000
Salary cost of supervisors ($)	80,000
Operator and supervisor on-cost (%)	40
Capital costs	
Lang factor for installed equipment cost	1.8
Capital cost contingency (% of installed equipment cost)	15
Services (Steam supply and distribution, electrical, auxiliary buildings) (% of fixed equipment cost)	12

Table A4. Cash flow and profitability analysis for selected specialty ingredients manufactured by the food processing venture within a 15 year project timeframe

Operating Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Whole material (Powder) (t/year)		4,573,029	6,859,543	9,146,057	10,289,314	10,289,314	10,289,314	10,289,314	10,289,314	10,289,314	10,289,314	11,432,571	11,432,571	11,432,571	11,432,571	11,432,571
Fibre extract (t/year)		15,392,814	23,089,221	30,785,628	34,633,832	34,633,832	34,633,832	34,633,832	34,633,832	34,633,832	34,633,832	38,482,035	38,482,035	38,482,035	38,482,035	38,482,035
Ferment (solid) (t/year)		1,086,235	1,629,353	2,172,471	2,444,030	2,444,030	2,444,030	2,444,030	2,444,030	2,444,030	2,444,030	2,715,589	2,715,589	2,715,589	2,715,589	2,715,589
Ferment (Conc) (t/year)		1,410,017	2,115,026	2,820,034	3,172,539	3,172,539	3,172,539	3,172,539	3,172,539	3,172,539	3,172,539	3,525,043	3,525,043	3,525,043	3,525,043	3,525,043
Ferment spray dried (t/year)		2,932,836	4,399,253	5,865,671	6,598,880	6,598,880	6,598,880	6,598,880	6,598,880	6,598,880	6,598,880	7,332,089	7,332,089	7,332,089	7,332,089	7,332,089
Extract (Conc) (t/year)		952,813	1,429,219	1,905,626	2,143,829	2,143,829	2,143,829	2,143,829	2,143,829	2,143,829	2,143,829	2,382,032	2,382,032	2,382,032	2,382,032	2,382,032
Extract (spray dried) (t/year)		210,396	315,594	420,793	473,392	473,392	473,392	473,392	473,392	473,392	473,392	525,991	525,991	525,991	525,991	525,991
Capital Investment (AUD)	-24,770,832															
Sales Revenue (AUD)		26,558,140	39,837,210	53,116,280	59,755,815	59,755,815	59,755,815	59,755,815	59,755,815	59,755,815	59,755,815	66,395,350	66,395,350	66,395,350	66,395,350	66,395,350
Total Expenditure before interest (AUD)		24,889,975	31,854,064	38,818,152	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197	42,300,197
Net Cash Flow (AUD)	-24,770,832	1,668,165	7,983,146	14,298,128	17,455,618	17,455,618	17,455,618	17,455,618	17,455,618	17,455,618	17,455,618	24,095,153	24,095,153	24,095,153	24,095,153	24,095,153
Cumulative net cash flow (AUD)	-24,770,832	-23,102,667	-15,119,521	-821,393	16,634,225	34,089,844	51,545,462	69,001,080	86,456,698	103,912,316	121,367,935	145,463,088	169,558,241	193,653,394	217,748,548	241,843,701
Present value (AUD)	-24,770,832	1,516,514	6,597,642	10,742,395	11,922,422	10,838,566	9,853,241	8,957,492	8,143,175	7,402,886	6,729,896	8,445,204	7,677,458	6,979,508	6,345,007	5,768,188
Net Present Value (AUD)	-24,770,832	-23,254,318	-16,656,677	-5,914,282	6,008,140	16,846,706	26,699,947	35,657,440	43,800,614	51,203,500	57,933,397	66,378,601	74,056,060	81,035,567	87,380,574	**93,148,762**
Interest (6%, AUD)	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250	1,486,250
Variable cost (AUD)		13,928,178	20,892,266	27,856,355	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399	31,338,399
Non-variable direct cost (AUD)		2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922	2,465,922
Fixed cost (AUD)		8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875	8,495,875
Discount factor @ 10%	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505	0.3186	0.2897	0.2633	0.2394
Net Cash Flow after interest	**-23,284,582**	**181,915**	**6,496,896**	**12,811,878**	**15,969,368**	**15,969,368**	**15,969,368**	**15,969,368**	**15,969,368**	**15,969,368**	**15,969,368**	**22,608,903**	**22,608,903**	**22,608,903**	**22,608,903**	**22,608,903**
Cumulative net cash flow after interest	**-23,284,582**	**-23,102,667**	**-16,605,770**	**-3,793,893**	**12,175,476**	**28,144,844**	**44,114,212**	**60,083,581**	**76,052,949**	**92,022,317**	**107,991,685**	**130,600,589**	**153,209,492**	**175,818,395**	**198,427,299**	**114,631,220**

Table A3. Sensitivity analysis on Net Present Value (NPV), Net Return Rate (NRR) and Internal Rate of Return (IRR). Input variables are ranked by effect on output mean.

	NPV			NRR			IRR		
Rank	Name	Lower	Upper	Name	Lower	Upper	Name	Lower	Upper
1	Fibre extract (Powder) (t/year)	$14,434,915	$126,898,642	Fibre extract (t/year)	4.3	37.6	Fibre extract (t/year)	17%	56%
2	Fibre extract (Powder) ($/t)	$34,601,172	$132,509,493	Fibre extract ($/t)	10.2	39.2	Fibre extract ($/t)	23%	58%
3	Average produce cost per ton	$31,130,474	$121,904,726	Average produce cost per ton	9.2	36.1	Average produce cost per ton	22%	55%
4	Whole material (Powder) ($/t)	$62,057,317	$93,664,223	Whole material (Powder) ($/t)	18.4	27.7	Whole material (Powder) ($/t)	33%	44%
5	Ferment spray dried (Powder) $/MT)	$68,190,683	$89,087,013	Ferment spray dried ($/t)	20.2	26.4	Year 1	35%	44%
6	Whole material (Powder) ($/t)	$67,447,928	$85,603,119	Whole material (Powder) (t/year)	20.0	25.3	Ferment spray dried ($/MT)	35%	43%
7	Ferment spray dried (Powder) (t/year)	$68,137,966	$83,792,032	Ferment spray dried (t/year)	20.2	24.8	Whole material (Powder) (t/year)	35%	42%
8	Ferment (Conc, liquid) ($/t)	$71,078,916	$86,039,424	Ferment (Conc) ($/t)	21.0	25.5	Year 4 -Year 10	37%	43%
9	Extract (Conc, liquid) (t/year)	$71,635,620	$84,615,344	Extract (Conc) (t/year)	21.2	25.1	Ferment spray dried (t/year)	35%	41%
10	Year 11 –Year 15	$72,891,262	$85,306,724	Year 11 -Year 15	21.6	25.3	Ferment (Conc) ($/t)	36%	41%

Table A4. Sensitivity analysis on Payback Time (PBT) and Return on Investment (ROI). Input variables are ranked by effect on output mean.

	PBT			ROI		
Rank	Name	Lower	Upper	Name	Lower	Upper
1	Fibre extract (t/year)	2.4	4.1	Fibre extract (t/year)	22	85
2	Fibre extract ($/t)	2.3	3.9	Fibre extract ($/t)	33	88
3	Average produce cost per ton	2.4	3.8	Average produce cost per ton	32	82
4	Year 1	2.8	3.4	Whole material (Powder) ($/t)	49	67
5	Whole material (Powder) ($/t)	2.9	3.4	Year 1	52	64
6	Year 2	2.9	3.3	Year 4 -Year 10	52	62
7	Year 3	2.9	3.2	Whole material (Powder) (t/year)	54	63
8	Ferment spray dried ($/MT)	3.0	3.3	Ferment spray dried ($/MT)	52	61
9	Ferment (Conc) ($/t)	3.0	3.3	Ferment spray dried (t/year)	54	62
10	Extract (Conc) (t/year)	3.0	3.2	Extract (spray dried) (t/year)	54	61

6.2 Smart specialisation: Industry 4.0

The hub may also comprise integrated technologies for Industry 4.0. Modern information and communication technologies like cyber-physical system, big data analytics and cloud computing, may help early detection of defects and production failures, thus enabling their prevention and increasing productivity, quality, and agility benefits that have significant competitive value. This will be a critical component for the long term success of the hub, given the various company inputs based on various needs, diversity of raw materials processed, and range of finished products delivered to various markets. As such, the hub will also be virtually represented through digital plant models with sensor data and will be able to make decentralised decisions.

Industry 4.0 is described as the digitalisation and interconnectedness of products, services and value chains. It can be defined in relation to current trends of improved automation, internet of things (IoT), big data, machine-to-machine and human-to-machine communication, artificial intelligence, augmented reality, data analytics and robotics. Figure 6 shows the evolutionary steps into the 21st century. The framework defining Industry 4.0 activities in shown in Figure A1.

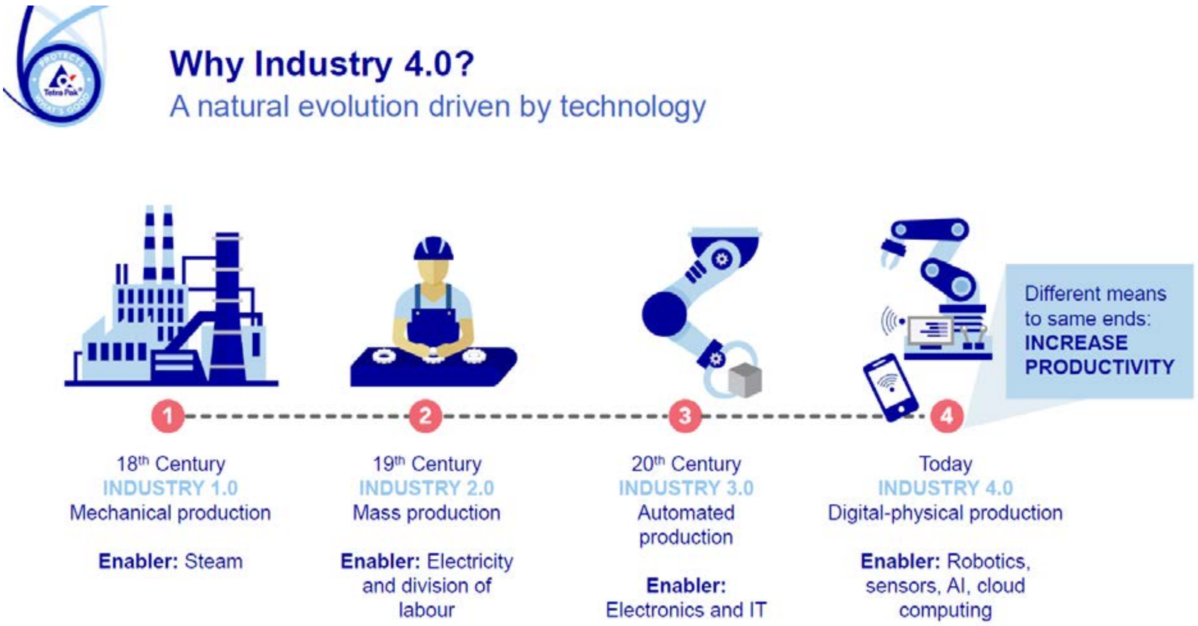
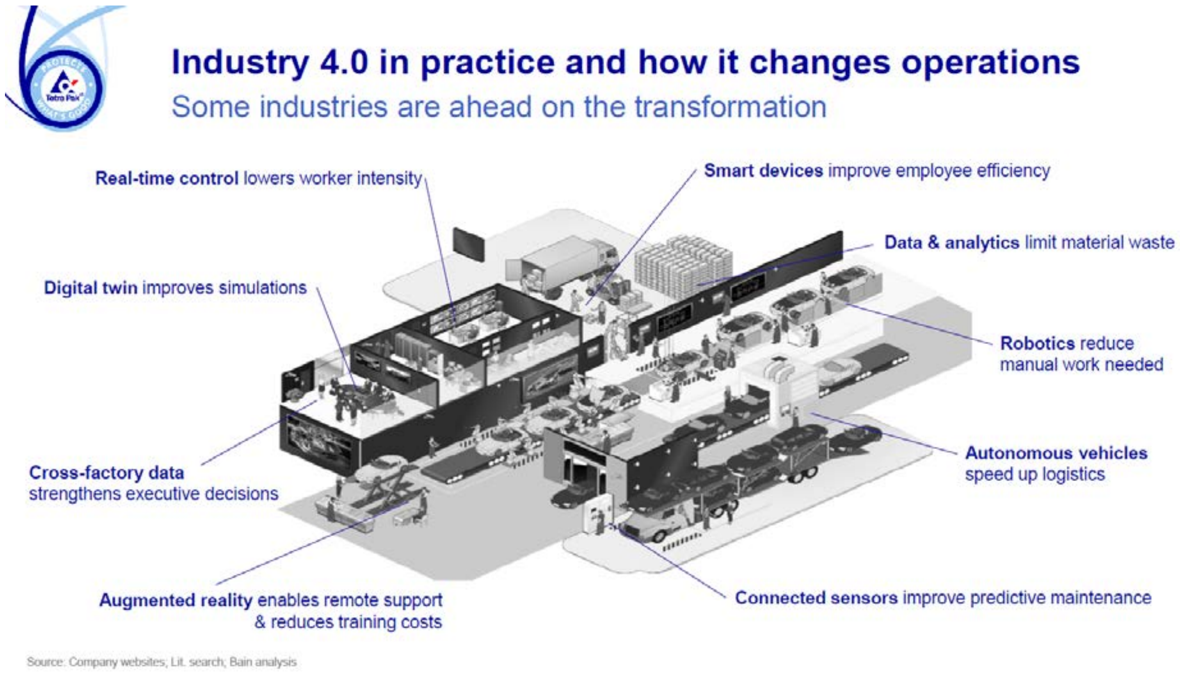


Figure A1. Industry 4.0 definition (source: TetraPack)

Figure A2. Industry 4.0 framework (Source: Leap Australia).

By applying an industry 4.0 approach the food manufacturing hub may potentially increase productivity, quality and support a high variant diversity of ingredients with increased flexibility. Figure 8 shows some examples of Industry 4.0 in the food industry. Communication with produce suppliers can be improved by placing machines in the field fitted with sensors (e.g., tractors/automated harvesters) to gather data on crop quality and volumes, which can be communicated to the hub for planning purposes. Data will be processed using standard production lifecycle management (PLM) tools superimposed by IoT platforms. Online communication with automated food processing equipment may occur through integration of IoT platforms, which will allow machines to communicate with systems, and systems to communicate with a cluster of systems.



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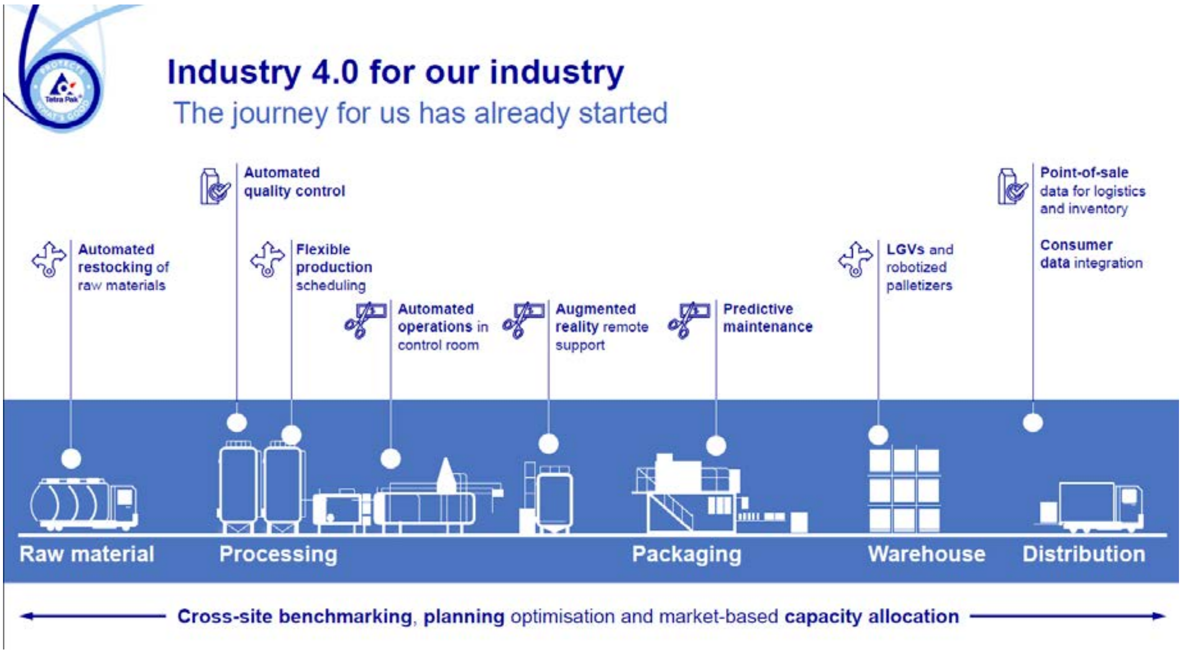

(b)

Figure A3. Examples of Industry 4.0 applications in the food industry

Food safety may be monitored in real time using online diagnostics and artificial intelligence may support product development through the collation of data on consumer preferences. Simulation platforms such as ANSYS may be used to create virtual prototypes, and process optimisation. These platforms will be applied to complex food systems across a diverse range of food unit operations (e.g., blanching, size reduction, fractionation, fermentation, concentration and drying) to monitor conditions in real time and adjust to specific bioactive or ingredient requirements. Real data from sensors and IoT may be used with digital twins. Augmented reality (AR) may be used for servicing, training and operation as well as process control. Raw materials entering the hub and final products can be classified using deep neural networks such as Tensorflow. NBIoT may be used to embed sensors in equipment and environment to monitor, these devices will have a battery life of 15 years.

Table 13 includes examples of key technology platforms suppliers globally. Some expert company providers of IoT technology include Australia include for exampler Leap Australia (https://www.leapaust.com.au/), Bosch Australia (https://www.bosch-si.com/iot-platform/bosch-iot-suite/homepage-bosch-iot-suite.html) and Vodafone https://www.vodafone.com.au/business/internet-of-things. Bosch vision for a manufacturing future is well described in this video. https://www.youtube.com/watch?v=ISk64bJ35yM&t=0s&index=7&list=PLToTXrdo6ZYErGakIx-C8VrI-pc8pW6NS

Table A5. Examples of technology platforms and commercial suppliers that could interact with the regional hub

Machine Learning Platforms • Amazon • Fractal Analytics • Google • Microsoft • SAS • Cisco • IMB • Informatica • Maana • Pegasystems • UiPath	Automation and IoT • PTC Thingworx • Schneider Electric • Rockwell • Bosch • GE • Yokogawa • ABB • Omron • Emerson • Hitachi • Honeywell • Mitsubishi	Robotics • Sarcos Robotics • KUKA rethink robotics • FANUC • Robotiq • IAM Robotics • Boston Dynamics • Ekso Bionics • Cybernetics • Lockheed Martin
Deep Learning Platforms • Deep Instinct • Fluid IA • MathWorks • Saffron Technology	Natural Language Generation • Attivio • Automated Insights • IBM • Nuance • Cambridge Semantics • Digital Reasoning • Lucidworks • SAS • Yseop	Design, PLM & Simulation • PTC Creo • PTC Windchill • ANSYS • Autodesk • Siemens • NEC • Mentor Graphics • Dassault Systems
Speech Recognition • NICE • Nuance Communications • OpenText • Verient Systems • Avaya • Microsoft	NLP • Basis Technology • Coveo • Flamingo • Indice • Knime • Lexalytics • Mindbreeze • Sinequa	Networking • Cisco • Vodafone • SigFox • ThingWorx • Sierra Wireless

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REPORT
Chapter 3: Business models and structuring

Project "Pre-feasibility options for an innovative food manufacturing hub"

Prepared for: Agriculture and Food, CSIRO

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CORELLI CONSULTING REPORT TO CSIRO

Project "Pre-feasibility options for an innovative food manufacturing hub"

Chapter 3: Business models and structuring

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CORELLI CONSULTING REPORT TO CSIRO
Chapter 3: Business models and structuring

BACKGROUND

The Agriculture and Food Business Unit at CSIRO (CSIRO) is collaborating with Horticulture Innovation Australia (Hort Innovation) in a project to develop technologies to transform vegetable loss streams into value-added product types: food and snack products, functional food ingredients and supplements, and fermented vegetables and beverages.

The global purpose of the research collaboration is to achieve both reduction of harvest-associated loss for the horticulture industry more broadly, and recovery of valuable nutrients and bioactive compounds from what is otherwise a waste stream.

The anticipated impact on horticulture producers from the translation of these technologies into commercial operations is to reduce losses in harvest-associated value, reduce environmental waste, generate additional revenues from a waste stream, diversify revenues, manage risk, and build brand [5].

However, the development of technologies will need a clear path to market to achieve the anticipated impacts for the horticulture sector.

Consequently, Hort Innovation commissioned a high level report to provide the aspiring grower with a broad, high-level understanding of the potential market landscape relevant to the value-added products, the supply and value chains required to bring new products to market, and operational models to leverage these new value-adding opportunities [5].

This project expands on that earlier work, providing addition detail and insights on the shape and prospects on a new venture in value-adding fresh horticultural produce. The purpose of this report is to provide critical information to the aspiring grower on the potential prospects for their current businesses, and to guide strategic decision-making.

The recommendations that follow are the opinions of Corelli Consulting based on analysis and review within the framework of the overall project, and may require further research, confirmation and comparison prior to a strategic decision being made by CSIRO or Hort Innovation.

OUTCOMES

The goal of this chapter is to examine company structures, business and operational models, risks, ownership and governance frameworks as options for a venture to leverage technical opportunities (such as those developed at CSIRO) to develop new value-added vegetable-based products. Lastly, the context of the competitiveness of the venture is considered.

The approach taken here is to gather data and intelligence by means of desk research and interview with industry participants and stakeholders across the horticulture supply and value chains. Interviews with key participants and stakeholders is intended to provide a reality check of, and additional insights into, the outcomes of desk research.

Desk research will make use of business management; industry reports for the horticulture, food and nutraceuticals and other relevant sectors; company websites and annual reports of potential client, customer and commercial comparables (successful expanded grower ventures, cooperatives, toll manufacturers, and joint venture partnerships established elsewhere); institute, industry association and government reports; and financial news and analysis.

SECTION A CORPORATE AND BUSINESS MODELS

EXECUTIVE SUMMARY

The goal of this section is to examine company structures, and business and operational models as options for a dedicated business venture to leverage technical opportunities (such as those developed at CSIRO) to develop new value-added vegetable-based products.

Potential company structure (incorporation or unincorporated) and type (proprietary companies, co-operatives, partnerships and joint ventures) for the new enterprise are reviewed. From a risk management perspective, proprietary companies, incorporated co-operatives, and joint ventures may offer attractive options as company structures within which to initiate the business. Case studies of proprietary companies, co-operatives, and joint ventures are provided as illustrations of the commercial sustainability and capacity to generate revenues of these company types. Further work is needed to refine the decision on company structure, based on, at least: the availability of a keystone participant from within or outside of the horticulture sector; the level of interest from a number of aspiring growers as co-investors in a company or as members of a cooperative; and the level of interest of a specialist processor or customer as a joint venture partner.

Operational models for the proposed venture need to account for the supply chain from field to finished product in an efficient and cost effective manner. The venture needs to consider whether the skills and capabilities needed to enable the business to operate successfully, in other words, each unit of operation, may be developed in-house, provided to the business by means of a sub-contractor, an acquisition, or by means of a collaboration such as a joint venture or partnership.

The elected company type will be a major driver of the operational model for the new venture. A clear understanding of the skills and capabilities required within the final operational venture, and the corresponding skills of the parties to the venture will determine how the shortfall in operational capability may be addressed. For example, a joint venture with a specialist processor may provide the company with critical experience and skills in, for example, process engineering at scale, and quality testing and management; a joint venture with a major customer may provide product specifications, clear path to market and security of offtake.

A financial model evaluating the cost-effectiveness of subcontracting operational units (such as specialist processing, marketing, packaging etc.), to support decision-making on the optimal business configuration, has yet to be completed.

The cost benefit and operational advantages to the new venture of a centralised or decentralised organisational structure were considered. A centralised operation is one that has all manufacturing steps (from pre-processing to finishing) and warehousing in one location. Decentralised companies can split out unit operations from within an overall production process or distribute entire production lines to different locations or regions. A decentralised strategy may be driven by the regional and/or seasonal availability of fresh produce as feedstocks or by the availability of highly skilled personnel in specific locations. This report considers that there may be cost and operational advantages to decentralise some units of operation or entire processes of the horticulture-based venture, based on the footprint of feedstock supply, by relocating the aggregation and pre-processing operations closer to fresh produce supply. By pre-processing fresh produce at the suppliers' sites, only process-ready feedstock would need to be transported to the manufacturing location. This report recommends that a cost benefit analysis is needed to define the optimal configuration for the agricultural value-adding venture.

Business models and scenarios to drive sustainable commercial operation of the venture /hub within the value chain were reviewed.

The business model can be refined by reflection on selected company structure and the strategic vision of the venture: as an example, a relevant strategic vision may be articulated as:

> "The core business is to add value to fresh horticultural produce as premium products for the food, beverage and nutraceutical industries, on behalf of shareholders or members."

The business model of the new venture may generate revenues by such avenues as:

- Core business: production of fresh produce and value added products including leveraging proprietary technologies; and
- Services contracts: leveraging skills, capability and capacity of the venture/hub in commercial scale mmanufacturing; supply chain management; quality assessment and reporting, quality certification; packaging: bulk or specialist packaging; warehousing and storage; pre-processing of fresh produce; and logistics and distribution.

Lastly, the market positioning of the venture by means of a business to consumer (B2C) or business to business (B2B) model was reviewed. B2C businesses are those that market and sell directly to consumers: therefore these businesses are product-driven, so investment in marketing and market trends, and a strong brand position is critical. By contrast, in the B2B model, products or services are marketed to business customers for use within their manufacturing operations. This report recommends that the new business venture consider the B2B market positioning: while B2B sales are more difficult to achieve, have a longer sales cycle and come with higher stakes for both buyer and seller, contracts tend to be longer term, often at a fixed price. This long term revenue may enable the new venture as a B2B businesses to make financial plans: clear expectations of profitability allow planning of future expenditure and returns to shareholders.

CORPORATE AND BUSINESS MODELS

This project assumes that the commercial activity of aggregating fresh produce, processing and marketing the final product will be conducted through a dedicated business venture. The underlying premise for the business venture is that the business operates on a sustainable commercial footing, and is profitable.

In an earlier report, options for that business venture were proposed as: an expanded single grower operation or as a cooperative grower operation. Access to the capabilities and capacities, necessary for the venture but outside the core skills of growers, were considered, including leveraging toll manufacturing and/or joint venture opportunities to provide specialised unit operations.

Ready access to fresh produce as feedstock is a major driver of venture success: access may direct the venture to co-locate with suppliers in order to aggregate and pre-process the manufacturing feedstocks. In this context, the venture may be considered a *processing hub* for feedstock aggregation.

Company structure

This section deals with relevant company structure for the establishment of the venture or hub as a business and is intended as a general overview only. This report recommends that, prior to a decision being made on final corporate and ownership structure, specialist advice such as legal and tax, is sought.

This section considers the options for an appropriate company structure for the manufacturing venture by company type (proprietary company, cooperative, joint venture or partnership) or by incorporation.

Incorporation

Incorporation of a venture has implications with respect to liability protection and tax, and whether a venture can raise capital through sale of shares of the company. Australian companies can be structured as incorporated or unincorporated entities:

- Incorporated entities: as proprietary companies, public companies, some joint ventures, cooperatives and incorporated associations; or
- Unincorporated entities: sole traders, partnerships, some joint ventures and trusts.

Decisions around the incorporation or otherwise of a new entity can be based on:

- Type and size of the entity;
- Ownership structure;
- Anticipated capital and financing needs of the entity; and
- Taxation and other practical organisational issues.

However, there are benefits to incorporation of a company or association, which may include [6]:

- Separate existence: the incorporated company is considered to exist separately from its directors and officers or shareholders and to have its own rights and obligations.
- Perpetual succession or existence: the incorporated company will continue to exist as a legal entity irrespective of changes to its individual shareholders. The company will cease to exist only on liquidation.
- Limited liability of shareholders: any business debts and obligations are considered to be legally those of the incorporated company. Therefore, if the company fails, the shareholders or members have to provide funds to the company only to the extent of the fully paid up value of their shares, rather than to meet any outstanding debts of the company. In a (public) company limited by guarantee, members have to meet only the amount they have guaranteed to the company.

Company Type

Proprietary company

This company structure dominates the Australian corporate landscape: ASIC reports there were 2,500,401 proprietary companies in 2017FY, representing the majority of all registered Australian companies [7]. Proprietary companies are private held, and operating at small or large scale: small to medium sized entities havie revenues less than A$25 million pa and fewer than 50 shareholders. Proprietary companies are unable to make public capital raisings, i.e. are unlisted, although these are able to offer shares to existing shareholders or employees of the company or a subsidiary of the company.

Compliance and reporting requirements less stringent for proprietary companies than for public companies. Proprietary companies must have at least one director and need not have a company secretary.

Co-operative
Co-operatives are owned and run by their constituent members. These businesses are established to provide services to their members, although members may also benefit financially from the services provided.

Co-operatives are governed by state and territory laws and by means of a set of rules designed specifically for each co-operative, rather than according to a constitution, by which proprietary companies are run. Should an incorporated co-operative fail financially, members' liability is limited to the amount of their original subscription, and any other amounts defined by an individual co-operative's rules.

Corporate governance of the co-operative requires that a board of directors is appointed by the members, with directors' duties as regulated under the Corporations Act 2001 (Cth) [8].

Partnership
Partnerships are unincorporated ventures established by two or more parties agreeing to establish a business together, in order to generate a profit for the partners. The corporate obligations and liabilities of this type of company is specified by the relevant State and territory Partnership Acts [9], and by the individual partnership agreement.

Notably, the unincorporated nature of a partnership means that, while the partners share the benefits that arise from the operation of the business, they equally bear personal liability for all debts of the partnership. This is in contrast to the shareholders of an incorporated company who have limited or no liability for company debts.

Joint venture
Joint ventures (JVs) are typically dedicated ventures where two or more parties enter into an agreement for the purpose of a specific business enterprise. A party to a JV may be a co-operative. The joint venture agreement defines how the JV is controlled and managed, usually by means of a management committee that represents each joint venture party.

Joint ventures may or may not be incorporated: incorporation of the joint venture has the advantage that liability may be limited to the joint venture legal entity as distinct from the joint venture partners.

Case studies
The following case studies are intended to illustrate collaboration between parties in the supply and value chain and the extent to which the collaboration generates benefits to each party in addition to revenues.

Joint venture: Supplier and Customer

Ermenegildo Zegna is an Italian luxury fashion label reporting gross revenues of €1.156 billion (A$1.72 billion[1]) in 2016FY, making it the largest menswear brand in the world by revenue. In 2014, Zegna formed a joint venture with Achill farm, a fourth-generation, family-owned 2564 hectare farm in NSW's New England region, running ~12,500 sheep. The joint venture delivers Achill's superfine 14-17 micron wool to its JV partner and customer, while its annual production of 20,000 kg pa is a fraction of Zegna's annual manufacture of ~500,000 kg of wool pa [10].

The benefits for Zegna are much broader than revenues or security of supply: this deal validates the company's corporate vision of "closing the loop" from manufacture to retailing. The JV positively impacts Zegna's branding and competitive position within the fashion industry, as the "first fashion company to become fully integrated from sheep to shop". In addition, Zegna clearly values the provenance and market significance of the rural location of its Australian partner as a supplier of premium suit wool.

In a similar way, the benefits for grower are in the branding ascribed to a commercial relationship with a significant European fashion house, guaranteed offtake for produce and risk mitigation of the overall business, otherwise so reliant on weather and market prices. The significance of the deal on the sector overall is not lost on the Australian Wool Innovation: "This joint venture is a clever move and one step towards invigorating the marketing of wool".

The JV is now investing in product improvements at Achill by means of better quality rams to enhance the genetics of breeding.

> "This joint venture is a clever move and one step towards invigorating the marketing of wool,"
>
> Walter Merriman
> Chair
> Australian Wool Innovation [1]

Co-operative: international perspective

US

Co-operatives are often established in the agriculture or primary production sector by growers or producers in order to aggregate fresh produce to a scale that generates a competitive position in negotiating contracts with processors, suppliers, logistics companies and/or customers.

Currently, around 2 million US farmers are member/owners of 2,106 co-operatives, with a share in ownership and a voice into the operations of the larger co-operative business [11]. As members of a co-operative, growers may derive benefits from an increased scale of access to consumers and an improved likelihood of product sales.

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[1]based on an historical exchange rate of 1 Euro equals 1.49 Australian Dollar, 30th June 2016 https://www.xe.com/currencycharts/?from=EUR&to=AUD

Co-operatives may decide to purchase supplies and services on behalf of members, passing on the savings from bulk purchase to reduce the costs for individual growers. This benefit of scale would otherwise be unavailable to the individual grower, providing security in the competitive landscape of food production.

In a co-operative, the members are shareholders. As members, growers own the co-operative and participate in decision-making and, when co-operative business is profitable, each member receives a share of that revenue. This means that, as stipulated by the co-operative model, all of net revenues is distributed back within the agricultural sector.

The experience in the US is that farmers have increased fresh produce sales by means of the co-operative structure. Farmers are also able to take advantage of services the cooperative offers in terms of networking, insurance coverage, rental space in cold storage, discounted seeds, and inexpensive website development [12].

Co-operatives have been created in many industry segments, and grower cooperatives have been established in all areas of agriculture, animal, dairy, and horticulture (see Table 1), with the model extended more recently to the production of biofuels and other commodities based on agricultural feedstocks [13].

Co-operatives can generate considerable revenues. In 2014, US co-operatives generated US$247 billion in total revenue; the 100 largest agricultural co-operatives generated a total revenue of US$176 billion. The largest US and 10th largest global co-operative by revenues, CHS, is a diversified global energy, grains and foods business established by farmers in 1929 [14]. (see Table 1).

Table 1: Top 20 US agriculture cooperatives, 2016 and 2015, by gross revenue (billion US$)

Ranking		Name	Type	Total Revenue	
2016	2015			2016	2015
1	1	CHS Inc	Mixed (Energy, Supply, Grain, Food)	30.532	34.696
2	2	Dairy Farmers of America	Dairy	13.619	13.906
3	3	Land O'Lakes, Inc.	Mixed (Supply, Dairy, Food)	13.273	13.069
4	4	Growmark Inc.	Supply	7.075	8.744
5	5	Ag Processing Inc.	Mixed (Grain, Supply)	3.411	4.45
6	6	California Dairies, Inc.	Dairy	3.002	3.182
7	8	Northwest Dairy Association	Dairy	2.106	2.558
8	11	Ocean Spray Cranberries Inc.	Fruit	1.708	1.706
9	10	Prairie Farms Dairy Inc.	Dairy	1.686	1.752
10	13	Blue Diamond Growers.	Nut	1.674	1.65
11	9	Southern States Cooperative Inc.	Supply	1.602	1.904
12	12	Associated Milk Producers, Inc.	Dairy	1.47	1.666
13	15	Foremost Farms USA,	Dairy	1.465	1.504
14	14	Select Milk Producers Inc.	Dairy	1.43	1.534
15	19	American Crystal Sugar Company.	Sugar	1.292	1.216
16	7	United Suppliers, Inc	Supply	1.264	2.635
17	18	South Dakota Wheat Growers Association	Mixed (Grain, Supply)	1.215	1.322
18	21	Sunkist Growers Inc.	Fruit	1.208	1.15
19	17	MFA Inc	Mixed (Supply, Grain)	1.19	1.441
20	20	Central Valley Ag Coop.	Mixed (Grain, Supply)	1.189	1.162

Source: Adapted from US Dept. of Agriculture [15].

Australia

Australian co-operatives range in size from small not-for-profit organisations to billion dollar commercial enterprises serving national and international markets. The following table shows the top 20 co-operatives registered under Australian co-operatives law [16].

Table 2: Top 20 Australian Co-operatives.

Rank	Co-operative	Industry	State	Turnover 2016FY
1	Co-operative Bulk Handling Ltd	Wholesale	WA	$1billion+
2	Norco Co-operative Ltd	Manufacturing	NSW	$1b - $500m
3	Geraldton Fishermen's Co-operative Ltd	Wholesale	WA	$500m - $100m
4	Independent Liquor Group Co-operative Ltd	Wholesale	NSW	
5	Western Australian Meat Marketing Co-operative Ltd	Wholesale	WA	
6	Namoi Cotton Co-operative Ltd	Wholesale	NSW	
7	Northern Co-operative Meat Company Ltd	Manufacturing	NSW	
8	Independent Liquor Group (Suppliers) Cooperative Ltd	Wholesale	NSW	
9	Plumbers Supplies Co-operative Ltd	Wholesale	NSW	
10	Dairy Farmers Milk Co-operative Ltd	Wholesale	NSW	
11	University Co-operative Bookshop Ltd	Retail	NSW	
12	New South Wales Sugar Milling Co-operative Ltd	Manufacturing	NSW	$100m - $50m
13	Hastings Co-operative Ltd	Retail	NSW	
14	Rapid Group Co-operative Ltd	Wholesale	NSW	
15	The Community Co-operative Store (Nuriootpa) Ltd	Retail	SA	
16	CCW Co-operative Ltd	Wholesale	SA	
17	Oz Group Co-op Ltd	Wholesale	NSW	
18	Master Butchers Co-operative Ltd	Wholesale	SA	
19	Yenda Producers Co-operative Society Ltd	Retail	NSW	
20	Lenswood Coldstores Co-operative Society Ltd	Wholesale	SA	$50m - $35m

Source: Adapted from Business Council of Co-operatives and Mutual [16].

In 2016FY, the agriculture sector was well represented among the largest national co-operatives: of the top 20 co-operatives in Australia, 7 were in agribusiness (~29%) (Table 2).

Within the corporate landscape, Australian agricultural co-operatives perform well: the second largest national co-operative by annual turnover was Norco Co-operative Ltd with revenues of A$1-A$500m pa (See Case Study).

While the business model of many co-operatives is based on aggregating and delivering fresh produce to the consumer, not all agri-based co-operatives are wholesalers: three report manufacturing as the core business (~40% of the agri co-operatives and 15% overall): Norco Co-operative Ltd, Northern Co-operative Meat Company Ltd and New South Wales Sugar Milling Co-operative Ltd (Table 2).

A feature of the manufacturing activities of these businesses is the value-adding of fresh produce.

Business and operating models

An earlier report considered a horticulture-based value chain with levels of increasingly specialised processing, and the risks, impediments and challenges facing the aspiring grower. That report outlined operational and organisational approaches that may provide the opportunity for the aspiring grower to embrace those challenges of value-adding, mitigate and manage the risks, and leverage the asset inherent in the horticultural feedstock.

This section will further explore business and operating models for the aspiring growers to consider in order to build further value within their current horticulture businesses.

Operational model

Operational models for the proposed venture need to account for the supply chain from field to finished product in an efficient and cost effective manner. The venture needs to consider whether the skills and capabilities needed to enable to business to operate successfully, in other words, each unit of operation (see Figure 1), may be developed in-house, provided to the business by means of a sub-contractor, an acquisition, or by means of a collaboration such as a joint venture or partnership.

<table>
<tr><th></th><th>Business operations</th><th>Feedstock production</th><th>Aggregation</th><th>Preprocessing</th><th>Specialist processing</th><th>Packaging, warehousing</th><th>Distribution</th><th>Role of customer</th></tr>
<tr><td colspan="2" rowspan="5">Interdependencies</td><td rowspan="5">Varietals determined by specialist processor or customer</td><td colspan="5">Market opportunity confirmed</td><td rowspan="5">Early review of manufacturing facility & production process</td></tr>
<tr><td colspan="5">Scale of supply (customer heads of agreement)</td></tr>
<tr><td colspan="5">Cost benefit analysis (financial model)</td></tr>
<tr><td colspan="5">Scale of commerically realistic business (financial model)</td></tr>
<tr><td colspan="5">License for proprietary technology</td></tr>
<tr><td colspan="2" rowspan="4">Unit operations</td><td rowspan="2">Feedstock production</td><td rowspan="2">Quality mgmt of feedstock received & dispatched</td><td rowspan="4">L1 or similar process</td><td>L3 or 4 process</td><td rowspan="2">Specialist packaging</td><td rowspan="4">Logistics management</td><td>Market insights</td></tr>
<tr><td>Process engineering</td><td rowspan="2">Formulation of final product</td></tr>
<tr><td rowspan="2">Harvest engineering</td><td rowspan="2">Traceability reporting</td><td>Quality analysis: inputs & outputs</td><td>Cold chain management</td></tr>
<tr><td>Marketing & sales</td><td>Inventory management</td><td>Customer testing</td></tr>
<tr><td colspan="2" rowspan="3">Contracts</td><td colspan="2" rowspan="3">Supply agreement with contract growers</td><td rowspan="3">Contract with pre-processor</td><td colspan="3">Shareholder agreement to establish specialist processor venture</td><td rowspan="3">Supply agreement with customer</td></tr>
<tr><td colspan="3">Agreement with toll manufacturer for specialist processing</td></tr>
<tr><td colspan="3">JV or partnership agreement with established specialist processor</td></tr>
</table>

Figure 1: Indicative overview of the requirements for a prospective business that value-adds fresh produce by means of CSIRO technologies. The supply chain from feedstock to customer is described, along with the parameters or interdependencies for the foundation of the business, the unit operations within the value and supply chain, and the contracts required to underpin business operation. Source: Corelli Consulting on behalf of Hort Innovation [5].

For successful operation, the venture needs skills and infrastructure to undertake and oversight each unit operations related to the supply and value chains: feedstock production and aggregation, feedstock pre-processing, specialised processing, packaging, warehousing and distribution (Figure 1). Some of those unit operations may require skills outside the core business of the growers, particularly those more specialist areas such as from quality analysis and management of feedstock (input) and product (output) and traceability reporting, through to process engineering, marketing and sales, and logistics management.

The venture then needs to consider whether to upskill existing employees, acquire those skills in-house, or to outsource, even initially, in order to shorten the timeframe to commercial operation.

Out-sourcing or In-house

Contract service providers or toll manufacturers may provide a cost-effective, and certainly an immediately, available option to a venture that is considering undertaking more specialist manufacture. This approach may be a useful interim measure to establishing a fully integrated value-adding venture.

Contract service providers may complete the venture's initial requirement for those specialist capabilities essential for successful execution of the business model. The benefit of this approach is that the investing grower(s) has immediate access to skills, capabilities, experience, equipment, and potentially an appropriately certified facility, in commercial scale process engineering, and in technical and quality analysis and management.

Similar consideration may be given to other essential components of a commercial-scale manufacture in terms of marketing and customer relations, and specialist packaging. Table 3 provides examples of commercial-scale services with credentials within the agri and food industries, and representative companies providing the service.

Table 3: Toll or contract manufacture: Representative Australian toll manufacturers and service offerings. Source: company websites

Service	Representative company	Website
Logistics, supply chain management	Toll Group	www.tollgroup.com/industries/chemicals-agribusiness
Liquid-based manufacturing (up to 26,000L), blending, formulation, quality assurance and lab testing	Imtrade Australia	www.imtrade.com.au/services/toll-manufacturing/
Manufacture and blending of powdered & dry food products.	Maltra Foods	www.maltrafoods.com/
Dehydrated powders and speciality food chemicals; distribution	Hellay Australia	www.hellay.com.au
Specialist packaging	Multipack	www.multipack.com.au/

Furthermore, contract services providers can be used to streamline production costs for the venture. Industry respondents among the specialist processors report delegating feedstock aggregation, traceability reporting and pre-processing to external contractors; not because these activities were technically challenging but outsourcing these activities allowed the business to focus on delivering against its area of expertise in speciality ingredient manufacture. Similar consideration may be given to outsourcing accounting functions, supply chain management, and logistics.

During establishment phase of the venture particularly, toll manufacturers may be contracted to provide:

- Demonstration-scale manufacture as part of the proof of concept of the scalability of a new process or product;
- Optimisation of commercial-scale manufacture;
- Protocol development (especially GMP[2]) for commercial-scale manufacture; and/or
- Specialist staff actually located at the venture facility to operate and oversight specific unit operations such as specialised processing at commercial scale.

A financial model evaluating the cost-effectiveness of subcontracting operational units (such as specialist processing, marketing, packaging etc.), to support decision-making on the optimal business configuration, has yet to be completed.

Case Study: Outsourcing

Flinders Ranges Premium Grain

Flinders Ranges Premium Grain Pty Ltd (FRPG) is a private company owned by four farming families, based in South Australia and established in 2001. The Company grows a specialist wheat variety used to produce a high protein flour, initially for the Japanese sponge and dough market, now marketed for artisan baking and patisseries. FRPG recognised that milling the specialist grain into a premium flour was outside the company's skill set and subcontracted that unit operation to Allied Mills in Adelaide under a toll milling arrangement "whereby we (FRPG) own the wheat, they mill the wheat for a fixed price; …we then (resume) control of the flour and make our own export arrangements" [3].

Commercial scale production of innovative technology

Toll manufacturing can be used to bridge the gap between lab scale and commercial scale manufacture by providing sufficient quantities of market-ready product for commercial trial and secruiring of a contract of sale to a customer. As an exemplar is an innovative technology developed by CSIRO to microencapsulated high fat powders using a patented encapsulation technology Micromax® that stabilise fats and represented a means of adding shelf-stable fat ingredients into various beverage or package food applications.

A number of Australian ingredient companies collaborated with CSIRO to commercialise the technology. One ingredient company was interested in selling high fat microencapsulated omega 3 powders and a second company was interested in selling microencapsulated powders with high fat oil blends. Figure 2 shows the steps undertaken by the companies to commercialise the innovative technology.

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[2] Good manufacturing practice (GMP) is the food industry is defined as the operational requirements necessary to enable a food business to produce food safely. https://haccpmentor.com/cleaning/gmp-in-the-food-industry/.

[3] Industry respondent.

The ingredients company contracted CSIRO's Food Innovation centre's pilot-scale capability: to generate a market-ready powder formulation, optimise large scale manufacturing condition, and conduct stability trials. As a result of successful pilot-scale trials, the ingredient company signed a licensing agreement with CSIRO for commercialisation of the technology into microencapsulated omega 3 powders. A technology evaluation step carried out by the company followed, which consisted of a desktop study to understand the technical and financial viability and scalability of the technology. The information captured during this stage also enabled a market study to determine the demand for the ingredient in various markets. Projected demands determined the scale requirements for market testing and commercial feasibility.

Subsequently, the ingredients company identified an Australian toll processor with all the equipment necessary to manufacture sufficient volumes to supply key clients for market testing. As a result, the ingredients company secured a larger clientele and today still uses the toll processing facility to manufacture larger volumes to meet market demands. As a result of the scale of manufacturing, the toll processing facility is now offering a significantly reduced cost of goods, i.e., toll manufacturing pricing was reduced by a factor of 6 as a result of increasing volume from 1 ton to 20 ton batch of microencapsulated omega 3 powder.

A second company has followed a similar journey and has also set up a license with CSIRO to commercialise microencapsulated powders with high fat oil blends. The only hurdle the second company faced was during commercial feasibility. The company found it difficult to identify a commercial toll processing facility able to fulfil volume requirements for market testing and commercialisation for the intended application. In this case, the company invested in expanding the infrastructure of an existing toll processing facility to be able to reach the required volumes. Given the investment incurred, the company was able to negotiate down the price for toll manufacturing and therefore obtain higher margins from sales of microencapsulated powders.

Both approaches to toll manufacturing of innovative technology would potentially apply to any company wanting to commercialise specialty fruit and vegetable ingredients. The company can either hire the food processing hub as a toll contractor to manufacture their own ingredients, or even co-own or co-invest in the hub to reach competitive advantage on price in the market or increase sale margins.

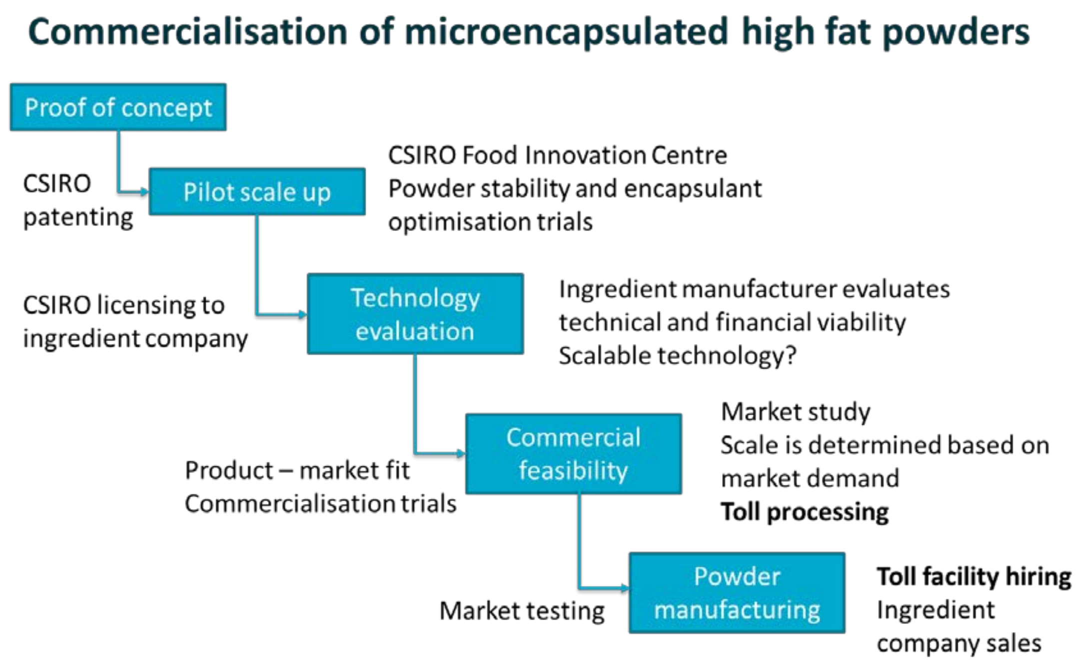

Figure 2 Pathway to commercialisation of novel and differentiated specialty ingredients: example of use of a toll processing facility for market testing and commercialisation of microencapsulated high fat powders..

Centralised or de-centralised operations

A consideration for the venture is whether a centralised or decentralised (or distributed) organisational structure would provide optimal cost benefits and operational advantages.

A centralised operation is one that has all manufacturing steps (from pre-processing to finishing) and warehousing in one location. A central factory can dramatically reduce production costs per unit product by consolidating all production in one site such that the same equipment can be leveraged for different products, enabling the company to achieve economies of scale. Centralised operations tend to have lower manufacturing costs, as well as higher raw material inventory turnover rates and production schedule efficiencies than decentralised manufacturers.

On the other hand, decentralised companies can split out unit operations from within an overall production process or distribute entire production lines to different locations or regions. A decentralised strategy may be driven by the regional and/or seasonal availability of fresh produce as feedstocks or by the availability of highly skilled personnel in specific locations. Decentralised manufacturing and/or warehousing brings advantages such as flexible and responsive production, and potentially closer location to customers. However, multiple production sites require a larger investment of capital to set up, so the per-unit costs may be higher than mass-produced products made in one centralised plant. An additional and significant challenge may be to maintain consistency of quality in products and processes across the distributed organisation [17, 18].

This report considers that there may be cost and operational advantages to decentralisation of some units of operation or entire processes of the horticulture-based venture. Decentralisation may enable the value-adding venture to extend the footprint of feedstock supply, by relocating the aggregation and pre-processing operations closer to fresh produce supply. By pre-processing fresh produce at the suppliers' sites, only process-ready feedstock would need to be transported to the manufacturing location (see Case Study: GLK).

One of the assumptions of the business model is that the growers will be licensees of the proprietary technology underpinning the value-adding operation (Figure 1). Consequently, entire specialist process lines (from aggregation to finishing) could be distributed to other regions closer to an extended range of potential feedstocks. This could benefit the commerciality of the venture overall by extending the seasonal availability of fresh produce.

This report recommends that a cost benefit analysis is needed to define the optimal configuration for the agricultural value-adding venture.

Case study: Decentralisation

GLK Foods

GLK foods is a US-based, family-owned company with a 118 year tradition of producing sauerkraut from fresh cabbage. GLK is now the largest sauerkraut producer globally, with 172 full-time employees, and 206 temporary and seasonal employees.

GLK owns and controls every unit operation in sauerkraut production, from cabbage growing to specialist packaging in cans and jars. The company's two factories are co-located within the major cabbage growing regions of upstate New York and Wisconsin. Fresh produce (140,000 tons of raw cabbage pa) is delivered to the company's centralised facilities, where pre-processing begins with coring and chopping.

GLK has developed a mobile cutting unit comprised of flatbed trailers carrying coring machines used to pre-process fresh produce grown in the off-season in Texas and Florida. Cored and chopped cabbage is then shipped to the company facilities: this is more cost-effective than transporting cabbage heads, firstly as the chopped produce occupies less space in the trucking container, and secondly mobile pre-processing leaves the waste (40% of cabbage head) behind [19].

Business model

This section focuses on business models and scenarios to drive sustainable commercial operation of the venture/hub within the value chain.

The business model can be refined by reflection on the elected company structure and the strategic vision of the venture: an example of a strategic vision may be articulated as

> "The core business is to add value to fresh horticultural produce as premium products for the food, beverage and nutraceutical industries, on behalf of shareholders or members."

A simple illustration of an indicative value chain for horticultural produce and exemplars of products delivered to market by various levels of value-adding is provided in Figure 2.

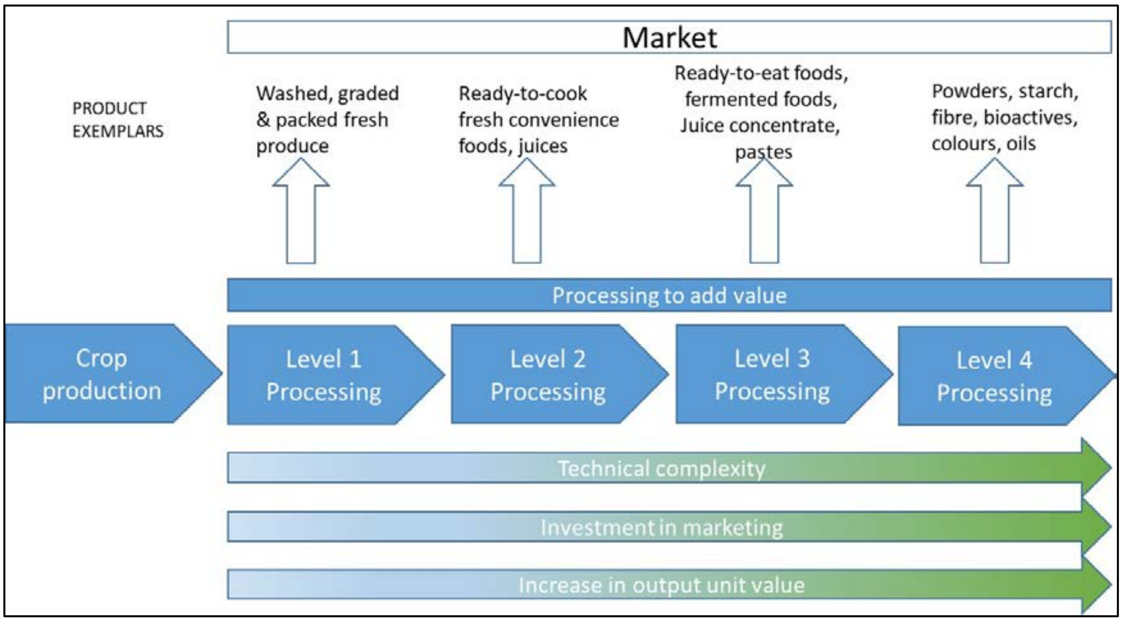

Figure 3: An indicative value chain for vegetable industry: Prospects for value-adding feedstock streams by means of level 1 to level 4 processing, each with product exemplars as indicative outputs. The sophistication of the value chain outputs increases with technical complexity of processing (from level 1 to 4), requiring a proportionate increase in investment in marketing, as market outreach, ongoing monitoring of consumer trends and management of customer relations. The increase in sophistication or complexity of the outputs is also characterised by an increase in unit value, compared with that from preceding processing level(s). Source: [5].

The core business model will be one that ideally will account for all activities in the proposed operation, including:

- Sourcing appropriate fresh produce from set of suppliers co-located with the hub (i.e. within a defined aggregation radius);
- Aggregation of fresh produce and completion of traceability records;
- Pre-processing and quality assessment of incoming produce;
- Processing (Level 1 to Level 4 processing) to manufacture the final product (see Figure 2);
- Quality assessment of the final product;
- Packaging; and
- Storage, ready for distribution to end-user or customer.

Ideally, a venture can mitigate operational risks by diversifying the means by which revenues are generated. By understanding the value proposition inherent in each unit operation, these assets and/or capabilities may be leveraged, to the benefit of the venture, generating a greater return on investment. In this way, the horticulture-based venture business model may propose to generate revenues by such diversified avenues as:

- Core business: including leveraging proprietary technologies
  - o Revenue from aggregated fresh produce: Level 1 processing (see figure 2).
  - o Revenues from value added products: Level 2-4 processing (see figure 2).
  - o Diversification of products with lead and portfolio of products rolled out over time.
- Services contracts: leveraging skills, capability and capacity of the venture/hub

- o Manufacturing at up to commercial scale (i.e. including pilot and demonstration scales):
  - Small scale contract manufacture, especially in the off-season.
  - Specialist one-off manufacture.
- o R&D development contractor:
  - For businesses to trial an innovative processing of fresh produce at demonstration scale.
  - For research organisations to trial innovations in processing at scale.
- o Quality assessment and reporting, and quality certification.
- o Packaging: bulk or specialist packaging.
- o Warehousing and storage.
- o Pre-processing of fresh produce.
- o Logistics and distribution.

A commercial enterprise based on agricultural feedstocks would expect to have periodic downtime based on the seasonality of those feedstock: this downtime, while facilitating equipment maintenance, also may enable the opportunity to commercially leverage this excess capacity. In this way, the seasonality of agriculture-based production may provide the opportunity to generate additional revenues by means of contract services to external parties.

The potential competitive positioning of the venture proposed by the business model may reflect such attributes as:

- Cost effective manufacture of final (specialist) products at scale based on the regional production;
- Clear traceability systems and established provenance[4];
- Diversified product and services strategy;
- Long term supply agreements with suppliers;
- Australian farm-based business;
- “Clean and green”;
- Product portfolio leveraging innovative and proprietary technology;
- Vegetable-based bioactives and other products responding to market drivers (eg in the aging market, addressing gut health etc.); and
- Investment in ongoing innovation for process and product improvement for cost-efficient manufacture and diversified product and services.

Market positioning: B2B or B2C

In addition, in formulating the business model, a fundamental issue to be decided for an emerging business is which market the business will address: business-to-consumer (B2C) or business-to-business (B2B).

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[4] Blockchain is a transparent public ledger available to all parties within a supply chain including producers, retailers, logistics providers, and regulators. Blockchain provides a comprehensive record of each asset, any transaction history, and current ownership. This ledger platform is a repository for data that demonstrates where, how and when food was produced, processed and distributed, thereby improving traceability and transparency of food security and provenance.
https://assets.kpmg.com/content/dam/kpmg/au/pdf/2017/western-sydney-fresh-food-precinct.pdf>

Business to Consumer model

B2C businesses are those that market and sell directly to consumers: therefore these businesses are product-driven so marketing and a strong brand position are critical. To be competitive, these businesses need to make significant and ongoing investment directly into monitoring consumer trends, responding proactively with innovation and novelty in product design and packaging, and in marketing and sales [20].

Supply chain issues relevant to the B2C model are those that extend from field to table, from sourcing raw materials to manufacture, packaging and distribution of the final product. Sales volumes can be from single units to relatively small batches, but often within a large target market.

Sales are based typically on a short decision-making process, for which the product needs to catch the consumer’s attention. A consistent purchase price is typically expected for the product, irrespective of the consumer.

Disadvantages of the B2C model is that “the work of winning and retaining customers becomes a complicated balancing act between growth, product and profitability” [21]. In addition, B2C businesses need to commit to being alert to stay ahead of consumer trends and making the right investment bet on proactive product development.

Business to Business model

In the B2B model, products or services are marketed to business buyers for use within their manufacturing operations. Consequently, as part of the manufacturer's supply chain, B2B suppliers need to meet the product specifications of their customer or end-user, in terms of quality and volume, consistency, reliability, and timely delivery. Not surprisingly then, B2B sales are secured following a longer decision-making procurement process than in B2C businesses. A strong brand may drive consideration of purchase only, as only a part of the customer’s decision-making. Procurement is a multistep process involving multiple stakeholders as decision-makers, with a longer sales cycle; buying decisions are often based on value delivered to the customer’s business [22].

The B2B client base is by definition smaller than for B2C, but is a more focused target market. In addition, the customer is a more sophisticated buyer, so a different type of product knowledge is needed to support the sale than is required in B2C, such as:

- More detailed technical knowledge, higher level of understanding of product composition;
- Clear understanding of product differentiation compared with competitors; and
- Ongoing provision to the customer of technical updates and ongoing support.

Lengthier relationships with the B2B customer is typical of this model: B2B businesses need to invest time in cultivating a relationship with potential buyer during the longer decision-making process to secure a sale, and afterwards. Therefore, sales in the B2B model are often relationship-driven.

Price may vary by customer: those who place large orders or negotiate special terms may pay different prices to other customers. However, the opportunity for long-term contracts enables B2B businesses to make financial plans: clear expectations of revenue and profitability allow planning of future expenditure to build the business [22].

The disadvantage to the B2B model is that sales are more difficult to achieve, have a longer sales cycle and come with higher stakes for both buyer and seller. The procurement process is a challenging one: it's often more difficult to persuade a business customer to invest in a product or service than it is to convince a consumer to buy for personal use. But the advantage for the B2B supplier is longer term contracts, often at a fixed price. And lastly, earnings from the B2B business may be used to develop a B2C business, as the venture matures [21].

Case study: An enduring agricultural business

Norco

Norco Co-operative Limited (Norco) is a co-operative limited by shares, incorporated and based in Australia. Established in 1894 and now employing 837 staff, Norco reported an annual milk intake of 222 million litres, turnover of A$555.6 million and retained net profit of A$1.12 million in 2017FY [2, 23]. The organization has a number of wholly-owned subsidiary companies including: Norco Pauls Milk, Norco Wholesalers Pty Limited, and Norco Rural Stores Group.

Business structure

Norco is a 100% Australian farmer-owned dairy co-operative with 326 active members on 220 dairy farms in northern New South Wales and southeast Queensland. Norco actively manages its membership and only admits new members to match contract and other revenue opportunities, after existing members are given the option to increase production as opportunities arise [3].

The overall Norco business is to process and market members' fresh produce as well as to provide rural supplies and stockfeeds at competitive prices to members. The business is managed as four distinct operating units, vertically integrated within a co-operative business structure: Corporate office, Norco Foods, Milk Supply, and Norco Rural Stores and Norco Agribusiness (Figure 3) [2]. This structure is reported to provide members with control, "either directly or indirectly, over a large portion of their supply chain" [3].

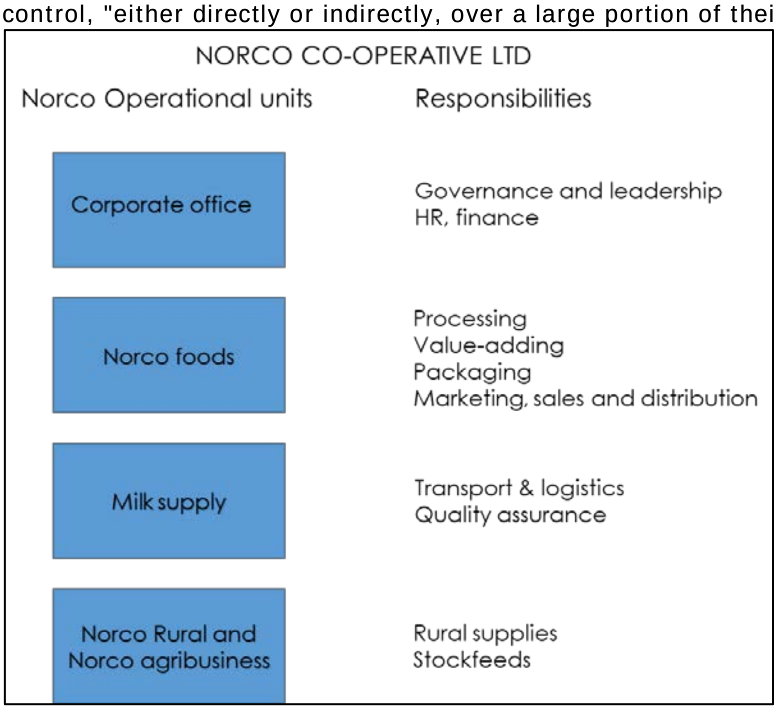

Figure 4: Norco business structure. Source: Adapted from [2, 3].

The corporate office is responsible for the business and operational functions, and for organisational governance. The three cash generating units (CGUs) for the co-operative are Norco Foods, Norco Rural Retail and Norco Agribusiness. The three CGUs all have distinct outputs within the overall business, contributing to the diversification of the product portfolio, thus de-risking the overall business. Each CGU is tasked as [2, 23]:

- Norco Foods: comprises the Ice Cream Business Unit, Norco Milk and Milk Supply and is responsible overall for
  - Milk transport and logistics services, and quality assurance;
  - Milk processing, value-adding and packaging; and
  - Marketing, sales and distribution services.
- Norco Rural Retail: retail operations that stock "everyday essentials to highly specialised products" from seed, fertiliser, fodder, agricultural and veterinary chemicals, fencing, irrigation supplies etc; and
- Norco Agribusiness: bagged and bulk stockfeeds and grains.

Market analysts consider the diversification of the business into three CGUs allows Norco to mitigate the financial risk of the overall business in terms of seasonal variation in supply and price of fresh produce, and the Co-operative's investment in plant and equipment [2, 3].

Business model

The Norco business model aims to bring value to members by means of both direct and indirect economic benefits. The principal activities of the co-operative are the processing, manufacture and sale of dairy products, the manufacture and sale of stockfeeds, and rural retailing. The business is based on a business to customer (B2C) model.

The Norco co-operative built the business over time by means of a series of strategic acquisitions begun in 1958 to expand the footprint over which supply was aggregated. Those strategic transactions continue to build supply and processing capability, particularly in new products, to [24]:

- Expand the supply footprint by acquisition of other dairy co-operatives;
- Build value-adding and processing capability: eg acquisition of ice cream manufacturers, and a JV with a US manufacturer (1987); and
- Diversify product offering by acquisition of agricultural business (1984).

From the early days of operation, Norco owned and controlled the supply chain from field to fork [24]:

- Aggregation of fresh milk;
- Packaging;
- Processing to value-add fresh produce: (butter production) from 20 factories in 1932 co-located with fresh supply;
- Cold storage and warehousing;
- Logistics: from steamships (1921) to trucks;
- Sales and marketing; and
- Retail stores: first opened in 1943; now 30 stores nationally.

The benefit of control of supply chain is to deliver both cost advantage for products and services, as well as protection of the cooperative's smaller supplier/members from acquisition by other "larger interests" [3]. Norco's commitment to their farmer members is to buy every litre of milk generated on farm.

A key aspect of the Norco business model is the route to market. From outset, the business has operated a business-to-consumer (B2C) enterprise, principally by means of:

- Rural domestic retail and agribusiness stores, owned and operated by the co-operative;
- Retail outlets through partnership with national retailers eg Coles, Woolworths, Harris Farm etc; and more recently,
- Export to the Asian market.

The performance of the co-operative business structure may be assessed by farm gate milk prices: total average farm gate milk price paid by Norco to its farmer members was 57.42 cents per litre (cpl) (57.30 cpl for 2015/16)[2], reportedly well above industry average for 2017FY [25].

Access to capital

One important feature that distinguishes the co-operative structure is access to capital. The cooperative business structure is more limited in access to capital than are proprietary or public companies, a limitation that may constrain growth of the business. The primary source of capital for a co-operative is generally limited to the shareholdings of members.

Norco has proactively built a diversified business on behalf of members by acquisition as well as joint ventures to explore new business opportunities, either expanding or ceasing the collaboration with time depending on the level of success [24]. In addition, Norco reports implementing processing and product innovation to strive to reduce production costs, while keeping abreast of the dynamic of the consumer market, and more recently has built channels into the Chinese fresh milk market. However, to continue to build the business, by investing in innovation and exploring new commercial opportunities, co-operatives need capital. To raise capital, Norco has leveraged compulsory share acquisitions, contributions from new members, and retained profits, which are an important source of capital. In addition to traditional bank financing, Norco has reportedly sought alternative forms of financing to support business growth over time, such as trade payables and secured term loans [2, 3].

> Norco is absolutely focused on consistently showing that a farmer owned co-operative model with solid strategy, direction, management and performance can continue to prosper.
>
> Greg McNamara
> Chair
> Norco [2]

RECOMMENDATIONS

The goal of this section is to examine company structures, and business and operational models as options for a dedicated business venture established to leverage technical opportunities (such as those developed at CSIRO) to develop new value-added vegetable-based products.

This report recommends that to initiate and operate the business venture, consideration be given to:

- *Company type*: from a risk management perspective, proprietary companies, co-operatives, and joint ventures offer attractive options to the grower or shareholder. Further work is needed to refine the decision, based on: the availability of a keystone participant from within or outside of the horticulture sector; the level of interest from a number of aspiring growers as co-investors in a company or members of a cooperative; and/or the level of interest of a specialist processor or customer as a joint venture partner. Specialist legal and tax advice may also be sought.

- *Company structure*: from the perspective of the investors or members, an incorporated structure may provide risk management benefits. Specialist legal and tax advice may also be sought.

- *Operational models*: options are proposed to account for the supply chain from field to finished product in an efficient and cost effective manner. Further work is needed to consider the ideal approach to addressing the skills and capabilities gaps to enable to business to operate successfully, by means of a sub-contractor, an acquisition, or by means of a collaboration such as a joint venture or partnership. In addition, a financial model evaluating the cost-effectiveness of subcontracting operational units (such as specialist processing, marketing, packaging etc.), to support decision-making on the optimal business configuration, needs to be completed.

- Decentralisation of some units of operation or entire processes of the horticulture-based venture may offer cost benefit or operational advantages to the new venture based on the footprint of feedstock supply, by relocating the aggregation and pre-processing operations closer to fresh produce supply. By pre-processing fresh produce at the suppliers' sites, only process-ready feedstock would need to be transported to the manufacturing location. However, a cost benefit analysis is essential to define the optimal configuration for the agricultural value-adding venture.

- *Corporate strategic vision*: The business model needs to reflect the overall strategic vision of the venture: for example, "The core business is to add value to fresh horticultural produce as premium products for the food, beverage and nutraceutical industries, on behalf of shareholders or members."

- *Business model*: of the new venture may generate diversified revenues by such avenues as:
    - Core business: production of value added products by leveraging proprietary technologies; and
    - Services contracts: leveraging skills, capability and capacity of the venture/hub in manufacturing; supply chain management; quality assessment and reporting, quality certification; packaging: bulk or specialist packaging; warehousing and storage; pre-processing of fresh produce; and logistics and distribution.

- *B2B market positioning*: while sales are initially more difficult to achieve, have a longer sales cycle and come with higher stakes for both buyer and seller, contracts in the B2B model tend to be longer term, often at a fixed price. This may enable the new venture to make financial plans: clear expectations of profitability allow planning of future expenditure and returns to shareholders.

SECTION B RISK

EXECUTIVE SUMMARY

The goal of this section is to examine the risks involved in a potential venture that may be established for the purpose of leveraging technical opportunities (such as those developed at CSIRO) to manufacture new value-added vegetable-based products.

This section overviews the risks, challenges, impediments and gaps that are inherent or may arise in a new venture with a business and operating model to value-add fresh produce as ingredients for the food and nutraceutical industries. Approaches are outlined to mitigate, avoid or manage those risks.

The key areas of risk are considered to be those at initiation of the venture, financial and business execution risk, and the challenges in market delivery and expectation. This report considers that some of the risks identified may represent “stop-go” points in the decision by the investor to progress a commercial, value-adding venture. In particular, those risks may include: financial risk, market pull, market dynamics, product differentiation, offtake agreements, and seasonality. The level to which other issues identified here are managed may significantly undermine or support the level of success enjoyed by the venture.

The key risks associated with the launch of the venture include the robustness of the business plan, alignment of purpose between key venture participants, estimated economic scale of production, market pull for the proposed final product, engagement with potential customers and suppliers, and the need for demonstration scale for a new process. The role of government in mitigating the risk of a new venture is also considered.

The key financial risks may be managed by the availability of sound economic analysis to support the project and by meeting the detailed requirements of investors to win adequate funding to finance the venture.

The key risks to sound business execution may be managed by recruitment and retention of professional business managers to deliver against clear timeframes, establishment of robust corporate governance, securing of formal contracts, protection of the supply chain, provision and training of technically-skilled staff and managers, and ongoing investment in market trend research and customer relationships. A sustainable business in the horticulture sector needs also to build in risk management approaches to address the seasonality of feedstock availability.

The key risks of the venture in meeting the expectations of the end-user or customer may be managed by actively monitoring market trends, investment in product quality and differentiation, and by building a culture of relevance and responsiveness to market dynamics and changing expectations into the business, particularly in terms of the export market and the global portal offered by e-commerce.

RISK

This section of the report overviews the risks, challenges, impediments and gaps that are embedded or may arise in a new venture with a business and operating model to value-add fresh produce as ingredients for the food and nutraceutical industries. Approaches are outlined to avoid, mitigate or manage those risks.

The key areas of risk are associated with venture initiation, financial and business execution risk, and market delivery and expectation. This report considers that some of the risks identified may represent "stop-go" points in the decision by the investor to progress a commercial, value-adding venture. In particular, those risks may include: financial risk, market pull, market dynamics, differentiation, offtake agreements, and seasonality. The level to which other issues identified here are managed may significantly undermine or support the level of success enjoyed by the venture.

Venture Initiation

The key risks associated with the launch of the venture are the robustness of the business plan, alignment of purpose between key venture participants, estimated economic scale of production, market pull for the proposed final product, engagement with potential customers and suppliers, and the need for demonstration scale for a new process. The role of government in mitigating the risk of a new venture is also considered.

Business plan

The prospective value-adding project needs to be couched in terms of its value proposition, approaches to secure a regular supply of feedstock, to address a specific market demand or application, an outline of the manufacturing process at scale, and a preliminary estimate of capability to meet volumetric manufacture of the product of reliable composition and quality. The business plan should validate that a venture has the potential to secure a commercially-relevant market share for the product under consideration.

A robust business plan may need preparation and investment. Respondents report exemplars of preliminary investment in independent advisors delivered a sound business and operating model and robust technical and engineering designs based on an extensive due diligence and site visits; these investments delivered an international contract manufacturer for a manufacturing facility (see Section D BPA) and a commercial ethanol manufacturer (see Section D Dalby Biorefinery). The logical progression of project development ideally would also meet the requirements for securing finance (see below).

There are risks inherent in any business operation: good business planning may manage those risks by means of:

- Diversified product range;
- Diversified end-user segment, such as premium ingredients for food and beverage manufacture, shelf stable produce, nutraceuticals, and pet foods;
- Diversified business units: such as in-house manufacture and contract toll manufacture or other skilled services; and
- Control over the supply chain from farm gate to warehouse or table.

Alignment of purpose

As discussed elsewhere[5], the ownership model of choice may be predicated on preferences of the owner or investor, in terms of their motivation for investment and the investor's long-term goals and ambitions for the venture. Motivations for investment in an undertaking can vary widely among investors as illustrated by the case studies: from building a sustainable business and commercial advantage (Dalby Biorefinery), capacity-building and prestige (BPA[6], MRBPP[7]), to achievement of political goals (BPA). Alignment of purpose between investors, and between investors and the board and management of the venture is critical to the success of the business, its sustainability and to the creation of long-term value for shareholders.

Scale of production

Understanding the commercially realistic scale of production of any value-adding venture may be pivotal to success. Evidencing reliable and appropriately scaled production to the potential end-user is considered key to attracting and securing a commercial partner. Added to the anticipated downtime due to seasonality for a processing or packing facility owned on-farm, the essential nature of scale of production adds to the investment risk. Therefore, the report recommends that gaining an understanding of both the scale of production to meet end-user or customer demand and the economic scale needed to underpin a commercially-realistic business is a priority.

Market pull

The appropriate business model needs to respond to, or anticipate, a clear market demand. The business model needs to be supported by a clear understanding of how the venture will respond to the requirements of the market, which, in terms of food, beverage and nutraceuticals markets, are notoriously faddish, are intensely competitive and price-driven [5].

Engagement with customer

Prudent advice to a new venture may emphasize a commercial imperative of having end-users or customers involved at an early stage of project development, with the eventual goal of securing a long term supply agreement. The input of these groups in process, packaging or product development may confirm, guide and support the new venture and verify the commerciality of the venture to investors. The end-user brings to that early engagement with a project an in-house capability to confirm the addressable market, to provide detailed analysis of market size and consumer demand, consumer testing, design, refinement and testing of product format. Even more significantly, the end-user or customer will provide an early definition of product specifications and performance metrics including quality and composition, and the volumes of supply. Together, the end-user/customer and venture investors will evaluate the requirements for a new business to be competitive in a cost-driven market, such a food and food ingredients.

Engagement with supplier

Securing the feedstock supply, in quantities, at a quality and timeliness to meet production targets, and from within a cost-effective radius of the facility, is critical to the success of the manufacturing operation.

Demonstration scale

Regional and national capacity at demonstration scale production of the target products from fresh produce is lacking and may affect the interest of the investor in the project.

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[6] Biopharmaceuticals Australia.

[7] Mackay Renewable Biocommodities Pilot Plant.

As the technical opportunity to value-add fresh produce is rolled out, there is a need for demonstration scale infrastructure to, at least, prove a new process and generate market-ready quantities of product for commercial assessment by prospective partners.

Government role and perception

Respondents report that State governments may currently under-estimate the size and value represented by the horticulture industry, and consequently the potential benefits of economic growth and job creation from developing value-adding within the industry. From the perspective of the grower respondents, government support is recognized as a key driver in building successful value-adding businesses within the sector. Therefore, this report recommends that the recognition by government of the economic role of horticulture, the value proposition of investing in the sector, and the willingness of government to pay a role, needs further investigation.

Financial

The key financial risks in the project may be managed by the availability of sound economic analysis to support the project and by meeting the detailed requirements of investors to win adequate funding to finance the venture.

Financial risk

A detailed economic analysis of the business proposition is critical prior to securing investment. An economic model is a priority requirement to define the costs, timelines and financial benefit to investors, based on an in-depth market opportunity analysis and understanding of market dynamics, with detailed input and guidance from the prospective end-user or customer. Care must be taken to factor into the analysis the cost of such significant production inputs as energy and water, which reportedly may range from expensive to prohibitive. The financial impost of these costs is to bring production to the edge of profitability. Government underwriting of key equipment or partnership with an equipment supplier may support the project in securing critical investment, as the cost of customized equipment alone may be sizable.

Securing Investment

Respondents to this and an earlier report recognized that sourcing grant funding and other external financial support early in company development would have accelerated businesses achieving sustainability faster. If the respondents from these value-adding or specialist processing companies were to start their businesses again, they assert they would not have depended on revenues alone to build the business organically [5].

Investment by Federal and/or State governments was crucial to the initiation and establishment of businesses in previous case studies (see Section D) and well as to anticipated plant expansion for mature businesses. Investment by government is often perceived by other external investors as mitigating their own financial risk in a project.

Critical to security venture finance is for the project to meet the investor's conditions that may include at a minimum:

- Economic scale of production: size of proposed plant estimated as that able to deliver an commercially viable scale of production;
- Customer and offtake agreement secured for the lead product;

- Top tier builder for building execution or EPC[8] phase: a top tier builder is often one regarded by the bank as "too big to fail" [26];
- Bankable cost estimate: this estimate is conducted by the engineers together with the EPC builder to deliver accurate, actual costings (+/- 10%), not preliminary costings (+/- 30%);
- Technology: must be have a demonstrable history of execution elsewhere i.e. proven to work at scale.

Business Execution

The key risks to sound business execution may be managed by recruitment and retention of professional business managers to deliver against clear timeframes, establishment of robust corporate governance, securing of formal contracts, protection of the supply chain, provision and training of technically skilled staff and managers, and ongoing investment in market trend research and customer relationships. A sustainable business in the horticulture sector needs also to build risk management approaches to address the seasonality of feedstock availability.

Professional management

Attracting and retaining experienced professional managers are considered key to flexible and responsive business practices. Good management teams demonstrate a preparedness to respond to change and to make rapid business decisions within a small company framework. Professional managers bring capability and acuity to the venture at onset and the capacity to calibrate management skills in line with the growth and evolution of the core business [3, 27].

An executive team of business professionals with support of the Board, working to deliver clear strategic objectives (eg to build a self-sustaining operation) will mitigate against the risk of a project not meeting objectives and timeline (often a condition of bank finance) and the risk of commercial failure.

In particular, experienced managers with relevant technical and/or business skills would mitigate the risks associated with some or all of:

- Specialist processing, production management and specialist equipment operational skills;
- Feedstock management, and feedstock and final product warehousing: to match critical scale of production and any product maturation requirement; with flexibility to expand capacity;
- Marketing capability: to reliably build customer relationships and develop business branding;
- Contract design, negotiation and enforcement; and
- Financial and accounting acumen.

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[8] EPC or Engineering, Procurement, Construction is a prominent form of contracting agreement in the construction industry. The EPC contractor conducts the detailed engineering design of the project, procures all the equipment and materials, and then constructs to deliver a functioning facility or asset to the client. Normally the EPC Contractor has to execute and deliver the project within an agreed time and budget, commonly known as a Lump Sum Turn Key (LSTK) Contract. An EPC LSTK Contract is responsible for schedule and budget. www.epcengineer.com/definition/132/epc-engineering-procurement-construction

Strong governance

Good corporate governance to protect members' assets and to deliver business sustainability is essential for the long term operation a successful venture. A robust governance and reporting structure is required at the outset of venture, providing management with clear objectives and timeframe of execution, and reinforcing investor confidence.

Formal contracts

Successful and sustainable businesses have in common the practice of basing commercial decisions on formal contracts rather than informal arrangements. Formal agreements such as confidentiality, intellectual property and licensing, supply, material transfer, offtake agreements, heads of agreements, and tenancy and lease arrangements, are anticipated to underpin decisions to invest feedstock, equipment, secure warehousing and employ staff.

Protection of the supply chain

Long term but flexible supply contracts and a high level of engagement with suppliers stabilises and secures the venture's production of value-added products. Direct engagement by investors and venture managers with both suppliers and end-users and customers will allow the venture to reap lasting benefits. As respondents to this project, some specialist processors report that their suppliers alert them to such critical issues as upcoming feedstock shortages, due to a robust business relationship built over 25 years.
In addition to the supply side, consideration needs to be given to the availability and sufficiency of cold chain facilities to effectively manage the movement of finished produce to ports.

Technical Skills

A value-adding business based on fresh horticultural produce may be a more technology-based operation than is usual within the horticulture sector or within a regional community. There is a risk, especially at initiation of the business, that there will be a critical need for experienced technical staff to operate the production line and maintain equipment, and to upskill local employees. In the absence of a pipeline of technically trained staff and in the case of poor retention of skilled technical managers, the venture will have an ongoing reliance on external recruitment, perhaps internationally, for reliable plant operation. This risk needs to be recognised and addressed early in the business by an investment in training of local staff and in retention of overseas technical specialists, in acknowledgement of the isolation faced by newcomers to regional Australia [26].

Timeframes to uptake

The uptake of new product by the market may take time: the customer or end-user will need to trial a new product to assess quality and differentiation, as well as appropriateness and fit within their current portfolio. The customer or end-user may conduct extensive final product formulation trials and consumer testing. Therefore, there may be a delay before a supply agreement is reached: in some instances, timeframes are reported of "maybe 2 years before an order is placed".

Investment in Marketing

Industry respondents[9] in a previous report emphasised the sizeable investment their businesses have made in marketing, both in trend research and customer relationships over time. One respondent evidenced the value he placed in the relationships with his customer base as having taken "10 years and millions of dollars to build". Another respondent reported that one third of the operating expenditure in his specialist processing business was invested in marketing.

Business culture

Alignment of the culture of the business (board, management and staff) with the goals and expectations of owners and investors and shareholders is key to building a sustainable business.

Seasonality

Seasonality of feedstock affects the sustainable operation and overall profitability of a horticultural-based operation, as the business needs to be able to amortise the capex and opex over the entire year to be cost-effective. Business investors and managers may need to build feedstock flexibility as well as other options to make best use of the facility's infrastructure and staff assets in the off-season. One approach to manage this risk is to equip the venture with feedstock- or application-flexible equipment to provide the venture with a capability to extend operation with alternate feedstocks and/or processing in the "off-season.

Market Delivery / Expectation

The key risks of the venture in meeting the expectations of the end-user or customer may be managed by actively monitoring market trends, investment in product quality and differentiation, and by building a culture of relevance and responsiveness to market dynamics and changing expectations into the business, particularly in terms of the export market and the global portal offered by e-commerce.

Market dynamics

The food and ingredients markets are notoriously fickle and consumer trends can change rapidly and dramatically. Building a business on today's trends may fail – the current demand for the product may disappear in the time it takes to get the new business operational. This report recommends that an understanding of the approaches that established and successful horticultural companies use to address stability of revenues in their value-adding businesses may provide key learnings for other aspiring growers.

Product definition

Risks in production may be mitigated by understanding and consistently meeting the product definition requirements as agreed with the end-users and customers. Those requirements may include: standardised and competitively priced product at a specified quality, composition, origin, and volume.

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[9] Respondents were growers who had integrated value adding of fresh produce into their horticulture business, or specialist processors who extracted or refined fresh produce into premium ingredients or shelf stable foods.

Differentiation

For a new venture in value-adding fresh product to be successful, it may not be sufficient for that business to aim at delivering quality. In the highly crowded, competitive and price-driven sector of food and food ingredients, the business case for the new product (powders as ingredients, for example) may need substantial and verifiable differentiation to displace competitors and earn market share. Differentiation may address price, convenience, quality, shelf life, speciality, nutritional composition, local origin, or health benefits, among others.

> "If there is a market for the product, then you must establish the point of difference to secure an edge especially in a highly competitive market" (such as the ingredients market)
>
> Specialist processor
> Industry respondent

Relevance and Responsiveness

A major challenge for a business is to be aware of the industry and the market more broadly to be responsive to upcoming and potentially rapid changes in consumer trends, feedstocks, staff, shareholders and stakeholders. The onus is on the business owners and executives to stay abreast of global consumer trends for their value-adding business, and stay informed of developments in best horticultural practice.

Addressing the Export Market

Value-adding and other ventures that have arisen from within the horticulture industry have a history ("remembered by all") of unsupported attempts at developing export contracts that have not gone well. Consequently, the horticulture industry overall is shy of the export market, and "sticks to the domestic market". Therefore, this report recommends an examination of how best to support building an export trade for the outputs of new value chains within the horticulture sector, including in initiating and securing a customer, partnership management and contract negotiation.

E-commerce

Processor respondents comment that initial sales in the early stages of their new business were entirely dependent on their online presence and direct e-sales to consumers. However, industry association respondents report that a preponderance of growers in the sector do not understand the scale of the opportunity that e-commerce represents for the export market in general, but particularly to China. This direct route to market enables growers to circumvent distributors and agents, both of which take a percentage of the grower or grower/processor's profit margin. The initiation and management of a successful e-commerce business needs skills currently outside of the core business of horticulture sector.

Interestingly, respondents advise that some regional governments and authorities (eg in Queensland) are "gearing up" to meet the opportunity represented by e-commerce, with infrastructure in place or planned to accommodate direct sales from regional agribusinesses to markets in Singapore and Hong Kong. So, this report considers there is a gap between the awareness and preparedness of regional infrastructure to leverage the opportunity of e-commerce with Asian consumers and customers, and the awareness and preparedness of the horticulture sector to recognise and navigate that opportunity.

Summary

In summary, the key business risks and strategies to mitigate, manage or avoid those risks are listed in Table 4.

Table 4: Key business risks and strategies to mitigate, manage or avoid those risks.

Risk	Key mitigation strategy
Failure to launch	Robust business plan completed and verified
	Alignment between key venture participants
	Economic scale of production defined
	Market pull for final product confirmed
	Engagement with customers and suppliers established
Financial failure	Sound economic analysis to support the project completed and verified
	The detailed requirements of investors are met
Failure in business execution	Professional business managers are recruited and retained
	Clear timeframes for delivery of defined milestones are provided to managers
	Robust corporate governance established
	Culture of the business (board, management and staff) with the goals and expectations of owners, investors, and/or shareholders are aligned
	Formal contracts (eg offtake, supply, cooperative, JV etc) are secured
	Supply chain is protected
	Seasonality is managed with feedstock flexibility and/or feedstock- or application-flexible equipment
	Technically-skilled staff & managers are recruited; local staff trained/upskilled; ongoing budget provided
	Investment in market trend research & customer relationships is budgeted
Market Delivery/Expectation	Market trends actively monitored
	Investment in product quality and differentiation is ongoing
	Relevance and responsiveness to market dynamics and changing expectations into the business culture

RECOMMENDATIONS

This section has considered the key risks in the proposed venture in order to build a commercially sustainable business with prospects of long-term value for investors, shareholders and stakeholders.

The key risks are considered to be those associated with the launch of the venture. Those risks may include:

- Robustness of the business plan;
- Alignment of purpose between key venture participants;
- Recognising an estimated economic scale of production;
- Confirming market pull for the proposed final product;
- Establishing productive engagement with potential customers and suppliers, and
- Need for demonstration scale for a new process.

The role of government in mitigating the risk of a new venture is also considered.

This report considers that some of the risks identified may represent “stop-go” points in the decision by the investor to progress a commercial, value-adding venture.

Therefore a key recommendation is to address those aspects to which the investor is alert: in particular, financial risk, market pull, market dynamics, product differentiation, offtake agreements, and seasonality. In addition, the level to which other issues identified here are managed may significantly undermine or support the level of success enjoyed by the venture.

An additional key recommendation is the development of a financial model based on sound economic analysis to support the project, which meets the detailed requirements of investors to win adequate funding to finance the venture.

Further recommendations include a commitment of the venture to:

- Recruit and retain professional business managers capable of delivering operational and commercial milestones to meet proposed timeframes;
- Establish robust corporate governance;
- Secure formal contracts to support all business and financial dealings;
- Recruit experienced, technically-skilled managers to operate the value-adding process at the outset of business operations;
- Provide a budget for ongoing technical and operational training of local employees as staff and managers, and
- Invest in ongoing market trend research and the development of interactive and productive relationships with end-users and customer.

SECTION C OWNERSHIP MODELS

EXECUTIVE SUMMARY

The goal of this and the following section is to examine the ownership models and governance frameworks for a potential venture that may be established for the purpose of leveraging technical opportunities (such as those developed at CSIRO) to manufacture new value-added vegetable-based products.

This section reviews models of ownership of a business in general, in order to provide a shortlist of models as possible options for the venture. A review of the options for ownership of companies suggests a broad scope of arrangements and combination of arrangements can occur: from proprietary company or public limited company, co-operative ownership, partnership contract, anchor, leasing, and government- or employee-owned models.

The assumption underpinning this review is that the choice of ownership model for this project will be one that delivers maximised returns, and, depending on the purpose for which owners establish the venture, sustainability over longer term. However, how various ownership models maximise returns depends on strategic vision of the enterprise, management and governance structure, the availability of finance, the treatment of surplus, regulation, and other factors.

Case studies of ownership structures and governance frameworks from within and adjacent to the horticulture sector are presented at the end of Section D Governance.

OWNERSHIP MODELS

This project assumes that the commercial activity of aggregating fresh produce, processing and then marketing the final product will be conducted through a dedicated business venture. The underlying premise for the business venture is that the business operates on a sustainable and commercial footing, and is profitable.

This section considers models of ownership of a business in general, in order to provide a shortlist of models as possible options for the venture. A review of the ownership structure of companies suggests a broad scope of arrangements and combination of arrangements can occur: from public and private, joint-venture, government- or employee-owned models.

The assumption underpinning this review is that the choice of ownership model for this project will be one that deliver maximised returns, and, depending on the purpose for which owners establish the venture, sustainability over longer term. However, how various ownership models maximise returns depends on strategic vision of the enterprise, management and governance structure, the availability of finance, the treatment of surplus, regulation, and other factors.

The owners or investors in the business may be drawn from both within the business concept (as participants in the supply and value chain), or from outside the business (as governments or corporate or private investors). An indicative overview of potential participants in business ownership in any of the models below, is represented in Figure 5

Value chain	Supply of fresh produce	Aggregation	Specialist processing	Finished product
Participants in value chain operation	Grower	Grower/aggregator, Aggregator	Grower/aggregator, Aggregator Specialist processor	End-user Customer
Investors and/or Business owners	Grower/aggregator, Aggregator			
	Specialist processor			
	End-user, Customer			
	Local and regional government			
	State government			
	Federal government			
	Corporate investors (agribusiness, real estate, crowdsourcing, development banks)			
	Private investors			

Figure 5: Potential roles of value chain participants or external investors in selected ownership models in a hub venture that manufactures specialty fruit and vegetable products.

The ownership structure within a business is one of a number of defining characteristics of an operating models for a business, which may differ in terms of:

- Control of the business: by public sector, private sector or mixed ownership providers;
- Market positioning: local, regional or global; business to business or business to customer, etc;
- Ownership of assets (fixed and mobile): particularly infrastructure and capital equipment; and
- Management style and focus.

In addition, there are variations within ownership models, based on a distinction between ownership and control of the business [28]. These distinctions are summarised in Table 6.

Corporate Ownership Structures

This section considers options for ownership models within corporate business structures. These are businesses in which revenues generated are used to cover capital costs and the ongoing costs of business operation and maintenance, leaving a profit or surplus [29]. These models include proprietary company or public limited company, co-operative ownership, partnership contract, and leasing.

Proprietary or Public Limited Company: Shareholder Value Model

In a proprietary company, ownership and control usually resides one person or small group of investors as co-owners. The owner may own or hold the lease on all assets from feedstock, equipment, and infrastructure to intellectual property. The owner is responsible for all strategic and operational decisions in running the facility: is responsible for all costs and retains all net revenues; manages the operation, service and maintenance, sales, and administration; and owns all contracts for land lease, environment permissions etc.

In the public company model, ownership of the business is publicly traded or privately held as shares. The business is generally operated by professional managers, and the owners or shareholders play a minimal role in controlling the business, usually limited to electing board members. This ownership model works well when the business requires a significant infusion of outside capital, or when owners are too numerous or dispersed to be engaged actively in decision-making.

In this model, owners (shareholders) benefit by an increase in the unit value of the shares held, and potentially by a dividend payment. Dividends are a proportion of net revenues that companies can elect to pass to their shareholders, as cash, or shares. Some mature company with stable earnings and a lower strategic requirement to reinvest in the business may elect to issue dividends. Other well-established companies may choose to use these funds to start a new project, invest in new assets, repurchase some of their shares or acquire another business. On the other hand, a new and growing company usually chooses not to pay dividends, but retains those funds to invest in further business growth.

The case study for this proprietary or public company model is the Dalby Biorefinery (see Case Studies).

Co-operative Ownership Model

A co-operative is a legal entity owned by a group of people who come together voluntarily for a purpose of mutual benefit, for example, to achieve a common economic goal to benefit all members. Unlike a corporation, ownership (membership) of the co-operative is not transferable.

As a registered legal entity, the ownership of a co-operative differs from that of a company in that it requires at least five shareholders, each of whom hold equal voting rights. Generally, all shareholders are expected to participate and share the responsibility of running the organisation [30].

The controlling principle of a co-operative is that of pursuing owners' interests, which may be considerably different from the controlling principle of shareholder value for a publicly listed company.

The members who own a co-operative are responsible for the day-to-day operation of the organization: all members have an equal share of control. In other words, decisions affecting the co-operative may be made together by all members. Owners of the co-operative can decide if any financial surplus is reinvested in the business or returned to the members after tax.

In most corporations, including cooperatives, owners have residual rights of control and income distribution. Among most co-operatives, shares generate only bank interest levels of dividends, if any. Surpluses are generally distributed as a bonus based on transactions, such as hours worked or dollars spent. Therefore, based on financial return alone, the incentive for potential owners to invest capital in co-operatives may be minimal, so co-operatives have difficulty raising enough capital to compete with public companies whose shares are traded on stock exchanges [31]. However, advantages of co-operatives may include equal votes and more control for owners [30]:

- Equal votes: All shareholders have an equal vote at general meetings, regardless of their shareholding or involvement in the co-operative.
- More control: A co-operative is member-owned and -controlled, rather than controlled by outside investors.

The case study for the co-operative model is Norco (see Case Studies).

Partnership contract model

In the partnership contract model [29], ownership and control are not separated. In this model, ownership of the venture lies with the investors who own the infrastructure i.e. the facility and equipment. To operate the venture, investors agree to form a consortium with the responsibility to:

- Operate the facility
    - Responsible for all costs and revenues;
    - Management of the operation, service and maintenance, sales, and administration; and
    - Ownership of all contracts for land lease, environment permissions etc.
- Distribute costs and revenues.

In this ownership model, costs and revenues are pooled and shared among investors in proportion to percentage ownership. A surplus is paid regularly to the investors, as directed by the Board.

Each investor is responsible for their own financing for the venture: this financing has to be in place before the facility is constructed, installed and commissioned

Leasing model

In the leasing model [29], owners don't operate the business, i.e. ownership and control are separated. In this ownership model, investors own the infrastructure, i.e. have invested in the facility and equipment. However, another entity is formed by the owners to control the venture: investors make a partnership agreement to form (and own) a management company with delegated responsibility to lease the equipment and facility from the owners and operate the facility. In other words, the management company does not own the facility but is solely responsible for:

- all costs and revenues;
- management of the operation, service and maintenance, sales, administration; and
- all contracts for land lease, environment permissions etc.

The management company pays rent to the investors from net revenues derived from the operation of the facility (usually the majority of net revenues), while retaining a small percentage of net revenues as working capital to invest in the business and in equipment.

The financial return to the owners is in share value and in distribution of net revenues proportional to their investments.

The case study for the leasing model is the BioPharmaceuticals Australia (see Case Studies).

Alternative Ownership Models

Three main alternative ownership models to corporate, shareholder-value models, outlined above, are municipal and locally-led ownership models, government (national or state) ownership, and employee ownership or employee stock ownership plans (ESOPs).

Municipal and locally-led ownership models

Locally-led ownership [28] is a form of ownership based around the "regionalization" of economic control of a business. That is, economic decisions in the business are used to advance the interests of the local community or region. Local ownership models can be as simple as a group of local farmers forming a farmers' market, designed to support the interests of a local farming community.

An extension of this model is that of building local economies through the use of 'anchor institutions' to help grow the local economy, in which local cooperatives would seek to win service contracts for work from local 'anchor institutions' with large budgets, such as a local university or hospital.

The case study for the anchor model is the Mackay Renewable Biocommodities Pilot Plant (see Case Studies).

Government ownership

In this model, an organisation is either fully or partly owned, controlled and operated by the government, as state owned enterprises (SOEs). Some observers reflect on how much government ownership is sufficient to deem an enterprise as 'state-owned', and use a common definition of government ownership as those in which "the state has significant control through full, majority, or significant minority ownership" [28].

Government-owned ventures are not unusual business structures: globally SOEs account for a significant proportion of economic activity. However, often in these ventures the distinction between ownership and control is clear, in that a corporate executive team (rather than public servants) are responsible for economic decision-making.

The case study for the state-owned model is BioPharmaceuticals Australia (see Case Studies).

Employee-owned and employee stock ownership models (ESOPs)

The final alternative ownership model is that of companies with employee-owned (EOBs) and employee stock ownership models (ESOPs) [28].

In this ownership model, ventures have the potential to build a business based on a cohort of employees with an "owner's commitment to the enterprise" [32]. However, in this model the distinction between ownership and participation in the running of a company less clear than in other ownership structures.

Sector analysts report EOBs may outperform non-EOBs on a range of measures, such as profit before tax, job creation, higher levels of management innovation, as well as being more resilient over the business cycle. The combination of stock plans and worker involvement in decision-making may have positive productivity effects, by means other than the provision of direct incentives, by encouraging employee and retention.

To deliver these corporate benefits, employee ownership requires managerial practices and policies to reinforce the strategy, commitment at board level, and employees developing a true sense of company ownership [32].

An example of the employee ownership model is Science Applications International Corporation (SAIC), a US-based research and development contractor, which, prior to listing, reportedly employed ~45,000 people at state-of-the-art facilities in San Diego. Until the company became publicly traded in 2006, the company had grown to generate annual revenues of ~US$6.5 billion to US$8 billion, making it potentially the largest employee-owned firm in the world [33]. SAIC reported the benefits of employee ownership to include focus on long-term goals, higher productivity, reduced workforce turnover, better recruits, and larger profits [32].

Table 5: Ownership models: summary of key features

	Ownership Model							
Features of company type	**Proprietary**	**Public**	**Co-operative**	**Partnership control**	**Leasing**	**Regional**	**Government**	**Employee stock ownership plan**
Business ownership	One investor or small group of investors/co-owners	Ownership publicly traded or privately held as shares	Owned by members (minimum 5) under agreement of mutual benefit	Investors	Investors own infrastructure	Owners are located in a certain region (e.g. farmers)	Government fully or partly owns (full majority or significant minority)	Cohort of employees
Business control	Owner or co-owners	Shareholders play a minimal role in controlling the business, usually limited to electing board members.	Members have control	Investor consortium; may be represented by an investor Board	Management company (investor-owned) with delegated responsibility to lease the equipment and facility from the owners and operate the facility.	Anchor institution or local owner – can use proprietary, co-operative or partnership control models	Government fully or partly controls as "state owned enterprises";	Employees can play a role in decision-making but professional managers control the business,
Asset ownership	Owner or co-owners	Shareholders	Members	Investor consortium	Investors	May be owners or shareholders	Partial or partial government ownership	Depends on the company
Cost control -feedstock -equipment -infrastructure -IP	Owners may own or hold the lease	Operated by professional managers under CEO who is appointed by board members	Members, or by means of professional managers appointed by members' Board	Investor consortium. Costs are pooled and shared among investors according to % ownership.	Totally or partially management company	May be owners or shareholders or professional managers	Corporate executive team (rather than public servants) are responsible for economic decision-making	Depends on the company

Management responsibility -operation -admin -services + maintenance -marketing -sales contracts/ leasing	Owners responsible for strategic and operational decisions	Professional managers under CEO who is appointed by board members	Members, or by means of professional managers appointed by members' Board	Investor consortium	Management company – paying rent to investors	May be owners or shareholders or professional managers	Corporate executive team (rather than public servants) are responsible for economic decision-making	Depends on the company
Revenue management	Owners retain all revenue	Owners (shareholders) benefit value increase in shares-potentially dividend payment-new investment decisions	Members have residual rights of income distribution	Investor consortium distributes costs and revenues. Revenues are pooled and shared among investors according to % ownership Surplus paid regularly to the investors, as directed by the Board	Management company pays rent to investors from net revenue, while retaining working capital. Financial return to owners in share value and distribution of net revenues proportional to their investments	May require operational support; may be not-for-profit	Revenue distribution depends on business strategy ie not-for-profit or for-profit	Employees as shareholders may benefit potentially benefit from dividend payment
Investment	No external investors	External investors may provide significant capital infusion	Limited access to external investment	Each investor is responsible for their own financing for the venture.	Access to external investment depends on business model	Access to external investment depends on business model	Access to external investment depends on business model	Access to external investment depends on business model

RECOMMENDATIONS

The goal of this section is to examine the ownership models for a potential venture that may be established for the purpose of leveraging technical opportunities (such as those developed at CSIRO) to manufacture new value-added vegetable-based products.

This report recommends that to initiate and operate the business venture, consideration be given to the ownership model of choice, which is predicated on the owner or investor, in terms of:

- *Motivation for investment* and the investor's long-term goals and ambitions for the venture. The case studies have illustrated various investment motivations: from commercial outcomes for owners (Dalby Biorefinery), prestige and building capacity (BPA, MRBPP), to achievement of political goals (BPA);
- *Investors and investment*: Number of potential investors and the investment of quantum per investor at project outset;
- *Legal ownership*: the extent of legal ownership of the venture required/desired by the investor. Governments may invest in the project at initiation or during expansion phases without taking an ownership position in the venture;
- *Control*: the level of control required over business operation by the investor;
- *Return on investment*: Size, nature and timing of the expected return on investment. Different owners or investors may be equally motivated for the venture to succeed, although the exact outcome anticipated for each investor or owner can vary;
- *Need for future financing*; and
- *Tolerance of business risk:* different investors can have vastly different tolerance of risk; compare that of entrepreneurs, governments and farmers.

While this section has outlined various ownership models, from corporate, co-operative and alternative structures, further detail is required to determine the optimal ownership model for this project. Specialist legal and tax advice may also be sought.

SECTION D GOVERNANCE

EXECUTIVE SUMMARY

This section reviews the governance framework and practices associated with options for business operating and ownership models considered elsewhere. The section reflects on the essential elements of good governance, the relationship between the governance framework and the management of business and other risks, and the ideal governance and reporting structure between the owners and the executive team, and within the company structure. The creation of sustainable long-term value on behalf of all owners and shareholders is considered the ultimate measurement of successful corporate governance.

This section also presents case studies of ownership structures and governance frameworks from within and adjacent to the horticulture sector to illustrate similarities and differences in the essential ownership and governance. Those case studies are for the proprietary or public company (Dalby Biorefinery), the co-operative model (Norco), state-owned entity and leasing models (Biopharmaceuticals Australia), and anchor ownership models (Mackay Renewable Biocommodities Pilot Plant).

GOVERNANCE

This section considers the governance structures associated with options for business operating and ownership models considered elsewhere.

Goals of Good Governance

Corporate governance delivers leadership and oversight to a venture, often by means of a company board and/or executive team. The governance structure of a company refers to the practices that direct and monitor the way in which an organisation carries out its business. Good governance refers to the processes implemented by the organization to produce favourable results to meet the needs of its stakeholders and owners, while making the best use of resources available: human, technological, and financial. Good governance is responsive to both the current and future needs of the organization, exercises prudence in policy-setting and decision-making, and ensures that the best interests of all stakeholders are taken into account [34, 35]. The creation of sustainable long-term value on behalf of all owners and shareholders is considered the ultimate measurement of successful corporate governance [36].

Best practice in good governance has a number of key attributes: it is a practice that is participatory, consensus-oriented, accountable, transparent, responsive, effective and efficient, equitable and inclusive, and follows the rule of law [34].

A major outcome of corporate governance is for the board and executives to provide the overarching direction for the business, based on a clear strategy and an understanding the current and future issues the company faces. The transparent articulation of the company mission and vision statements provides staff, shareholders and customers with an unambiguous understanding of the purpose and ambition of the company's business activities.

Good corporate governance provides leadership oversight within the business. In publicly-owned companies, for instance, the company board monitors and assesses decisions and actions of the CEO and other executive officers, to ensure that leaders act in the best interest of all shareholders and other stakeholders, and are efficient and effective. In smaller businesses, executive teams assume this role, although without a Board's disinterested oversight, there is a risk of power devolving to one person.

Governance and Risk

Good corporate governance is responsible for achieving a balance between the implementation of business strategy with management of risk, which can require navigation between competing forces. Often this balance requires reconciliation of the often conflicting demands within the operation and its culture and value systems, as well as those of regulators and investors from outside the business [37]. Reconciliation of these demands requires a clear view of the nature of these competing drivers by the board and executives, followed by high level decision-making and agreement of how best to proceed.

Management of business risk is, not surprisingly, focused on financial and legal aspects of an operation. Robust corporate governance practice includes the establishment of internal controls for timely monitoring of compliance with company policy and external regulation, and early detection of impeding problems. The lack of strong basic financial controls is reportedly at the core of the collapse of Parmalat, the Italian dairy conglomerate and that nation's largest milk processor in 2003: weak financial oversight and poor accountability practices allowed inaccurate financial reporting and fraud, resulting in a US$14 billion "black hole" and company bankruptcy [38].

Governance Framework

There are defined structures within a business to support good governance and risk management. The composition of boards and the number, structure and composition of board oversight committees underpin the governance culture within a business. While many boards may have a composition largely representative of owners or investors, the presence of even a small number of external directors brings independence of thought, additional relevant skills and experience, and reduced conflicts of interest to board deliberations on behalf of all investors and stakeholders [39].

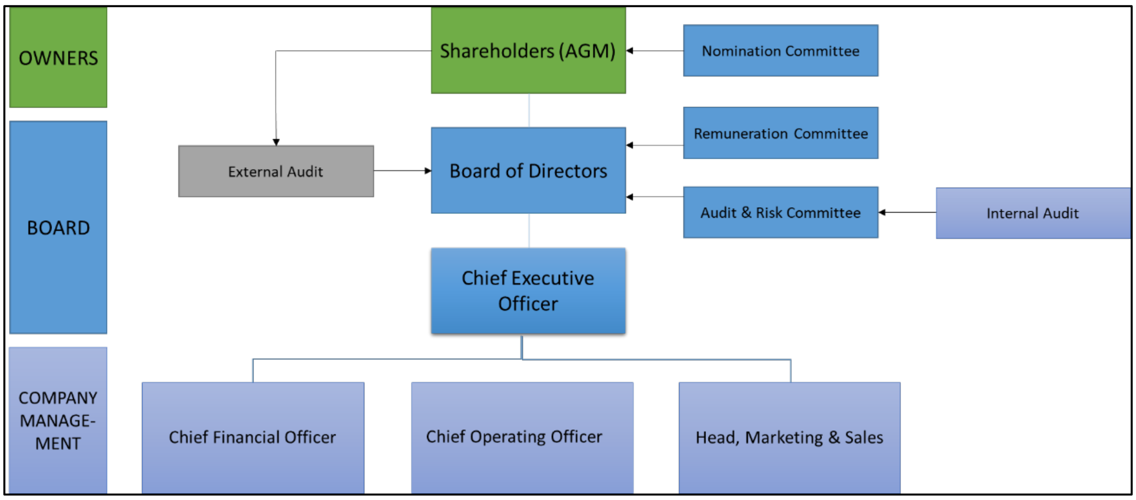

Figure 6: Indicative governance structure of a company or co-operative: the owners of the business are the shareholders who elect the Board at the AGM as advised by the Board's nomination committee; the

Board of Directors establishes a remuneration committee and audit and risk committee, at least; the audit and risk committee is advised by the internal audit team. The Board is advised by an external audit committee nominated by the Board and approved by shareholders. The Board appoints the Chief Executive Officer who establishes a company management team to execute the company strategy. Note that in some models, such as a proprietary company, the governance structure does not necessarily include a Board of Directors. (Source: Adapted from [40])

A framework for good governance is represented in Figure 1. The board is responsible for the appointment of the chief executive, who then recruits the management team. The development of a management culture of participation is a means by which centralisation of power in a single or small number of autocrats can be avoided.

The board is responsible for establishing the framework of internal controls and for monitoring the development of a working relationship between the management systems and those controls to provide an effective system of checks and balances for sound operational practices and decision-making consistent with strategy. Good governance ensures a clearly defined role for internal auditors and risk managers, with an appropriate structure of reporting to senior executives, to board committees and hence to the board (see Figure 1).

CASE STUDIES

In this section, case studies of ownership structures and governance frameworks for proprietary or public company (Dalby Biorefinery), the co-operative model (Norco), state-owned entity and leasing models (Biopharmaceuticals Australia), and anchor ownership models (Mackay Renewable Biocommodities Pilot Plant) are presented. A summary of the ownership models is provided in Table 7.

Dalby Biorefinery: proprietary or public ownership model.

The ownership model for the Dalby Biorefinery is one driven by commercial opportunity, and cost and competitive advantage, i.e. quantitative metrics.

Dalby Bio-Refinery Limited is a grain-to-ethanol production facility, founded in 2002 and based in Australia. As of May 2011, Dalby Bio-Refinery Limited has operated as a subsidiary of United Petroleum Pty Ltd. The core business of the venture is the manufacture of ethanol from sorghum grain; by-products are syrup and a high protein animal feed as distiller's grain. The facility is co-located with the feedstock in Dalby, Queensland [26, 41].

The venture was initiated, funded and owned by Petrofuels, a private Australian fuel distributor with commercial links to Caltex. The facility was conceived for production of 5 million litres of ethanol p.a. in response to the opportunity for Petrofuels to generate E10 fuel for distribution to the company's existing client base. However, as a result of a cost benefit analysis, the production capacity of the facility was expanded to an economically viable scale of 70 million litres p.a., at which scale ethanol could be manufactured cost-competitively. Consequently, due to the size of the owner's existing business, Petrofuels was required to secure offtake agreements for ~93% of plant production [26].

The facility was subsequently purchased by United Petroleum, a company with a similar business model but with a substantially larger distribution base in Australia. United

Petroleum had a higher volumetric requirement for ethanol for E10 that necessitated offtake agreements for only 30% of production [26].

Key lessons from the Dalby Bio-Refinery that proved critical to the success of the venture included that [26]:

- In contrast to those ventures that are owned by feedstock producers, ventures that are owned from within the relevant industry (i.e. by an end-user) are more likely to succeed due to the existence of the owner's direct links to market; and
- The extent to which total production was consumed with owner's commercial operation was critical, as this minimised the venture's dependency on offtake agreements with third parties for economic viability.

As a subsidiary of United Petroleum, Dalby Biorefinery is now operated by United Petroleum business managers and reports up through the company business structure.

NORCO: co-operative model

Norco Co-operative Limited (Norco) is a dairy co-operative limited by shares that is incorporated and based in Australia, and established in 1894.

Norco is a 100% Australian farmer-owned venture with 326 members (i.e. owners). Norco actively manages its membership and only admits new members in order to meet emerging contract and other revenue opportunities, after existing members are given the option to increase production in response to those opportunities [3].

The alignment of the dairy co-operative's corporate interests with those of the farmer members and the members' community is reported by Norco as enabling the construction of a loyal shareholder base. The business relationship between members and the co-operative is reportedly a close one, based on a corporate vision of "lowering the member's input prices, rather than a focus on the supplier's profit". The ongoing commitment of owner members to the co-operative requires an economic imperative, which Norco aspires to meet by means of competitive farm-gate milk pricing and a commitment to collect every litre of milk that members produce. Other economic benefits make co-operative membership an attractive option for farmer owners and include annual dividends, patronage scheme rewards, credit facilities, training and extension services, and assistance in times of special need, such as natural disasters [2, 3].

> "We have no external shareholders, so our members know we need to make enough for an acceptable profit to reinvest, but that everything we make above that goes back to them. We have regular supplier–member meetings, about four times a year, and we have a huge turnout at those. We go through all of the financials, the strategies, and answer any questions. I believe our members truly understand that we are a highly successful business but that it all belongs to them; they are the owners."
>
> Brett Kelly [4]
> Norco CEO 2008 - 2017

Stewardship of assets

Norco is an incorporated dairy co-operative limited by shares. The co-operative is governed according to the Co-operatives National Law (NSW) [42] and a set of rules or charter. The charter represent a contract between the co-operative and each member, the co-operative and each director and officers, and between the members.

An important aspect of Norco's co-operative governance structure is the "one member, one vote" principle, in which farm size does not determine a member's contribution to the decision-making of the co-operative. In reality, the Co-operative reports that generally only just over 50% of members choose to vote on a ballot at General Meetings [3].

Norco has a clearly articulated corporate vision statement that underpins the governance of the Cooperative, which is to act for the long-term benefit of its members. Norco's purpose is to build wealth, security and sustainability for "our shareholders, business partners and employees, by [2]:

- maintaining a diverse and strong range of businesses;
- being a competitive regional purchaser and supplier of milk; and
- creating integrated solutions for our partners".

Board of Directors

The Co-operative has a Board of Directors, with a duty to manage and control the business of the co-operative and the long-term interests of the farmer members, and to represent all members. The Board is elected by members on a rotational basis, with two directors retiring each year. The Board comprises six farmer members as well as up to two independent directors, who are nominated by the Board and elected by the members. The Chair is elected from among Directors by the Board for a one-year term. In the 2017FY, there were no independent members on the Board [2].

The challenge for the Norco Board is to weigh the opportunity to pass more revenues to the members against the opportunity to retain profit to build the business, on behalf of members. Board decision-making is reportedly streamlined by the requirement to consult with members only for major decisions, such as listing or selling a business [3].

> There is a balancing role for the board between paying more to members and retaining funds within the co-operative to invest in projects that improve long term profitability and sustainability."
>
> [3]

Board committees

As are many corporate boards, the Norco board is assisted by a series of sub-committees staffed by directors, with clearly defined roles and responsibilities to provide recommendations to the board overall. The committees are similar to those supporting decision-making in most corporate boardrooms (audit and risk, and remuneration advisory committees) as well as those related to the specific strategic goals and business of the Co-operative (milk supply advisory, brand management advisory, member services, and communication committees):

- Audit and Risk Management Committee: provides a view on the accounting and reporting practices of the Co-operative and subsidiaries, the framework of internal control and appropriate ethical standards for the management of the Co-operative.
- Remuneration Advisory Committee: makes recommendations regarding remuneration of the Senior Management team, Chief Executive Officer and Board of Directors and in relation to incentive programs within the Norco business.
- Milk Supply Advisory Committee: provides recommendations around the acquisition of milk by the Milk Supply business unit and the sale of that milk to its external and internal customers.
- Brand Management Advisory Committee: maintains a watching brief and makes recommendations regarding Norco's brands and animal welfare issues for both Norco and Norco's farmer members.
- Member Services Committee: considers the adoption of policies relevant to member issues other than milk supply, including providing initiatives such as improving farming techniques, study tours and improving business skills.
- Communication Committee: maintaining a clear channel of corporate communication to members and other stakeholders.

Executive team

A feature of Norco's operation is the engagement by the owners of an executive team comprising independent, professional senior managers: the chief executive officer, a general manager for each of business units, chief financial officer, and human resources manager. Norco's most recent CEO was a professional manager, bringing to his role experience gained within the pharmaceuticals, international brand retailing, fast-moving consumer goods and wholesale industries. Significantly, Norco has not only attracted bu retained these key executives: most recently, the Norco CEO served from 2008 to 2017, maintaining corporate memory and culture.

Norco has built a culture of member communications and engagement supporting a consultative process within the co-operative business model. Information is provided to members through the annual report and newsletters, meetings on-site in supplier locations, and an informal communications network. At "two interactive rounds of meetings with members each year, the Chair and CEO update members on important board decisions made or under consideration" [3].

BioPharmaceuticals Australia: leasing model and state-owned entity

BioPharmaceuticals Australia Pty Ltd (BPA) was a proprietary company, limited by shares, with the sole shareholder being the state Minister for Housing and Public Works and for Science and Innovation [43]. In other words, BPA was an entity wholly-owned by the Queensland State government, established for the purpose of housing a commercial operation.

On establishment, key investors in the facility were the Commonwealth, a State government, and a research institute.

Both Federal and State governments were motivated to establish a large-scale cell-based manufacturing facility due to the recognition of significant gaps in the national capacity in biopharmaceutical and cell-based manufacture, as alerted by several independent reviewers. The Commonwealth contributed A$10 million to the project by means of a special purpose grant, at project outset [27].

In addition, investment by the State government was driven by the State's ambition to establish prominence in the national biotechnology industry. The State government took the lead on the project, with goals for the venture's core business as [44]:

- Design, fund and construct a new GMP[10] facility to be operated by a specialist contract manufacturer; and
- Facilitate synergies between complementary providers of clinical development services.

The State government had a ten-year plan to turn the selected region into a hub for world-class biomedical research activity, a plan inclusive of project due diligence, plant engineering design and costing, construction and commissioning, and securing a specialist pharmaceutical contract manufacturer as a leasee. BPA was conceived as a development vehicle by the Queensland State government to achieve the goals of the government. The Queensland State government contributed A$7 million to the project, at project outset.

Investment in the facility by the state-based institution was driven by a need to expand institutional presence to build prestige. A contribution of A$33 million to the biomanufacture project was made by the Translational Research Institute (TRI), as the project proceeded, to facilitate the co-location of the BPA facility with the Institute [45].

Ownership and operation of the facility are separated: the biomanufacturing facility is a state-owned entity (SOE) and operated by a company (BPA). The ownership of the facility building itself is the property of the Queensland Dept. of Health and the facility is built on hospital land, co-located with the research institute. The premises are leased by the research institute from the owner (the State); the institute sublets the premises to BPA (the management company) which sub-sublets to the contract manufacturer. At the end of 10 years, BPA was wound up as an entity (as planned); the research institute (TRI) now sublets the facility directly to the contract manufacturer (DSM).

The outcome of this ownership model is regarded as successfully delivered, by both quantitative and qualitative measures.

From the State's perspective, DSM has operated at capacity[11] since commencement, and is commercial sustainable. DSM has created employment (130 FTEs) at the facility; has upskilled staff; operates 24/7; and reports a high level commercial return on a gross revenue of more than A$20 million - $30 million p.a. The original leasee, DSM Biologics, has since been spun out of Royal DSM and merged with Pantheon, and then acquired by Thermo

[10] Good Manufacturing Practice (GMP) is an internationally recognised system for ensuring that medical and pharmaceutical products are consistently produced and controlled according to quality standards. GMP is designed to minimize the risks involved in any pharmaceutical production that cannot be eliminated through testing the final product. GMP is concerned with all aspects of production from the starting materials, premises, and equipment to the training and personal hygiene of staff. https://ispe.org/initiatives/regulatory-resources/gmp

[11] producing 500 kilograms of drugs pa with potential to double to 1 tonne pa.

Fisher Scientific, so there are now elevated expectations regarding the scale of operation and resources to be brought to bear to the Queensland production facility [27].

The total benefit or return to the State as owner of the facility over 10 years is regarded by the State as substantial, although qualitative: attraction of an internationally recognised company as the contract manufacturer; high quality specialist skills training (50 skilled positions were created by the project); both direct and indirect employment brought to the region; attraction of business to Queensland with a view to establishing manufacturing contracts at the facility; and establishment of a commercial scale, mammalian cell facility to meet a capability and capacity gap nationally. DSM brought to the facility proprietary technologies, otherwise unavailable within the region. The State government considers that the investment in the facility has made Queensland an international showcase and hub for development in cell-based manufacture or pharmaceutical sector [27, 44].

In addition, there are benefits of this ownership model to the contract manufacturer as leasee (DSM). The leasee has access to a A$50 million, state-of-the-art facility in exchange for a commitment to a long term lease (10-year lease initially, then 5-year leases), as well as exclusive access to the market opportunity for contract cell-based manufacture in Australia.

During its ten-year operation, the governance structure of BPA was a simplified version of the hierarchy represented in Figure 1 [27], comprising:

- Board: of independent directors only, with no government representation i.e. no representation by owners. This structure allowed the State government to maintain a professional and political distance from the commercial operation of the state-owned entity;
- Shareholder: BPA had a single shareholder, the Queensland State Minister for Housing and Public Works and for Science and Innovation;
- Executive: The management of BPA was in hands of independent, experienced and professional executives, not employees of the owner (i.e. not public servants).

From the outset, both the ownership and framework within which management operated was clear. The facility was State-owned and company-operated; company management had clear objectives and timeframe of execution. The reporting structure similarly was defined at the outset of the venture: the CEO reported to the shareholder through the BPA Board.

Mackay Renewable Biocommodities Pilot Plant: anchor ownership model

The Mackay Renewable Biocommodities Pilot Plant (MRBPP) is a pilot scale fermentation facility for the conversion of lignocellulosic biomass such as sugarcane bagasse into biofuels [46].

While the facility is owned by the Queensland University of Technology (QUT), and operated through the university's Institute of Future Environments, the venture was financed by Federal and State governments and QUT. The Federal government contributed A$5 million through the National Collaborative Research Infrastructure Strategy (NCRIS) and the Education Investment Fund, the Queensland State government A$3.1 million through the Smart State Facilities Research Fund, and QUT A$2 million from research funding and education revenues. The facility is co-located with Mackay Sugar Limited, one of Australia's leading sugar manufacturers and a feedstock provider, on the site of the Racecourse Mill in Mackay, Queensland, on a 30-year lease [46].

The facility is made available for use public and private sector researchers under the requirements of the NCRIS program. Although revenue is earnt through contract research, predominantly from the anchor institute (QUT), the majority (50-60%) of operational costs are provided by QUT [47, 48].

The governance structure of the MRBPP reflects the facility's university ownership. The facility operates as an external QUT site and is managed through the Institute of Future Environments [49] on behalf of QUT. The executive head of the Institute delegates responsibility for the operation of the facility to the Institute's Head of Research; the executive head of the Institute reports through normal university channels to the vice-chancellor. The facility's executive team comprises a program leader (a business development role and coordination of the research facility), and a pilot plant manager is responsible for the day-to-day running of the facility, maintaining the technical equipment, purchasing thorough the Institute.

Case study ownership models

The ownership models of the case studies are summarised in Table 7 below.

Table 6: Summary of the comparable ownership models of the case studies

Case study	Dalby Biorefinery	Norco	BPA		Mackay Renewable Biocommodities
Ownership model	**Proprietary**	**Co-operative**	**Government**	**Leasing**	**Regional**
Business ownership	Subsidiary of United Petroleum Pty Ltd	100% Australian farmer-owned by 326 members	Government fully owns BPA as a proprietary company. One government shareholder.	Government owns infrastructure	Queensland University of Technology (QUT) as anchor institute
Business control	Owner (United Petroleum)	Members have control through a representative Board and professional managers	Government delegates control to professional managers	Business control is delegated to professional management company that negotiated lease with specialist manufacturer	Queensland University of Technology (QUT)
Asset ownership	United Petroleum	Members	Government owns infrastructure and some equipment	Government owns infrastructure and some equipment	Queensland University of Technology (QUT),
Cost control	United Petroleum	Members, or by means of professional managers appointed by Board	Corporate executive team (rather than public servants) are responsible for economic decision-making	Specialist manufacturer operates the facility	University employees as professional managers
Management responsibility	United Petroleum is responsible for strategic and operational decisions	Members, by means of professional managers appointed by Board	Corporate executive team (rather than public servants) are responsible for economic decision-making	Specialist manufacturer operates the facility	University employees as professional managers
Revenue management	United Petroleum retains all revenue	Members have both direct and indirect financial benefits including income distribution and cost reductions	Government benefit is intangible: achievement of strategic goals	Specialist manufacturer pays rent to investors, while retaining net revenues.	University provides operational funding to supplement contract revenues
Investment	No external investors	Limited access to external investment	No external investors	No external investors	No external investors

RECOMMENDATIONS

The goal of this section is to examine the governance models for a potential venture that may be established for the purpose of leveraging technical opportunities (such as those developed at CSIRO) to manufacture new value-added vegetable-based products.

This report recommends that to initiate and operate the business venture, consideration be given to strong governance framework and practices, established at the outset of the venture, that are required to protect owners' assets and to deliver long-term business sustainability. Good governance will seek to align the venture's corporate goals with those of the owners. The ideal governance structure will have an element, at least, of independent oversight, provide mechanisms for owners to have input into strategic decision-making, and to receive financial and performance reporting from business operations. Irrespective of ownership structure, critical to the successful business operation is the engagement of professional management: attracting and retaining good managers is considered essential to flexible and responsive business practices or "plasticity in business structure".

SECTION E COMPETITIVENESS

EXECUTIVE SUMMARY

The goal of this section is to examine the long-term competitiveness, including product differentiation potential, of a potential venture that may be established for the purpose of leveraging technical opportunities (such as those developed at CSIRO) to manufacture new value-added vegetable-based products.

This section considers the long term competitiveness of the venture as a sustainable commercial business. This report considers competitiveness both through the lens of the national competitiveness ranking of Australia from a global perspective, as well as the Australian horticulture sector delivering high value premium ingredients into the food, beverages and nutraceutical markets. Sectorial competitiveness of the venture may be based on branding, provenance and traceability, supply chain control, veracity of product specifications, critical scale of production, industrial R&D strength, transparency and stability, access to the Asian market, and ready access to support infrastructure.

COMPETITIVENESS

This section will consider the long term competitiveness of the venture to value-add fresh produce. This report considers competitiveness both through the lens of the broader national competitiveness ranking of Australia from a global perspective, as well as that of the horticulture sector delivering premium ingredients into the food, beverages and nutraceutical markets.

Australia's national competitiveness

A review of Australia's global ranking may provide context for an assessment of the competitiveness (and challenges) of the new rural, horticulture-based venture.

The World Economic Forum's annual Global Competitiveness Report ranks the competitiveness of 134 countries, using such indicators such as macroeconomic health, the quality of infrastructure, and labour market efficiency (see Table 8). Australia is now ranked the 21st most competitive economy in the world, four places below the nation's position in 2016. Australia is now behind most of its key competitor nations [50, 51].

Table 7: IMB world competitiveness rankings by country: 2017

Ranking (out 0f 29 economies)	Economy	Overall IMD Global Ranking (out of 63 economies)	Sub-sector Global Ranking (out of 63 economies)							
				Economic Performance		Government Efficiency		Business Efficiency		Infrastructure
1	USA	4	USA	1	Taiwan	10	Canada	11	USA	2
2	Canada	12	China	2	Canada	13	USA	14	Germany	9
3	Germany	13	Germany	7	UK	17	Taiwan	15	Canada	10
4	Taiwan	14	Thailand	10	Australia	18	Germany	16	France	12
5	China	18	Taiwan	12	Thailand	20	China	18	Japan	14
6	UK	19	Malaysia	13	Germany	21	Malaysia	19	UK	15
7	Australia	21	Japan	14	Malaysia	25	UK	21	Australia	18
8	Malaysia	24	Canada	16	USA	27	Thailand	25	Taiwan	21
9	Japan	26	India	18	South Korea	28	Australia	27	South Korea	24
10	Thailand	27	Saudi Arabia	21	Indonesia	30	Philippines	28	China	25
11	South Korea	29	South Korea	22	Saudi Arabia	31	India	29	Spain	26
12	France	31	France	24	Japan	35	Indonesia	30	Malaysia	32
13	Spain	34	Australia	25	Philippines	37	Japan	35	Italy	33
14	Saudi Arabia	36	Philippines	26	Spain	38	Mexico	36	Poland	34
15	Poland	38	Poland	27	Turkey	41	Poland	37	Russia	36
16	Philippines	41	UK	29	Peru	43	Saudi Arabia	38	Saudi Arabia	44
17	Indonesia	42	Mexico	30	Poland	44	France	40	Turkey	48
18	Italy	44	Indonesia	33	China	45	South Africa	41	Thailand	49
19	India	45	Spain	35	Russia	46	Spain	42	Brazil	51
20	Russia	46	Italy	38	India	48	Turkey	43	Argentina	52
21	Turkey	47	Colombia	41	South Africa	50	South Korea	44	Ukraine	53
22	Mexico	48	Turkey	43	Mexico	51	Italy	45	Philippines	54
23	South Africa	53	Russia	46	France	52	Brazil	49	Mexico	55
24	Colombia	54	Peru	50	Italy	53	Russia	51	South Africa	56
25	Peru	55	Ukraine	55	Colombia	56	Colombia	53	Colombia	58
26	Argentina	58	Argentina	56	Argentina	58	Peru	55	Indonesia	59
27	Ukraine	60	South Africa	58	Ukraine	59	Argentina	58	India	60
28	Brazil	61	Brazil	59	Brazil	62	Ukraine	59	Peru	61
29	Venezuela	63	Venezuela	63	Venezuela	63	Venezuela	61	Venezuela	63

Rankings for countries with populations of more than 20 million. Source: from the International Institute for Management Development (IMD) World Competitiveness Online 1995-2017 [51]; and Austrade.

The 2017 outcome reflects a decline in Australia's global competitiveness rankings in three of the four major factors: economic performance, government efficiency, and business efficiency, while the nation's global ranking in infrastructure has remained unchanged. However, Australia continues to rank in the top 10 of global economies for financial markets (6th best) and higher education and training (9th best) [52].

In terms of major attractiveness factors of the economy, Australia scored particularly well in the areas of effective legal environment, skilled workforce, high educational level, quality of corporate governance and reliable infrastructure. In contrast, Australia was ranked less well in terms of a competitive tax regime, cost competitiveness, competence of government, strong R&D culture and effective labour relations. Notably however, Australia was viewed as the 14th most resilient economy in the survey, reflecting the nation's global record for the longest period of recession-free growth for a developed country [53].

Business efficiency is the lowest ranking area in the 2017 assessment, falling by ten positions to 27th. Major drops in rankings were registered in apprenticeships, employee training, workforce productivity and entrepreneurship. However, some of the bright spots for Australia's reported business efficiency were foreign highly-skilled personnel, investment risk, regulatory compliance, corporate debt and stock markets [51, 54].

Some aspects of Australia's infrastructure ranking were perceived as uncompetitive, such as energy infrastructure, communications technology and connectivity. These aspects, combined with restrictive labour regulations, high tax rates and a relatively poor ranking of innovation, are considered the major inhibitors of national competitiveness [50, 52].

Sectorial Competitiveness

This section considers the aspects that may potentially contribute to the competitiveness of a value-adding horticulture-based venture delivering premium ingredients into the food, beverage and nutraceuticals markets. Sectorial competitiveness of the venture is based on branding, provenance and traceability, supply chain control, veracity of product specifications, critical scale of production, industrial R&D strength, transparency and stability, access to the Asian market, and support infrastructure.

Branding

The proposed venture from within Australian horticulture industry has the prospect of building a commercial branding that leverages its origins in a rural community as well as Australia's "clean and green" image. That branding has the potential to inspire offtake by end-users and customers, particularly in the export market, and to justify demand for premium prices for its products. This first-class positioning has worked effectively for the Norco dairy cooperative [2, 3], and recently was a major driver of the joint venture partnership between Ermenegildo Zegna and the New England wool producer Achill[12] [1, 10].

Differentiation

A new product needs to provide substantial and verifiable differentiation to secure market share in a highly crowded, competitive, and price-driven market.

Provenance and Traceability

There is export market interest, especially from Asia but increasingly from western markets such as the US, in the importance of knowing the origins of food and nutrients. That a premium price can be ascribed to those high protein foods with demonstrable provenance and traceability has been leveraged already within the Australian agricultural scene, most notably in meat and dairy. Domestic and export end-users and customers increasingly demand clarity and certainty around the origin and security of foods and food ingredients.

Consequently, provenance is now becoming a fundamental requirement of the performance metrics of supply from the horticulture sector to end-users and customers.

In contrast, the awareness of provenance and traceability as an attribute of horticultural produce, how to evidence provenance, and implementation of traceability reporting structures by growers within the sector is reportedly mixed but low. While the prospect of certified provenance and traceability associated with high value products of the venture is likely to deliver competitive advantage, the level of awareness among aspiring growers, and implementation of consistent and standardised traceability reporting and certification systems for validation still need to be addressed.

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[12] Ermenegildo Zegna is an Italian luxury fashion label with revenues of €1.156 billion 2016FY, making the company the largest menswear brand in the world by revenue. Achill is a family farm in NSW's New England region of 2564 hectares, with 12,500 sheep producing superfine 14-17 micron wool at 20,000 kg pa. The joint venture in 2014 was driven by the market significance of Australia as a rural supplier.

In contrast, end-users and customers interviewed for this work clearly understand the competitive value of provenance and traceability. These attributes have become essential tools used by these companies to secure their supply chain, to protect against forgery, and as a metric for both risk and quality management. For the markets those end-users and customers service, the strategic position of Australia as “green clean safe” is incredibly powerful in China, elsewhere in Asia and increasingly in the US.

Supply Chain Control

Controlling the supply chain is seen by end-users and customers as a key competitive advantage for any horticulture-based venture[13]. End-users and customers demand a product at a specified and standardised quality, competitively priced, traceable, and of surety of supply. While end-users and customers are intensely focused on the outputs of the supply chain, there is no interest in directly managing a large number of small growers within the supply chain, but prefer to rely on aggregators to do all of this on end-users’ behalf. Therefore, the role of the venture as an aggregator is much more pivotal and valuable to end-user, and robust supply chain management on behalf of end-users and customers may present as an opportunity to build competitive advantage for the venture overall.

Veracity of Product Specifications

A driver for uptake by end-users and customers of Australian premium, horticulture-based ingredients is the prospect of import replacements for existing products manufactured under an Australia label. The opportunity for those companies to access better quality and traceability-certified ingredients is market-driven, in response to a message from the consumer that is “incredibly powerful”[14].

Therefore, achievement of independent verification and evidence to support the quality and composition (and any bioactivity) of the value-added product may be considered a competitive advantage by the venture. End-users and customers require a clear evidence of claims, conducted in a scientific manner by an independent third party, to underpin contract negotiation with the customer for offtake. This verification will contribute further to the competitiveness of the venture by underpinning branding.

Critical Scale of Production

Operating at a commercially-critical scale of production is a key contributor to the competitiveness of the venture. This economic scale delivers to the venture the competitive benefits of[15]:

- Cost-effective, and potentially cost-competitive, manufacture of product;
- Expanded customer base: the capacity to secure an expanded customer base, and independence from reliance on single or few customers;
- Negotiating power to enforce terms of payment from customer; and
- Security of supply of feedstock: providing the venture with negotiating power in supply agreements.

[13] Industry respondents

[14] Industry respondents

[15] Specialist processor respondent

Industrial R&D Strength

Australia is recognised internationally for high quality research and development in industrial, environmental and agricultural sciences. Therefore, a competitive advantage for the venture may be the close association between industry and research communities which can be leveraged to develop a robust pipeline of new or replacement products for commercial exploitation, and translation of improved process productivity measures or crop production into the commercial context.

Transparency and stability

Australia has well-established and transparent regulatory structures, and provides a stable political and financial environment for manufacturing and investment. As a location for investment, particularly from international parties, Australia offers a western business community and reputation for IP security.

Access to the Asian market

Located with direct access to the Asian region and in particular the dynamic Chinese economy, Australia offers substantial advantages for the establishment of a premium ingredients business. Asia will be an important future consumer of high value horticulture-based products, and Australia has a long history of successful marketing and business relationships in the region.

Support Infrastructure

The co-location of the venture in regions with well-established horticulture production means that the venture will have ready access to deep water ports and/or transport logistics already in place to service the marketing of fresh produce.

Summary

In summary, the key metrics of sectorial competitive for the venture are listed in Table 9.

Table 8: Key metrics of sectorial competitive for the venture

Competitive Measure	Detail
Branding	Commercial branding that leverages its origins in a rural community as well as Australia's "clean and green" image
	Supported by independent verification of quality and composition
Differentiation	New product delivers substantial and verifiable differentiation
Provenance and Traceability	Clarity and certainty around the origin and security of foods and food ingredients
Supply chain control	Robust supply chain management guaranteed to deliver a product to the customer at a specified and standardised quality, competitively priced, traceable
Veracity of product specifications	Independent verification and evidence to support the quality and composition (and any bioactivity) of the value-added product
Critical scale of production	Operating at a cost-effective scale
Industrial R&D strength	Support for an innovative pipeline of new products and continuous process improvements
Transparency and stability	Transparent and stable regulatory structures, and political and financial environment for manufacturing and investment
Access to the Asian market	Co-located with direct access to the Asian region and in particular the dynamic Chinese economy
	Long history of successful marketing and business relationships in the region.
Support infrastructure	Co-location with horticulture production regions provides ready access to deep water ports and/or transport logistics

RECOMMENDATIONS

This section has considered the competitiveness factors in the proposed venture in order to build a commercially sustainable business with prospects of long-term value for investors, shareholders and stakeholders.

While as a nation, Australia has a high global competitiveness ranking, that ranking has slipped over recent years as that of other nations improved, and it is within that landscape that this venture intends to begin operating. In addition, the industrial markets into which the venture will deliver premium ingredients are recognised as notoriously subject to consumer fads, are intensely competitive and price-driven.

Therefore, to build the competitiveness of the venture, this section recommends that attention be paid to building on the key advantages of the project, to:

- Build branding as an Australian rural business delivering “green clean safe” products;
- Invest in provenance and traceability certification;
- Establish direct and evidenced control over the supply chain, on behalf of end-users and customers;
- Define a clear product differentiation;
- Verify product quality, composition and bioactivity, especially to meet customer specifications;
- Achieve a critical scale of production;
- Build cost-effective production processes and a pipeline of future products in response to market trends and leveraging Australia’s industrial R&D strength; and
- Build and invest in early linkages to access the Asian market.

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Chapter 4. Modelling the economic impact of a food processing hub

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Contents

Executive summary

- The paper provides an economic impact analysis for the proposed establishment of a horticultural food-processing hub in regions across Australia. A case study is provided as an example in Gippsland, Victoria.

- The economic impact case study covers three main components: 1) direct capital expenditure on its creation, 2) current expenditure on the operation of the hub, primarily on wages and salaries as well as farm incomes and 3) the flow-on effects of both areas of expenditure on the wider economy.

- Estimates show an annual impact of the hub on the Gippsland regional area of around $million 74 per annum or 1.5 to 2.0 per cent of the Gross Regional Product for the region (in the construction phase around $million 28).

- To the broader Australian economy the economic impact will be around $million 94 per annum.

- Around 55 jobs would be created from the operation of the hub, including those directly employed and those contractors associated with it. Another 50 or so jobs would be created in the region from the flow affects as newly generated income is spent in the region.

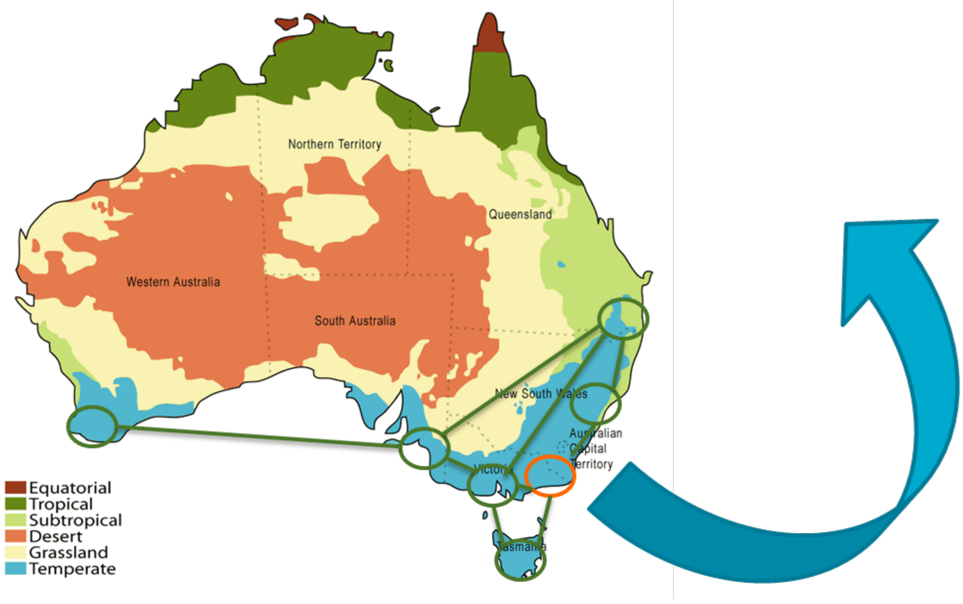
- Flow on effects from an increase in entrepreneurial activity in the region is likely to be created. Such a hub will create many jobs for newly formed micro and small enterprises, which further generate substantial employment opportunities, particularly for the young, and disadvantaged.

Introduction

The purpose of this paper is to provide an economic impact analysis of the proposed establishment of a food-processing hub in regional Victoria. The economic impact of this project would have three main components: 1) direct capital expenditure on its creation, 2) current expenditure on the operation of the hub, primarily on wages and salaries as well as farm incomes and 3) the flow-on effects of both areas of expenditure on the wider economy. The methodology used for this study is one commonly used for economic impact analysis by using a number of existing data sources for comparison, reconciliation and analysis without generating new primary data.

Case study

In this study, the case of Gippsland in the State of Victoria has been chosen as a representative region of Australia. The economic impact of the proposed hub has been designed in such a way that it would be expected to have a similar impact if it was located elsewhere in regional Australia. Although this study focuses on the impact of the proposed food-processing hub on a single particular region, the estimation of expected effects generated at a national level will also be undertaken. In this case, a particular region is identified for the purpose of the study. It is expected, therefore, that this analysis and investigation will have use as a template or model for further studies on the impact of food processing hubs established elsewhere in Australia.



Background

Gippsland is a south-eastern region of Victoria, covering an area of 41,556 square kilometres. Gippsland had a at the 2016 Census a population of 274,416 (Table 1), with the principal population centres of the region, in descending order of population, being Traralgon (25,485), Moe (15,509), Warragul (14,276), Morwell (13,540), Sale (13,511), Bairnsdale (12,952), Drouin (11,887), and Leongatha (5,119) (Australian Bureau of Statistics 2016). Gippsland is best known for its primary production such as mining, power generation and farming as well as its tourist destinations— Phillip Island, Wilsons Promontory, the Gippsland Lakes, and the Baw Baw Plateau. The region of Gippsland is comprised of six geographically, economically and socially diverse local government areas, namely; the Bass Coast Shire, East Gippsland Shire, South Gippsland Shire, Wellington Shire, Latrobe City and the Baw Baw Shire (see Figure 1).

The major concentration of population of Gippsland is centred in the Latrobe Valley region in the central part of Gippsland. The area has three major centres, from west to east, Moe, Morwell and Traralgon. The three local government areas of Baw Baw, Latrobe and Wellington roughly correspond to the Latrobe Valley region with the combined population of these three areas being164,719 in 2016.

Economically, the Latrobe Valley and broader Gippsland regions have been central to the development of the State of Victoria, and Australia as a whole. The region now faces a number of important challenges, as a result of industry and social changes. Of particular impact is the closure of the Hazelwood Power Station, which will require its former employees to learn and acquire a new set of skills and knowledge. An ageing population and workforce; high levels of youth unemployment and disengagement; increasing income inequalities within and between geographic regions that manifest themselves in different dimensions, including housing and health; the need to train, retrain its workforce and the imperative to attract skilled people and investment to ensure sustainable economic and social development (Esposto & Abbott 2011a, 2011b).

Although the energy sector is a significant employer of people in the region (7.8 per cent) agriculture, forestry and fisheries contributes 8.6 per cent of the value added of broader Gippsland region along with 9.5 per cent of employment (Table 2; NIEIR, 2014; Latrobe City 2017). These productive activities cover food growers, producers, manufacturers, fishing, viticulture, dairy and cattle farming. Gippsland's quality produce has an excellent reputation and is sold widely both across Australia and overseas. The health, transport and education sectors have also been important employers in recent years, both in the Latrobe Valley region and Gippsland more generally (see Table 2).

Figure 1: Gippsland local government areas

Table 1: Latrobe Valley, Gippsland characteristics 2016

	Latrobe	Latrobe Valley	Gippsland	Victoria	Australia
Current GRP/GSP/GDP	$m 5,694	$m 13,194	$m 57,483	$m 466,046	$m 1,959,696
Per capita GRP/GSP/GDP	$66,495	$68,000	$57,483	$68,681	75,127
Population	73,257	164,719	271,416	5,926,624	23,401,892
Median age	41	42	45	37	38
Labour Force	32,646	74,282	118,717	2,929,593	11,471,294
Unemployment rate	9.7%	7.5%	6.9%	6.6%	7.0%
Participation rate	54.4%	55.0%	53.0	60.5%	60.0%
Higher education qualifications	8.9%	9.7%	9.9%	19.9%	17.9%
Diploma/certificate qualifications	26.6%	26.5%	26.6%	21.4%	22.5%

Latrobe is the local government area of the Latrobe City. The Latrobe Valley region is the three local government areas of Latrobe, Wellington and Baw Baw. Source: Australian Bureau of Statistics, Census 2016. Latrobe City Council 2017.

The Victorian economy has been experiencing a moderate rate of growth since 1993 and is forecast to continue in the short to medium term. This growth rate is, however, not concurrently being experienced in the Latrobe Valley region. Tables 1 and 2 below provide a brief comparative snapshot of the Latrobe City local government area, the Latrobe Valley region, Gippsland, Victoria and Australia

Compared to Victoria and Australia, the Latrobe Valley region has experienced slower (and sometimes contracting) economic growth, a slower rate of population growth, lower levels of average income, an aging population and an over dependence on the electricity generation sector for employment. In addition, the majority of its workforce possesses diploma and certificate qualifications, with only a smaller proportion having higher education level qualifications (Table 1). Unemployment levels for a number of years have been on average higher in the Latrobe Valley region compared to the state overall. This high unemployment rate is concentrated in the Latrobe City and recent power plant closures have seen further rise in the unemployment rate which peaked at 11.2 per cent in December 2016 (Latrobe City Council 2017). It is notable as well that the participation rate in the Latrobe Valley and Gippsland regions is lower than the state and nation overall a reflection of the history of layoffs from the power industry, which has seen many workers take early retirement (Table 1).

Short, medium and long-term growth prospects will depend on the local economy attracting new types of (non-traditional energy) businesses, thus changing the current education, and training mix. As the regional economy grows based on exploiting local comparative advantages additional demands for skills to support these advantages and promote growth will be required (Esposto et al 2012; Esposto and Garing 2012, Esposto 2012).

Establishing the hub in a central part of Gippsland in Victoria would have some advantages. Victoria represents 21 per cent of Australia's fresh produce production (1.7 million tons of fresh fruit and vegetables), of which the Gippsland region contributes 9.1 per cent of Victoria's production (156 thousand tonnes). The region has a close proximity to ports and road and rail routes, which would give it access to broader Australian and international markets (Juliano 2018). The region has capacity to expand production and there is opportunity to make use of second grade, lost and damaged crops.

Table 2: Latrobe Valley, Gippsland characteristics 2016

	Value added by Industry				Industry of employment			
	Latrobe %	Gippsland %	Victoria %	Australia %	Latrobe %	Gippsland %	Victoria %	Australia %
Agriculture, forestry, fishing	2.8	8.6	2.1	2.4	2.2	9.5	2.2	2.5
Mining	3.5	5.5	0.9	5.6	1.6	1.3	0.3	1.7
Manufacturing	6.6	6.1	7.5	6.2	7.1	6.7	7.8	6.4
Electricity, Gas and Water	16.1	7.5	3.1	2.8	7.8	3.3	1.1	1.1
Construction	8.6	10.0	8.3	8.5	8.7	9.7	8.3	8.5
Wholesale	1.9	2.5	4.2	3.6	1.6	2.0	3.2	2.9
Retail	5.3	5.2	4.9	4.6	11.7	11.2	10.2	9.9
Accommodation/food services	2.6	3.3	2.8	2.9	6.6	7.7	6.6	6.9
Transport postal & warehousing	3.0	2.7	5.1	4.8	3.5	3.3	4.8	4.7
Financial and insurance	5.0	4.3	11.2	10.3	1.0	0.8	1.9	1.7
Renting, Hiring Real estate	12.8	14.4	13.9	13.6	1.8	1.5	3.9	3.6
Professional, scientific and technical services	3.1	3.1	7.3	6.4	1.3	1.2	1.6	1.7
Admin and support services	2.3	2.1	3.5	3.3	3.6	3.6	7.8	7.3
Public admin and safety	7.0	6.1	4.8	6.1	2.8	2.8	3.4	3.4
Education and training	5.6	5.7	6.1	5.9	8.8	6.6	5.3	6.7
Information Media & Telecommunications	1.8	1.3	3.4	2.9	8.4	8.8	8.6	8.7
Healthcare and social assistance	9.9	8.9	7.8	7.6	16.6	14.5	12.5	12.6
Arts & Recreation	0.5	0.7	1.0	0.8	1.0	1.5	1.9	1.7
Other services	1.7	1.9	1.9	1.9	3.8	4.0	3.6	3.7
Other							4.7	4.4
Total	$4,546m	$14,402m	$379,782m	$1,642,061m	32,389	105,677	2,736,125	10,683,842

Source: Australian Bureau of Statistics, Census 2016. Latrobe City Council 2017.

The food-processing hub

The food sector, particularly horticulture, faces considerable challenges emanating from a variety of sources. These include: economic, environmental, and lifestyle changes, global increases in food consumption/production, diminishing resources and changes in attitudes of society i.e. moving toward a health-driven and sustainable food sector. Other business trends in horticulture is the move towards non-aggregated small to medium companies producing fresh fruit and vegetables. Such companies in general have lesser marginal returns, where margins increase as we move further along the chain, and large retail groups or corporations have the power of negotiation on fresh produce.

In addition to these broad market and social changes, the sector faces a need to improve its competiveness and productivity. Efforts therefore are required in a number of interrelated and interconnected areas. These include such things as growing for purpose, improving production techniques, sourcing and manufacturing quality food products, recovering underutilised edible fresh and processed foods along the chain, creating more efficient distribution techniques, improving sales and marketing, and the creation of new business models. In addition, as most food is produced and grown in regional areas the skill sets of regional labour forces needs to be improved.

This means that regional development is strongly linked to the developed of new food processing techniques and products. Regions will need to adapt due to global shifts in demographics, economic connectivity, technology and communications. Regions in particular face considerable challenges in attracting and retaining a critical mass of its population and skilled workforce. Innovative hubs located in a region can help connect local communities and businesses with government, industry innovators and financiers. Multiple positive externalities can also flow from these.

The advantage of a hub is that it enables multiple users to make use of facilities and for the hub itself to react to changes in markets, both at home and abroad. The hub would be in principle a centralised processing facility used for commercialisation of premium ingredients, both as part of its core business and on a toll basis with other companies. It could also work in conjunction with other processing facilities of other hubs. The hub would allow for product market testing within a partnership model, and would have close links to the new product innovations developed by the CSIRO Food Innovation Centre or other innovative companies. The total project life of the hub is envisaged to be 15 years of wealthy cash flow, although major changes and modular processing additions might extend its life beyond that (Juliano 2018).

Processors who made use of the hub's facilities would source local vegetables and fruit and use them to produce a range of functional foods, including nutraceuticals, digestive health foods and drinks, packaged foods and other vegetable-based ingredients.

The operational model of the proposed hub is to source fresh produce from a set of suppliers co-located near the hub. Pre-processing and quality assessment would occur at the hub, as well as a range of other activities, such a processing, manufacturing, packaging etc.

In terms of employment a range of jobs would be created by the hub including such things as plant operators, plant supervisors, food technologists, administration, finance and marketing personal, fruit and vegetable processors, drivers, and other subcontractors (PriceWaterhouseCoopers 2002; Australian Agrifood Skills Council 2005). In some cases these are in short supply in the region, such as food technologists, although in other cases existing members of the local workforce could readily retrain and fill positions.

Direct impact

As stated in the introduction the hub would have three main impacts on income: the initial capital expenditure (equipment, building costs etc.), the ongoing income that would flow to farmers supplying produce and other operating costs (labour, maintenance, hub marketing, laboratory costs, water, electricity, packaging etc.), and multiplier affects that would flow across the general Gippsland community and Australia as a whole.

Of the direct expenditure undertaken some would be carried out in the construction phase and some during the years of operation. Estimations of the capital costs are given in Table 3, and Operating costs over the 15 years period of operation are provided in Table 4. In addition, Table 5 provides a breakdown of the expenditure undertaken by the hub, when it reaches full capacity.

Table 3: Capital cost estimation

	A$m
Total equipment cost	8.77
Fixed equipment cost (including installation)	18.17
Services (steam supply and distribution, electrical, auxiliary buildings)	2.18
Building cost	2.60
Total capital cost	22.95

Source: DeSilva, Juliano, and Sanguansri, (2018)

Not all of this expenditure will be undertaken in the Gippsland region itself. In the capital cost phase for instance most of the equipment would be purchased from other parts of Australia or from overseas. Installation and building costs would mostly be concentrated in the region. Deducting the equipment costs from the total capital costs leaves $14.2m. The bulk of which would be undertaken in the region.

Similarly, with the operation costs some would be incurred on operations outside of the Gippsland region. In the case of food and vegetable processing industries, the bulk of the costs would be incurred in the region given that the costs of labour and produce are the main ones. Table 6 provides data on the inputs to production percentages estimated by the Australian Bureau of Statistics. These show that typically 46.2 per cent of inputs are in the form of agricultural related inputs and 20.5 per cent compensation of employees. In addition, transport and wholesale trade are important but around one-half of this would be incurred outside of the region.

Around $37 million of direct variable and non-variable expenditure would be incurred in the Gippsland region, and in addition, 35 persons would represent direct labour (operators, plant supervisors, administration, laboratory and quality assurance, marketing and sales). Other labour outsourced as contractors would represent an additional 18 who would be associated with transport work, food technology research providers, drivers and others.

Table 4: Operating costs

Year	A$m
1	24.75
2	31.73
3	38.71
4	42.20
5	42,20
6	42,20
7	42,20
8	42,20
9	42,20
10	42,20
11	42,20
12	42,20
13	42,20
14	42,20
15	42,20

Source: DeSilva, Juliano, and Sanguansri, (2018)

Table 5: Costing based on full plant capacity

Year	A$m
Produce	33.0
Electric energy	1.63
Water	1.44
Packaging	0.99
Other direct variable costs	1,50
Labour costs	1.60
Maintenance	0.44
Other direct non-variable costs	0.43
Fixed costs	2.46
Contingencies	5.96
Total production cost	45.8

Source: DeSilva, Juliano, and Sanguansri, (2018)

Table 6: Inputs to production

	Fruit & vegetable product manufacturing %	Non-residential building construction %
Agriculture related	**46.2**	**0.5**
Textile products	0.0	0.5
Sawmill, wood, pulp etc.	**0.1**	**2.0**
Paper and stationery	1.4	0.1
Chemical, petroleum, coal product manufacturing	0.8	4.2
Glass	1.3	0.2
Ceramic and plaster products	0.0	1.6
Concrete products	0.0	2.7
Other non-metallic products	0.0	0.5
iron, steel, containers, other fabricated	0.1	4.4
Energy	**1.1**	**0.4**
Machinery and equipment	0.4	2.9
Water and waste collection	**0.5**	0.3
Wholesale trade (50%)	**13.0**	**2.5**
Retail	0.0	0.1
Food and beverage service	**0.1**	0.0
Construction services	0.0	**48.2**
Transport (50%)	**6.0**	**2.7**
Publishing	**0.1**	0.1
Finance and insurance	0.7	1.5
Broadcasting, internet, telecommunications	0.2	0.7
Rental and hiring	**0.6**	**3.2**
Professional and scientific	1.6	5.4
Administration etc.	**2.8**	**1.2**
Other services	**1.7**	**0.9**
Materials Total	79.5	87.8
Compensation of employees	**20.5**	**12.2**
Total	100.0	100.0

Source: Australian Bureau of Statistics 2015.

Indirect impact

Each dollar spent on the output of one industry leads to output increases in other industries. For example, expenditure on food processing requires inputs of produce, energy, communication services and so on. Part of the expenditure covers the cost of the buildings and equipment (spread over their useful lives) and there is a large portion for staff wages and salaries. The supplying industries such as produce, energy require inputs themselves, pay wages and salaries and so on. The effect on these supplying industries is known as the upstream or indirect production effect and is commonly measured by a number called a *multiplier,* which is defined as the ratio of the direct plus indirect effect, to the direct effect.

The effect brought about by the initial payment of wages and salaries is generally known as the downstream or induced consumption effect, as wages and salaries are used to purchase household consumption goods. Their production and sale requires inputs from other industries and so on as before. Again, a multiplier may measure the effect. The *total multiplier* is defined as the direct, plus indirect production, and induced consumption effects, divided by the direct effect.

Multipliers, however, need to be cautiously interpreted and carefully applied. The more powerful effect is that of the induced consumption multiplier. The initial wage and salary payments and the subsequent wage and salary payments lead to an increase in private consumption; another component of final demand. These generate inward flow-on effects and therefore generate an additional gain in GDP.

Multipliers for the indirect production effect are easily calculated from standard input-output tables produced by the Australian Bureau of Statistics. Thus for a given increment to final demand (exports, consumption etc.), we can determine the direct and indirect pattern of production needed to support that increment to final demand. Consumption induced multipliers are more complicated to determine as they require some assumptions about the links between the Production Account and the Income and Outlay Account in the national accounts. In particular, a link between private consumption (mostly household spending) and income from wages and profits needs to be established. Typically, this is accomplished by treating inputs of labour as an intermediate input and then treating private consumption as the industry, which produces labour. Enhancements to this approach include allowing for the distribution of operating surplus to households and for the leakage of household savings, taxation and spending on imports.

Accounting for all of these effects requires the use of a multi-industry general equilibrium model. Such a model incorporates all of the inter-dependencies in the economy, such as flows of goods from one industry to another, and the passing on of higher wage costs in one industry into prices and thence the costs of other industries. It automatically calculates net multiplier effects by reducing the gross effects to the extent that they pull resources out of other productive uses (that is trade diversion). In the case of the food-processing hub, the diversion affect would be relatively small, given that the intention is to process agricultural produce and to locate it in a region with a high level of unemployment, and low labour participation rate.

In general, the value of a multiplier falls the more removed the industry is from processing raw materials. Most of the value of processing raw materials is accounted for by the cost of the raw material input as well as the cost of wages and salaries.

Care, must be taken in interpreting the results of this sort of exercise and especially with the assumption that expenditure is an economic benefit. Real multiplier effects are usually low, especially in a full employed economy, and the assumption implies that people employed by the hub and other resources used have no alternative source of employment. It also assumes that spending is a benefit even though the funds could have been used elsewhere. It should be remembered that agricultural production in Gippsland has scope for expansion and for the use of waste by-products. In addition, there are substantial amounts of employment in the region, which means employment would not be drawn away from other sectors. Allowing, therefore, for a multiplier of up to 2.0 (i.e. the multiplier that is acceptable to the Australian Treasury for use in economic assessments), this could convert to a total value of about $28 million in the capital expenditure phase ($million 14 x 2.0) and then from zero up to $million 74 per annum ($million 37 x 2.0), when the hub works at full capacity (Australian Bureau of Statistics).

The impact of this venture is that additional employment beyond those directly employed at the hub will also be created. These should benefit long term unemployed youth and people requiring upgrading their skills in order to move from one industry sector to the next. Another benefit of this will be the creation of micro and small to medium sized enterprises. These would affect the region internally as well as adjacent economic regions and the Victorian and Australian economy as a whole. Overall it would be expected that the local economy of Gippsland would gain additional employment or around 50 people from the flow on effects of income generated and spent from the hub. These jobs would be spread over a dispersed area including the horticultural retail, transport and services sector more generally.

Economic Impact

Understanding the economic impact of the creation of the hub is difficult given that it is not possible to know what will eventually be developed as the use of the hub grows and links in with other parts of the food processing industry. What can be certain is that a number of very strong, focused impacts will occur both in and around the growing and processing of fruit and vegetables, as well as in the operation of the hub itself.

The estimates provided here of the impact can only be a very rough estimate of the impact of the initial investment in the hub, which may in the long term be affected by a range of other investments. Nonetheless, it is useful to see exactly what these benefits will entail.

Estimates of the impact of the construction of the hub are provided in Table 6. These figures are divided into those that fall within the Gippsland region itself, and the broader Australian economy. These are also divided into the initial expenditures and figures that incorporate multiplier effects.

Overall the annual impact of the hub on the Gippsland regional area will be around $million 74 per annum or around 1.5 to 2.0 per cent of the Gross Regional Product of the region. This in itself will make a significant contribution to the economy of the region although it must be noted that the contribution to the country as a whole is far less. That said if successful it is likely that other hubs will be developed in other locations, which means that the national contribution might be significantly enhanced.

The contribution prospects are probably more modest. Income increases generated from the hub will flow mainly to existing growers, and then multiply through local communities in the form of expenditure, but will be captured largely my existing business. Nonetheless, the hub will create employment that will benefit the region in a considerable way. Another impact not measured by the multiplier effect, is the increase in entrepreneurial activity in the region that such a hub is likely to create. Such a hub will create many jobs for newly formed micro and small enterprises, which generate substantial employment opportunities, particularly for the young, and disadvantaged.

Table 6: Economic impact

	Direct A$m	Overall A$m
Capital expenditure (Gippsland)	14	28
Capital expenditure (Australia)	23	46
Annual expenditure – full capacity (Gippsland)	37	74
Annual expenditure – full capacity (Australia)	46	94
Gippsland Gross Regional Product	A$m 57,483	

Next steps

Further studies will be required to understand the social and community impacts in the region as well as the nature of upskilling achieved. A more detailed feasibility study will also evaluate the attraction of collateral businesses to the region, through exemplars on particular case studies. Further studies to determine the impact on construction jobs will be determined.

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APPENDIX 7

Project M&E plan template

Project Title: Creating value from edible vegetable waste

Project code: VG15076

Project leader: Mary Ann Augustin

Delivery partner: CSIRO

Date: February 2019

Template structure

The template consists of several sub-sections that collectively form a comprehensive Project M&E Plan:

1. Program logic
2. Scope of project M&E
3. Performance expectations, and data collection and analysis
4. Evaluation
5. Reporting, learning and improvement.

1 Program logic

Figure 1 Logic model for project

Relevant SIP outcome(s)	- Increased farm productivity and decreased production costs through better utilisation of resources - Increased supply chain integration and development through improved supply chain management, development of collaborative models and partnerships - Improved capability of levy payers to adopt improved practices and new innovation through improved communication and extension programs, grower innovation support,
End-of-project outcomes	- Improve the export capability of Australian vegetable growers - Identify value-adding opportunities such as novel ingredients, food and beverage products and supplements to achieve price premiums for underutilised second grade vegetables - Reduce on-farm food waste including alternative uses such as value-added foods and beverages, and nutraceuticals amongst others - Support product differentiation that align with Australian consumer needs - Enhance the sustainability of the industry by adding value to underutilised vegetables - Support collaboration between growers and stakeholders along the supply chain to improve its efficiency - Support innovation that advance and grow the vegetable industry - Input into National Food Waste Strategy (through involvement in Government strategy committees)
Intermediate outcomes	- Visits to farms at the start and through life of the project to understand farmers interests and issues - On-farm technology (extruder to the farm) demonstrations - Connection with HI and VegNet /RMCG to reach farmer networks - Facilitated stakeholder workshops that led to understanding of project outputs - Meeting with stakeholders and farmers to advance government (Local / state) agendas for regional hubs - Media exposure on value adding to underutilised vegetables - Show-casing research outputs with HI at Hort Connections 2018 (including broccoli latte) - Formation of collaborative networks with stakeholders along the supply chain which resulted in connecting farmers to customers (ingredient/ food manufacturing companies, retailers and nutraceutical companies) - Interactions with KPMG and Ernst & Young to communicate outputs to the food industry - Awards: State (Victoria) and National Level awards for Industry Impact (AusVEG) - Overall: The intermediate outcomes have helped initiate strategy planning to facilitate uptake of technologies including the feasibility assessment and commercial planning for future farmer business opportunities
Outputs	- Milestone Reports & Presentations at Conferences - Specification sheets for new products developed in the project - Significant number of radio and TV interviews, web-based communications - Pre-feasibility study for establishment of regional hubs - Product concept samples provided at business meeting with prospective customers (with HI). This includes customer samples produced by growers using technology developed in VG15076 - Prototype samples made available at various events (eg Science Week at Victorian market, August 2017; Facilitated stakeholder workshops – 2017 & 2018; Hort Connections 2018, AgCatalyst 2018, Active Integrated Matter Conference in Feb 2018)
Activities	- Research and development on new ingredient/ food and beverages using broccoli and carrots – on laboratory and pilot scale – nutritional supplements, vegetable powders and extruded snacks, fermented products - Consumer testing of selected new ingredients and products - Understanding the risks/pathways for commercialisation /business models, with a focus of farmers/grower business - Extension– eg. workshops, farm visits, attendance at farm innovation days, developing communication material - Business development activities – facilitation of stakeholder networks, meetings with potential end users of ingredients/ food and beverage products with farmers - Pre-feasibility studies with a range of stakeholders for establishment of regional processing hubs

Foundational outputs	- CSIRO expertise in ingredient/food product science, analytical capabilities and process development (laboratory to pilot to commercial scale) for manufacture of nutritional supplements, powders and extruded snacks and fermented products - CSIRO relationship with food industry customers - CSIRO compilation of global food and ingredient market information
Foundational activities	- *Project Administration*: Development of proposals and variations, Contract management, Financial management - *Baseline data collection*: Food waste initiative at CSIRO started in 2014 - Establishing Partnerships: Established partnership with stakeholders along the chain (farmers, food ingredient / food product manufacturers, retailers and nutraceutical companies) - *Project Planning*: CSRIO has a long history in value addition to food loss; Food waste program specifically for vegetables initiated and preliminary scoping occurred form Oct 2015. - *Funding*: CSIRO internal funds to initiate discussions with regional hub clusters and funds for value addition to fruit and vegetable waste (nutritional fractions for supplements, powders and extruded snacks, fermentation)

2 Project M&E scope

2.1 Audience

Table 1: M&E audience and their information needs

Audience	Information need
Primary	
Project team	Project proposal, plans, budget and scope
Hort Innovation	Progress provided as Milestone reports (as per contract) Updates on stakeholder engagement Expressions of Interest in Technology
Secondary	
CSIRO	Progress of project on budget and on time
Farmers	Progress of project and demonstration of technology on farm (for extrusion)
Other stakeholders (eg retailers, food/ingredient manufacturers, nutraceutical companies)	New ingredient/ food product characteristics
Regional hub (interested parties)	Updates on project progress and pre-feasibility evaluation

2.2 Key evaluation questions

Table 2: Project key evaluation questions

Key evaluation questions	Relevant?	Project-specific questions
Effectiveness		
1. To what extent has the project achieved its expected outcomes?	Yes	Project has developed new technology that is now available for industry uptake – (Powders and extruded snacks) There have been a number of expressions of interest by farmers and food manufacturers. To date, one farmer has been involved in planning for commercialisation. Planning discussions for two regional processing hubs (Victoria, Queensland) are underway. Through media (various across 2017/2018), workshops and events (eg at Hort Connections 2018, Science Week at Victorian Market 2017) the project has improved knowledge and awareness of consumer trends.
Relevance		
2. How relevant was the project to the needs of intended beneficiaries?	Yes	There have been a number of expressions of interest by farmers and food manufacturers. To date, one farmer has been involved in planning for commercialisation. Planning discussions for two regional processing hubs (Victoria, Queensland) are underway.
Process appropriateness		
3. How well have intended beneficiaries been engaged in the project?	Yes	There has been good attendance by various stakeholders in the agri-food supply chain at facilitated workshops at which there have been updates on the project progress. There has communication through extension activities (eg VEGNET) Farmer is actively engaged in planning for commercialization.
4. To what extent were engagement processes appropriate to the target	Yes	Facilitated workshop were open to farmers and encouraged through networks (eg VegNET) There were also 3 on-farm demonstrations (extruder to

Key evaluation questions	Relevant?	Project-specific questions
audience/s of the project?		the farm). Project team has been involved in promoting the research and outputs at conferences (eg Hort Connection 2018, AIFST 2018)
Efficiency		
5. What efforts did the project make to improve efficiency?	Yes	To service the R&D needs of the project, staff across CSIRO with relevant expertise were deployed for the project. Where appropriate, external expertise and analytical services were used.
Other (if any)		
How to get collaborative networks formed across the chain to respond to market signals that will drive business for farmers?	Yes	This relates to update of the technology, identification of processing needs and the establishment of new sustainable value chains.

2.3 M&E budget

There was no formal M&E budget in the project. The project team monitored and evaluated progress and reported in Milestone reports as required for clearance by HI.

3 Performance expectations, data collection and analysis

Logic level	What to monitor	Performance expectation (KPIs) and/or monitoring questions	Data collection – method (e.g. survey) and source (e.g. growers)	Timing of, and responsibility for, data collection
Foundational activities	Formation of project team	Does the team have the appropriate capability?	*Not applicable*	Project Commencement
	Financial management	Project on budget and on time	Finance records	Project Leader
Activities and outputs	Milestone Reports	Reports delivered on time and accepted by HI	R&D data	On-going through project (Activity leaders and project leader)
	Product samples (prototypes) & Specification sheets for new products developed in the project	Relevant information provided to interested parties	Specifications developed based on R&D data	On-going through project (Activity leaders and project leader)
	Pre-feasibility study for establishment of regional hubs	Report	Market reports, stakeholder interest, business models	Activity leader
Intermediate outcomes	Visits to farms at the start and through life of the project to understand farmers interests and issues Connection with HI and VegNet /RMCG to reach farmer networks	Farmers visited	Interviews with farmers	Project team representatives
	On-farm technology (extruder to the farm) demonstrations	Three on-farm demonstrations completed	*Not applicable*	Activity leader
	Facilitated stakeholder workshops	Stakeholders engaged & Expression of	Interviews and meetings	Project team members

	Meeting with stakeholders and farmers to advance government (Local / state) agendas for regional hubs Media exposure on value adding to underutilised vegetables Show-casing research outputs with HI at Hort Connections 2018 (including broccoli latte) Interactions with KPMG and Ernst & Young to communicate outputs to the food industry	interest received		
	Formation of collaborative networks with stakeholders along the supply chain which resulted in connecting farmers to customers (ingredient/ food manufacturing companies, retailers and nutraceutical companies)	Stakeholder engagement and interest developed Proposals for commercialization initiated	Meetings	Project team, BD and extension team members
End-of-project outcomes	*e.g. Uptake and adoption of a specific best practice by growers; Implementation of a new protocol; A change in value/volume/quality*	*e.g. Practice change by a target percentage of production base (and result of that practice change)*	*e.g. Surveys and case studies (Growers)*	e.g. Annually and at end of project for Final Report (Project Leader)
	Improve the export capability of Australian vegetable growers Identify value-adding opportunities such as novel ingredients, food and beverage products and supplements to achieve price premiums for underutilised second grade vegetables Support product differentiation that align with Australian consumer	New technologies to enable production of new ingredients/ food products	R&D	On-going through project at end of project for Final Report (Project Leader)

	needs			
	Reduce on-farm food waste including alternative uses such as value-added foods and beverages, and nutraceuticals amongst others Enhance the sustainability of the industry by adding value to underutilised vegetables Support innovation that advance and grow the vegetable industry	Farmers provided with alternatives to add value to farm business and reduce losses	R&D and meetings with stakeholders	On-going through project at end of project for Final Report (Project Leader)

4 Evaluation

Overall: Current feasibility development activities have identified opportunity for utilisation of produce and conversion to value added ingredients & products in the range of 100,000 to 250,000 Kg p.a., with finished product market sales value in the order of $10M p.a. for each of three separate regional production value-adding interest groups. These initiatives are subject to current development planning and investment activity."

Table 4: Additional evaluation data requirements

KEQ	Data collection requirement	Source and method
1. To what extent has the project achieved its expected outcomes?	See overall evaluation above	*NOTE: Estimates based on BD and interactions with potential adopters*
2. How relevant was the project to the needs of intended beneficiaries?	Producer engagement by the project at forums and visits has initiated three key development interests in Werribee South, East Gippsland and Townsville region. In addition to other grower interests.	Responding to enquiries and meetings with producers and other stakeholders across the horticulture food value chain to facilitate market pull for value-added vegetable ingredients
3. How well have intended beneficiaries been engaged in the project?	Opportunity has been provided for individual meetings with project team, at CSIRO and in production regions.	Feedback relating to their feasibility and planning of development interests.
4. To what extent were engagement processes appropriate to the target	Engagement process operated at two levels, firstly opportunity awareness and sharing information, then	Feedback relating to their addressing specific interests on produce types for greater utilization and value-

audience/s of the project?	followed by individual group strategy meetings and project development type meetings fit-for-purpose relating to producer interests. Agendas related to value-added development strategy and feasibility activity relating to new business development strategy, products and markets. This has included introductions and meetings with prospective customers	adding interests.

Table 5: Independent evaluation studies (as required by Hort Innovation)

Type of evaluation	When (start and finish)
Mid-term evaluation	*HI to provide*
Final evaluation	*HI to provide*

5 Reporting and continuous improvement

For assistance, refer to Section 1: Project M&E Guide – part 6.

- *List the **report(s)** will you prepare, to whom and when.*

Note: Apart from usual project reporting, consider any reporting or communications to secondary audiences.

Table 6: Project progress reporting

Report type	To whom	Timing
Facilitated workshops	*Stakeholders across the whole value chain*	*2 major workshops during course of project including several meetings between farmers and end-customers (See Extension Activity Report)*
Milestone Reports and Final Reports	*HI*	*AS required in contract*

- *What learning and improvement process(es) will your project use?*

Table 7: Project continuous improvement activities

Continuous improvement process	Details	Timing
Reflection meeting with Hort Innovation R&D Manager	*Meeting between R&D Manager/Marketing Manager and Delivery Partner to discuss progress to-date and what's working well/not, and agree any follow up actions*	*Ad-hoc meetings as called for during project life*
Team meetings	*Meeting between project team members to discuss project trials and their timing/Meeting between project team members to discuss feedback from extension event participants to determine gaps in adoption and preferred learning styles for incorporation into project*	*Quarterly*
Project Reference Group meetings	*Not done formally for project* *In place of these, HI and CSIRO were involved in a series of workshops*	*As required during 2017 & 2018*