Bioactives from Australian agrifood by-products

Preliminary opportunity assessment

2025

Citation and authorship

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Executive summary

This report

CSIRO Futures was commissioned by AgriFutures Australia to identify preliminary opportunities for Australia's agriculture and food industries to supply bioactive raw ingredients to the complementary medicines industry. This involved developing a model that estimated the potential supply of bioactives within byproducts across the Australian agrifood sector, with insights supplemented and validated through interviews with experts across research, industry and government. The report aims to drive industry development by raising awareness around the potential scale of the opportunities and mapping out important next steps around assessing commercial validity.

Agricultural and food processing industries generate large volumes of by-products currently directed to low value uses.

These by-products often do not generate profits for farmers or producers. Given the resources used to grow these by-products, and in some cases, the cost of managing them, together with a challenging business environment for agriculture and manufacturing in Australia, value-adding to these by-products could represent diversified revenue streams.

Australia's complementary medicines industry is currently reliant on international imports for almost all raw ingredients.

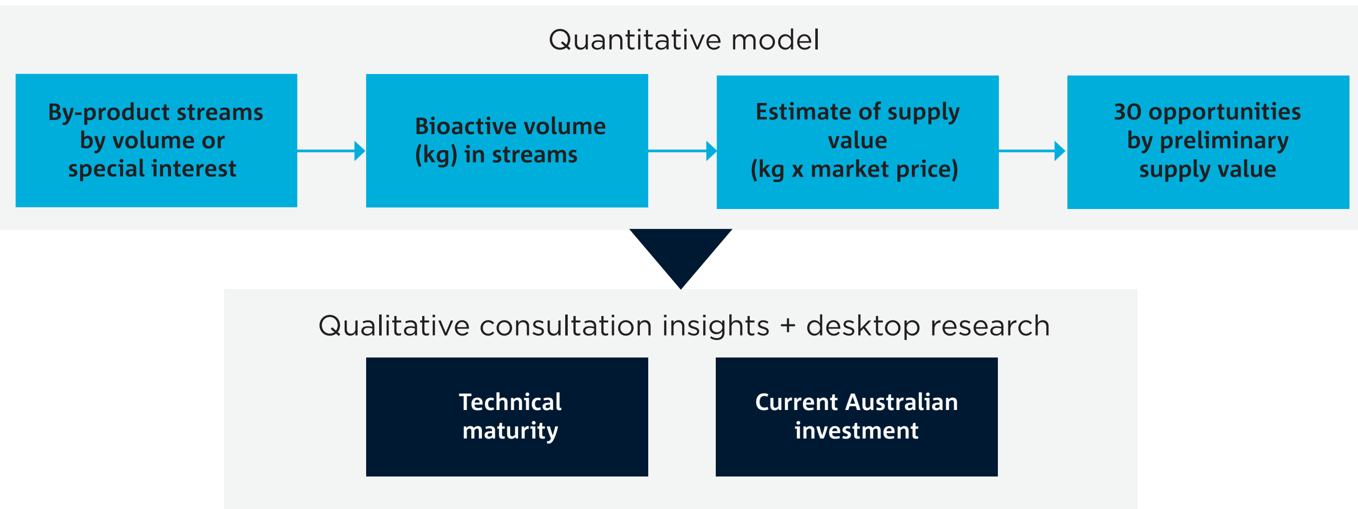
A key challenge faced by complementary medicines manufacturers is an under-developed sovereign raw ingredients industry. It is estimated that Australian manufacturers import around $1 billion of raw materials annually, representing around 99% of their requirements.[1] The industry would value more options to onshore its supply chain, should these options remain competitive in terms of supply, price and quality. Driving this is the desire to reduce vulnerability from geopolitical and climate threats, and support sustainability claims of products.

Working together, there is an opportunity for agriculture and food processors to divert by-products towards the Australian and international complementary medicines manufacturing industries by extracting and isolating high value bioactive compounds.

Bioactive extraction from agricultural and food by-products is an early-stage emergent industry with very few commercial examples in Australia. However, appetite exists from both sectors should key metrics around quality and cost be met.

By focussing on by-products currently allocated to lower value uses, a quantitative model was developed to identify 30 preliminary opportunities which represent high volume and value by-product stream / bioactive combinations. Qualitative research was then undertaken to provide initial assessments of technical maturity and Australian commercial investment (Figure 1).

Figure 1: Opportunity analysis methodology



1 NICM (2023) Securing the future of complementary medicines manufacturing in Australia. A strategic business case. Health Research Institute. Western Sydney university. DOI: 10.26183/kj2q-ee25

Five prospective opportunities were identified for commercial validation

Prospective opportunities of untapped potential were selected from the top 30 by considering where technical progress has been demonstrated in some capacity, but where relatively limited investment has been observed in Australia (Figure 2). While there are more mature opportunity areas (e.g., beef bioactives), these five represent areas where further commercial analysis would be valuable rather than duplicating existing analyses.

Consulted stakeholders provided further insights into the development of the emergent bioactive extraction industry, including:

- Prioritising scale of supply, quality and price is important. Dedicated innovative businesses and new business models may be needed.
- A staged approach to reaching complementary medicines grade outputs may derisk the scale-up (e.g., targeting functional food markets while developing complementary medicines ingredients).
- Avoid short lived trends when identifying candidate bioactive ingredients.
- Identifying areas at risk of climate disruption may be strategically valuable.
- Collaboration between industries, R&D, and enabling policies is critical.

Next steps: A structured approach is needed to validate commercial feasibility prior to investment.

Vital to progressing any opportunity is collaboration between potential suppliers (agriculture and food processors) and complementary medicines manufacturers to ensure both are working towards a shared understanding of supply quantities, quality and pricing. A structured and staged approach for assessing the commercial validity of identified opportunities is provided within the report (Figure 3).

Figure 2: Prospective opportunities

Polyphenols from sugarcane, trash, bagasse and molasses

Collagen from chicken trimmings, bones and offal

Polyphenols from canola meal

Polyphenols from olive pomace

Polyphenols from barley via spent brewers grain

Figure 3: Stage gate approach to determining the commercial viability of prospective bioactive extraction opportunities.

Stage gate 1:
Preliminary viability explores practicality, supply, price and quality considerations.

Stage gate 2:
Ecosystem viability explores partners, value chains and the international landscape.

Stage gate 3:
Business model viability and supporting research explores scale-up profitability, regulatory considerations and enabling research.

Contents

Glossary

Agrifood	Agricultural production and food manufacturing/processing industries.
Bioactives	Compounds that are naturally present in food and that could exert a beneficial or toxic biological effect when ingested. These compounds often have antioxidant, anti-inflammation, or antimicrobial properties or are used to enhance the growth of beneficial microbes.[2]
Bovine	Relating to cattle.
By-products	Secondary materials generated during agricultural and food production and processing, that are directed to uses other than the primary purpose.
By-product stream	The by-products generated at a stage of production or processing.
CAGR	Compound Annual Growth Rate.
Carotenoids	Naturally occurring yellow, orange and red pigment compounds found within plants. Certain carotenoids are sources can be converted to vitamin A i.e. beta carotene. Carotenoids include, retinol, α-carotene, β-carotene and equivalents, cryptoxanthin, xanthophylls (lutein and zeaxanthin).
Collagen	Collagen is the most abundant protein in the body, constituting 30% of the body's total protein and is the primary component of the skin matrix. Collagen has mechanical strength and moisture retention properties, helping maintain strength, flexibly and structure of body tissue. There are over 29 types of collagens that differ based on length of the internal triple helix structure and structure of non-helical portions. Type I is the most abundant.[3]
Commodities	Raw or primary agricultural products.
Complementary medicine	Low risk non-prescription medicines that include a wide array of products and ingredients such as vitamins, minerals and herbal materials.[4] Generally used for low level health indications (e.g., health enhancement and maintenance, prevention of dietary deficiency, and non-serious ailments). In Australia, complementary medicines are regulated by the TGA and are known as Listed Medicines.[5]
CoQ10	Coenzyme Q10 (CoQ10), also known as ubiquinone, is a fat-soluble vitamin like compound required by all living organisms. It is present in food products and synthesised in tissue.[6]
Creatine	Made up from 3 amino acids: arginine, glycine, and methionine. A natural substance that accelerates muscle growth.[7]
Essential Amino Acids	Nine of the 20 common amino acids cannot be synthesised by mammals are essential in the diet. These essential amino acids include histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine.
Extract	A substance manufactured by isolating or removing part of a raw material, often by using a solvent such as ethanol, oil or water.
Hyaluronic acid	A natural polysaccharide present in connective tissues which is used to assist mobility and hydration for joints and other tissues.[8]
Melatonin	A naturally produced hormone that helps regulate circadian rhythms and sleep. It is available within dietary supplements from organic sources or synthetically.[9]
Minerals	Inorganic elements essential for maintaining proper metabolism.

2 Facilitated Advancement of Australia's Bioactives (2022) What are Bioactives <https://www.faab.edu.au/about-2/> (accessed 22 April 2025)

3 Nuñez SM, Guzmán F, Valencia P, Almonacid S, Cárdenas C. (2020). Collagen as a source of bioactive peptides: A bioinformatics approach. Electronic Journal of Biotechnology, 48, 101-108.

4 Therapeutic Goods Administration (n.d.a) Complementary medicines. Department of Health and Aged Care. <https://www.tga.gov.au/products/medicines/non-prescription-medicines/complementary-medicines> (accessed 22 April 2025)

5 Therapeutic Goods Administration (n.d.b) Listed medicines. Department of Health and Aged Care. <https://www.tga.gov.au/products/medicines/non-prescription-medicines/listed-medicines> (accessed 22 April 2025)

6 Frost & Sullivan (2023) Global Nutraceutical Growth Opportunities: Increasing Consumer Awareness and Changing Dietary Habits, Post Pandemic, Drive Future Growth Potential.

7 Frost & Sullivan (2023)

8 Pereira H, Sousa DA, Cunha A, Andrade R, Espregueira-Mendes J, Oliveira JM, Reis RL (2018). Hyaluronic acid. Osteochondral Tissue Engineering: Challenges, Current Strategies, and Technological Advances, 137-153.

9 National Center for Complementary and Integrative Health (n.d.) Melatonin: What You Need to Know. National institute of Health. <https://www.nccih.nih.gov/health/melatonin-what-you-need-to-know> (accessed 30 April 2025)

Nutraceutical	A term generally used for products consumed for specific medicinal, health, wellness and/or additional nutritional benefits (usually food-derived). This includes vitamins, supplements and minerals; fortified foods (enriched with nutrients); and functional foods and beverages (contain ingredients offering health benefits). Nutraceuticals often result from the convergence of food and pharmaceutical technologies.
Ovine	Relating to lamb.
Polyphenols and phenols	A family of naturally occurring compounds primary characterised by having multiple phenol units. They are plant secondary metabolites, known for their antioxidant functions linked to various health benefits. Subtypes of polyphenols include phenolic acids, flavonoids, stilbenes and lignans.
Porcine	Relating to pigs.
Prebiotics	A type of non-digestible fibre compound that are can be metabolised by gut bacteria to promote their growth and activity. These include *prebiotics includes fructans* (such as fructo-oligosaccharides and inulin), galacto-oligosaccharides, polydextrose, resistant dextrin/maltodextrin, resistant starch, and xylo-oligosaccharides.[10]
Primary production	The production of raw materials for industry including businesses for plant or animal cultivation, fishing or pearling, or tree farming or felling.
Primary, secondary and tertiary processing	Food processing stages to turn fresh foods into food products. Primary processing is the conversion of raw materials to food commodities (e.g., milling). Secondary processing is the conversion of ingredients into edible products (e.g., baking). Tertiary food processing involves the manufacturing of complex foods like convenience and ready-to-eat foods, canned soups or frozen dinners.[11]
Protein Ingredients	Protein ingredients assessed were from plant or dairy sources. These included plant protein sources such as soy, wheat, rice, pea, lentil and bean. Dairy protein ingredients include whey protein, milk protein, and casein and caseinates.[12]
Raw ingredient	Inputs to processing, mainly food items.
Raw material	Inputs to processing, can include food items.
Therapeutic Goods Administration (TGA)	Australia's government authority responsible for evaluating, assessing and monitoring products that are defined as therapeutic goods.
Upcycling	Value-adding to by-products along the agriculture and food value chain so that they re-enter the food chain as part of a new product.
Valorisation	Adding value to a product or service.
Vitamin	Organic compounds that are essential for normal growth and nutrition and are required in small quantities in the diet because they cannot be synthesised by the body. They are classified as water and fat-soluble. Water-soluble vitamins include vitamins B and C. Fat-soluble vitamins include vitamins A, D, E, and K.

10 Frost & Sullivan (2023)

11 BulkInside (2025) Food processing <https://bulkinside.com/food-processing/> (accessed 22 April 2025)

12 Frost & Sullivan (2023)

1 Industry drivers for agrifood by-product management

Australia's agriculture and food processing industries generate large volumes of by-products. These by-products include produce that does not meet the requirements of consumer markets (off-specification) and non-edible streams from food processing (e.g., peel, seeds, husks, leaves, bone, offal, etc.) (see Table 1). Volumes of by-products can be variable, with larger volumes seen both when conditions are favourable (resulting in larger crops) or environmental conditions are unpredictable (bad weather or increased pests resulting in larger percentages of off-specification produce).

Agricultural producers and food processors always seek to fully utilise these by-products; however, they are often destined for lower value uses such as animal feeds, compost, waste-to-energy recovery, or in some cases, disposal to landfill. As by-products are diverted away from consumer markets towards lower value uses, the nutrients in these foods and food products are underutilised and potential value unrealised. Foregone nutrients represent both an ineffective use of the environmental and economic resources used to produce the foods, as well as the associated greenhouse gases produced.[13]

Across Australia's agriculture and food processing industry, consultations to inform this report (see Appendix 1) highlighted that there is enthusiasm to see food by-products diverted to higher value uses where it makes commercial sense. In addition to mitigating the challenges described above around improving the utilisation of Australian grown foods, this opportunity could also create diverse income streams for the agricultural and food sectors.

Other drivers leading producers and processors to consider alternative uses of their by-products include a challenging operating environment and the costs of by-product management. The agricultural operating environment has seen increased input costs drive the need for greater efficiency and productivity on farms and across supply chains. For example, fertilisers, chemicals, fuel, and labour costs have all increased over the past few years.[14] In the grain industry, it is estimated that the average spend on inputs has more than doubled over the past 10 years.[15] Further, management of certain by-products has associated costs and logistics to avoid environmental impacts such as land degradation, water pollution and higher greenhouse gas emissions.[16] For example, the acidic nature of citrus waste can negatively impact soil conditions and present broader ecological risks, necessitating specialised management and offsite disposal.[17]

Table 1: Types and volumes of agricultural by-products

SUB-SECTOR	EXAMPLE BY-PRODUCTS	APPROXIMATE ANNUAL BY-PRODUCT VOLUMES (2021)[18]
Broadacre crops Grains, pulses, oil crops, sugarcane	Crop residues such as stalks, leaves, straw, chaff; harvest losses and unused cover crops. Bran, meal, malt, hominy, bagasse, molasses, husks.	Primary production – 0.65M tonnes Processing – 1.96M tonnes
Horticulture Fruits, vegetables, nuts	Fallen fruit, vegetable trimmings, peels, seeds, discarded foliage, and unmarketable produce.	Primary production – 1.03M tonnes Processing – 1.37M tonnes
Livestock Bovine, ovine, porcine and poultry	Trimmings, blood meal, offal such as bones, heads, organs and skins.	Processing – 1.69M tonnes
Animal product Milk, eggs	Production losses of commodities, milk whey, eggshells, manufacturing losses.	Processing – 2.52M tonnes
Fisheries Fish, crustaceans, molluscs	Offal such as bones, heads and skins.	Processing – 0.016M tonnes

13 Hetherington JB, Juliano P, Macmillan C, Locj AJ (2022), Circular economy opportunities and implementation barriers for Australia's food, feed, and fibre production, Australian Farm Institute.

14 Parliament of Australia (2023) Australian Food Story: Feeding the Nation and Beyond. Inquiry into food security in Australia. House of Representatives. Standing Committee on Agriculture. Commonwealth of Australia. https://parlinfo.aph.gov.au/parlInfo/download/committees/reportrep/RB000221/toc_pdf/AustralianFoodStoryFeedingtheNationandBeyond.pdf

15 Hogan B (2024) Are rising input costs the biggest threat to farm profitability. Grains Research and Development Corporation. Australian Government. < https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2024/02/are-rising-input-costs-the-biggest-threat-to-farm-profitability> (accessed 22 April 2025)

16 Tonini D, Albizzati PF, Astrup TF (2018) Environmental impacts of food waste: Learnings and challenges from a case study on UK. Waste Management, 76, 744-766.

17 Suri S, Singh A, Nema PK. (2022) Current applications of citrus fruit processing waste: A scientific outlook. Applied Food Research, 2(1), 100050.

18 Adapted from the FIAL Food waste baseline data dashboard: FIAL (2021) National Food Waste Strategy Feasibility Study. – Final Report <https://www.fial.com.au/sharing-knowledge/food-waste> (accessed 1 April 2025); Livestock, animal products and fisheries do not contain data from the farming stages.

2 The complementary medicines market

Complementary medicines are low risk, non-prescription medicines used for improved health and wellbeing. They include a wide array of products such as vitamins, minerals and herbal materials.[19] Complementary medicines utilise raw materials and ingredients that are artificially synthesised and those that can be naturally extracted from organic materials.

2.1 Global complementary medicines

The global market for complementary medicines is estimated at around US $222 billion (2022) and is expanding.[20] Minerals including calcium, iron, magnesium and zinc are expected to reach global revenues of US $7.9 billion by 2030, growing at a compound annual growth rate (CAGR) of 5% (2023-30).[21] Vitamin ingredients are expected to reach global revenues of US $7.07 billion, growing at a CAGR of 4.7% (2023-30).[22]

Specialty ingredients are also a significant source of growth and innovation globally, driven by an ageing global population and growing interest in health, wellness and sports nutrition. These ingredients include creatine, hyaluronic acid, CoQ10, melatonin, collagen, omega-3 fatty acids, amino acids, prebiotics, lutein and zeaxanthin, probiotics, and protein ingredients (dairy and plant).[23]

19 Therapeutic Goods Administration (n.d.a)

20 NICM (2023) Securing the future of complementary medicines manufacturing in Australia. A strategic business case. Health Research Institute. Western Sydney university. DOI: 10.26183/kj2q-ee25; The value was converted to USD for ease of comparison using historic data for Q1 2023. AUD-USD conversion rate (1 AUD = 0.6826 USD)

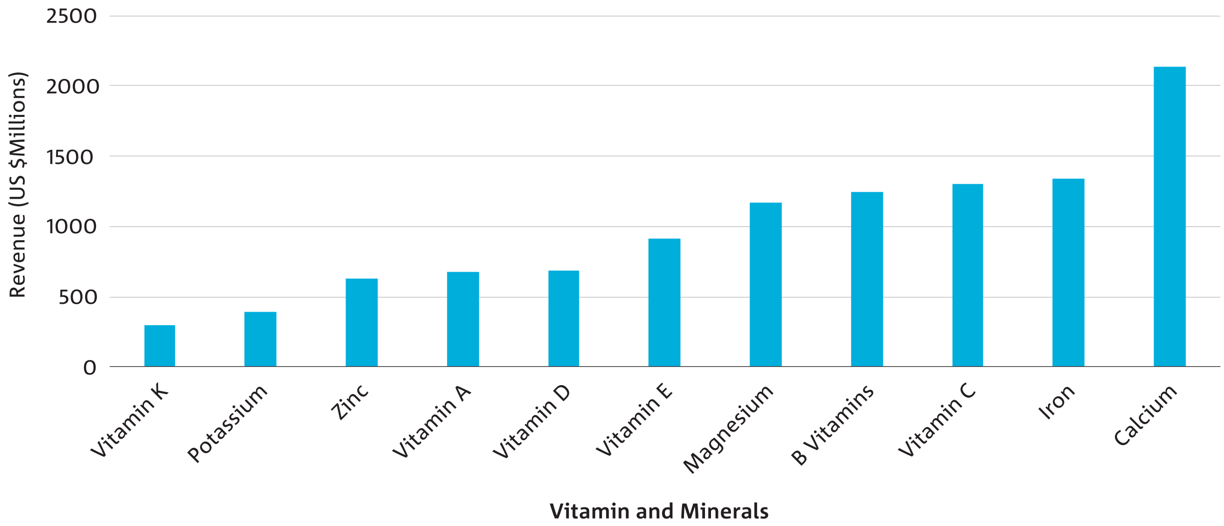
21 Frost & Sullivan (2024a) Growth Opportunities in Vitamin and Mineral Ingredients for Human Nutrition, Global, 2024–2030.

22 Frost & Sullivan (2024a)

23 Frost & Sullivan (2023)

Figure 4 and Figure 5 outline the 2023 global revenue for key vitamin, mineral and specialty ingredients.[24]

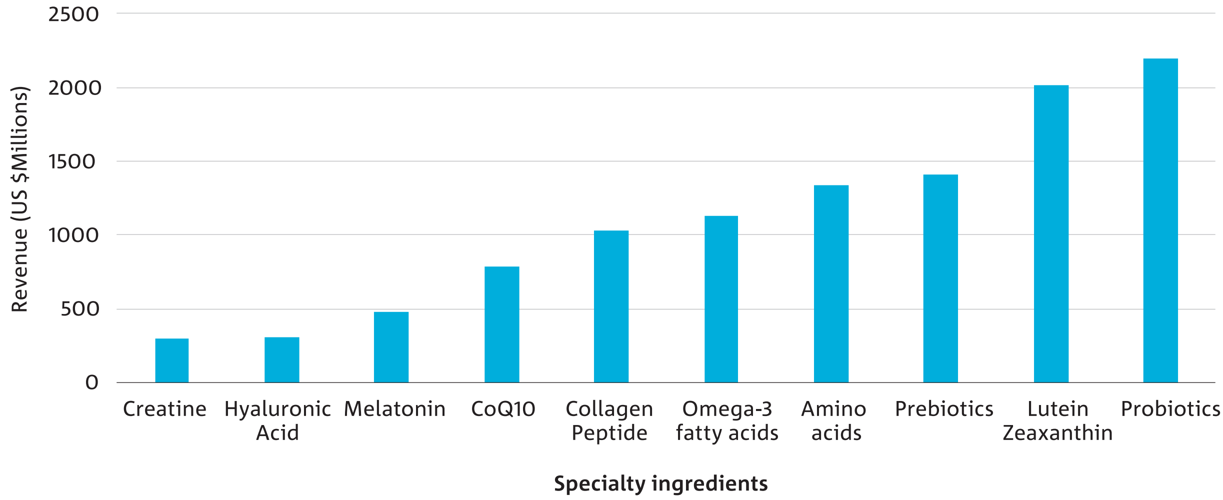
Figure 4: Global revenue for vitamins and mineral ingredients (US $Million), 2023



Note: applications include food and beverages, dietary supplements, specialised nutrition, personal care, cosmetics and pharmaceuticals.

Source: Frost & Sullivan, 2024

Figure 5: Global revenue for select speciality ingredients (US $Million), 2023



Note: applications include dietary supplements; functional food; and functional beverages.

Source: Frost & Sullivan, 2023

24 Frost & Sullivan (2024a)

2.2 Australian complementary medicines

In 2024, Australia's complementary medicine industry's annual revenue reached approximately $6.2 billion, with vitamins and dietary supplements accounting for 42% ($2.65 billion). In the same year, there were 82 Therapeutic Goods Administration (TGA) licensed manufacturing facilities across Australia.[25] Between 2024 and 2029, the industry is expected to grow at 5.7% CAGR.[26]

Complementary Medicines Australia (CMA), the industry's peak body, describe a growing consumer demand for products that are natural and sustainable. This includes products packaged using sustainable materials and formulated with natural and clean ingredients, which are perceived as having fewer side effects when compared to synthetic medicines.[27] Natural and clean ingredients include those inputs that are grown, rather than synthesised, and would favourably include inputs from Australia's agricultural industry. Consultations noted that incorporation of sustainably sourced ingredients is a point of differentiation for brands on the global market, enabling valuable storytelling for marketers and in some cases, attracting modest premiums (10-20%[28]) for demonstrated environmental sustainability.[29]

While the Australian market is small, Australian made products perform well in international markets. Australian made products benefit from premium branding, driven by strict manufacturing standards and TGA regulations that result in high quality and safety.[30] Exports of Australian made complementary medicines reached $1.2 billion in 2024, with China accounting for 75%.[31]

While the Australian complementary medicine industry has shown consistent growth and has cultivated a strong international brand image, a key challenge faced by manufacturers is an under-developed sovereign raw ingredients industry, necessitating heavy reliance on imported raw materials and ingredients.[32] These inputs are the single largest cost for Australian manufacturers.[33] It is estimated that Australian manufacturers import around $1 billion of raw materials annually,[34] representing around 99% of their requirements.[35] This introduces significant supply chain vulnerability and quality control risks.[36] Supply disruptions can have high-cost impacts on the industry through loss of sales when products are out of stock.[37]

25 Complementary Medicines Association (n.d.) Australian Complementary Medicine Business Explodes. <https://cma.asn.au/australian-complementary-medicine-business-explodes/> (accessed 22 April 2025)

26 Complementary Medicines Australia (2024) 2024 Industry Snapshot. <https://cmaustralia.org.au/wp-content/uploads/CMA-Snapshot-2024.pdf>

27 Complementary Medicines Australia (2024)

28 As indicated in consultations.

29 Frost & Sullivan (2024b) Upcycled Ingredients Industry, Global, 2024-2030. Market report.

30 Complementary Medicines Australia (2022) Pre-Budget Submission 2022-23. <https://treasury.gov.au/sites/default/files/2022-04/258735_complementary_medicines_australia.pdf> (accessed 22 April 2025)

31 Complementary Medicines Australia (2024)

32 NICM (2023)

33 IBISWorld, (2024) Vitamin and Supplement Manufacturing in Australia – Market Research report (2014-2019).

34 Spencer A (2021) The algae and seaweed opportunity: An Australian prospect. AgriFutures. <https://agrifutures.com.au/wp-content/uploads/2021/11/21-127.pdf>

35 NICM (2023)

36 Complementary Medicines Australia (2024)

37 NICM (2023)

3 Extraction of bioactives from agricultural and food by-products

There may be opportunities to build an Australian supply of raw ingredients for the Australian and international complementary medicines manufacturing industries by extracting bioactive compounds from agricultural and food processing by-products that are currently destined for lower value uses. Bioactive compounds are naturally occurring in foods and may benefit human health and wellbeing when consumed.[38] Extracting these compounds can add value to currently low value by-product streams (often referred to as upcycling or valorisation), potentially creating diverse income streams for the agricultural and food sectors and improving the utilisation of Australian grown agricultural products.

For Australian complementary medicines manufacturers, developing the domestic raw ingredients sector represents an opportunity to help reinforce local supply chain resilience,[39] develop naturally sourced products and strengthen 'Australian Made' claims. Industry stakeholders noted the importance of each of these benefits, if quality, price and supply thresholds can be met.

Table 2 lists example bioactive compounds that are prevalent across various agricultural produce. These bioactives were considered for this report's opportunity analysis presented in Chapter 4.

Table 2: Bioactives found in agricultural by-products

SUB-SECTOR	EXAMPLE BIOACTIVES
Broadacre crops Grains, pulses, oil crops, sugarcane	Prebiotics, proteins, essential amino acids, polyphenols, B vitamin complexes, vitamins D and E, calcium, magnesium, zinc.
Horticulture Fruits, vegetables, nuts	Prebiotics, proteins, polyphenols, carotenoids (including carotenes, lutein, lycopene), glucosinolates, B vitamin complexes, vitamins A, C and E, melatonin.
Livestock Bovine, ovine, porcine and poultry	Proteins (including collagen), essential amino acids, conjugated linoleic acids, vitamin B, vitamin D, omega-3 fatty acids, calcium, iron, magnesium, zinc, creatine, hyaluronic acid, CoQ10.
Animal product Milk, eggs	Proteins (including lactoferrin and casein), vitamin D, conjugated linoleic acids, carotenoids (lutein and zeaxanthins), CoQ10, melatonin.
Fisheries Fish, crustaceans, molluscs	Proteins (including collagen), omega-3 fatty acids, carotenoids (astaxanthin, lutein), vitamin D.

38 Kussmann M, Abe Cunha DH, Berciano S (2023) Bioactive compounds for human and planetary health. Frontiers in nutrition, 10, 1193848.

39 Complementary Medicines Australia (2024)

3.1 Current state of bioactive extraction

Extraction technologies (see Box 1) are advancing the opportunity for agricultural by-product upcycling to higher value uses. There is currently a strong commercial focus on extracting nutritional bioactives for supplying functional food, with emerging research and development for their use in complementary medicines. Generally, animal-based by-product upcycling is more mature than plant-based.[40]

While there are emerging examples of bioactive extraction from agricultural by-products in Australia, stakeholders note that these processes are more advanced internationally, and despite extensive research and interest, progress in supplying the complementary medicines industry remains limited. Extraction of bioactives requires specialised processes and equipment, and in many cases, ongoing research is required to enable increased efficiency, compound purity, sensitivity and scalability.

Box 1: Bioactive extraction technologies

The broader steps of the extraction process are similar across commodities, with cleaning of the by-products through mechanical or chemical methods (like grinding or hydrolysis), and extraction which is used to isolate and refine the product.[41]

There are numerous emerging extraction techniques and technologies including solvent extraction which often uses water, ethanol, or supercritical CO_2; ultrasound assisted extraction; microwave assisted extraction; and solid phase micro extraction.[42]

Bioactives can also be generated and retrieved through other production methods such as biorefining and microbial fermentation, however this is outside the scope of this report.

Case Study – Meat and Livestock Australia: Industry development for Australian bovine collagen and nutraceuticals

With around 20% of the carcase delivering 80% of its value, Meat & Livestock Australia (MLA), an Australian Research and Development Corporation (RDC), are investigating ways to fully utilise bovine and ovine products to generate value from traditionally low value by-products. This includes sourcing collagen from red meat by-products to meet growing demands within the nutraceutical industry. MLA has explored high throughput processing technologies, validated the market, and put forward a business case for bovine collagen development.[43]

MLA collaborates with multiple organisations to support industry development, including providing seed funding to Freeze Dry Industries, a company that has released an eco-friendly organic collagen product range for the commercial market.[44] Further, MLA has partnered with Kilcoy Nutrition to develop a nutraceutical strategy and examine the opportunities presented by harvesting bioactive compounds from underutilised products such as organs and glands. MLA reports that freeze dried organ powders can achieve high margins, up to 100-400 times the margin from rendering.[45]

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40 Frost & Sullivan (2024b)

41 Bhadange YA, Carpenter J, Saharan VK (2024) A comprehensive review on advanced extraction techniques for retrieving bioactive components from natural sources. ACS omega, 9(29), 31274-31297.

42 Bhadange YA *et al*. (2024)

43 Meat & Livestock Australia (2024a) Finding high-value solutions to low-value meat cuts and co-products <https://www.mla.com.au/research-and-development/product-and-packaging-innovation/> (accessed 7 May 2025)

44 Meat & Livestock Australia (2024b) Freeze dried collagen adds value and reduces waste. <https://www.mla.com.au/news-and-events/industry-news/freeze-dried-collagen-adds-value-and-reduces-waste/> (accessed 7 May 2025)

45 Coleby C (2023) Final Report – Kilcoy Global Foods Nutraceutical Market Evaluation. Meat & Livestock Australia. <https://www.mla.com.au/research-and-development/reports/2023/p.pip.0591---kilcoy-global-foods-kgf-nutraceutical-strategy/>

Case Study – Extracta: Pioneering the recovery from agricultural by-products

Extracta is an Australian manufacturer transforming nutrient-rich by-products from farming and beverage production, such as sugarcane husk, citrus peel, and grape marc—into premium plant-based ingredients for food, nutraceutical, and cosmetic applications.[46]

With a strong focus on prebiotic dietary fibre, Extracta partners with regional producers to capture surplus, process locally and supply directly to manufacturers through Australia's first edible surplus processing facility – supporting circular economy principles and reducing carbon in supply chains.[47]

Case Study – Upcycled Certified fish oil

In 2024, New Chapter, a vitamin and supplement company based within the United States, announced its first Upcycled Certified products. The company's Wholemega Wild Alaskan Salmon Fish Oil line uses materials sourced from Certified Responsible Alaskan Fisheries, including nutrient-rich salmon trim from products filleted for restaurants, that would have been otherwise unused.[48]

Using ingredients that would otherwise not be consumed by humans, upcycled foods can now be certified through a program developed by the US-based Upcycled Food Association,[49] which provides credibility for the sector and a recognisable mark for upcycled products (including bioactive compounds used in dietary supplements). There are calls for the upcycled food certification to be expanded to Australia.[50]

46 Extracta (n.d.a) Food Waste? <https://extracta.com.au/pages/food-waste> (accessed 7 May 2025)

47 Extracta (n.d.b) Powering Brands with Smarter Sourcing, Sustainability & Innovation. <https://extracta.com.au/pages/getting-you-to-net-zero> (accessed 7 May 2025)

48 New Chapter (2024) New Chapter launches First Upcycled Certified Products Including First to Market Upcycled Fish Oil. <https://www.prnewswire.com/news-releases/new-chapter-launches-first-upcycled-certified-products-including-first-to-market-upcycled-fish-oil-302297909.html > (accessed 22 April 2025)

49 Upcycled Food Association (2022) 2022 Impact Report. <https://www.upcycledfood.org/reports> (accessed 22 April 2025)

50 Goodman-Smith F (2024) Upcycled Food. Winston Churchill Trust. <https://endfoodwaste.com.au/wp-content/uploads/2024/04/UpcycledFood_ChurchillReport2024_FINAL.pdf>

3.2 Why now?

The opportunity to build an Australian industry around extraction of bioactives from Australian grown products and by-products is not new, with several organisations describing it in various forms.[51] However, industries that use and process agricultural production, including food and complementary medicines, are approaching turning points that are driving this opportunity:

- Post the COVID-19 pandemic, consumers have become increasingly aware of the importance of preventative health and overall wellbeing, driving up demand for complementary medicines.
- Australian complementary medicines manufacturers are motivated to source raw ingredients onshore to improve supply chain resilience in the face of ongoing climate and geopolitical risks.
- Pressures on agricultural producer profitability, and consumer awareness around sustainability and environmental impacts, are prompting producers to further prioritise the identification of diversified revenue streams and reduction of waste.[52]

Further, the Australian policy landscape also drives and supports this opportunity, including the announced *Feeding Australia* strategy that will identify opportunities to improve supply chain resilience;[53] the Future Made in Australia agenda to maximise Australian manufacturing opportunities; the 2024 National Waste Policy Action Plan which aims to halve the amount of organic waste sent to landfill by 2030;[54] and the 2024 National Circular Economy Framework which focuses on opportunities to capture new markets, including 'valorising agri-waste'.[55]

Stakeholder consultation suggests that despite a large global industry and appetite for sovereign manufacturing, there is a lack of awareness of the economic feasibility and potential in Australia, which is holding back industry growth. While individual companies have begun to explore this opportunity, cross-sectoral national-scale analysis is needed to identify and assess the most attractive opportunities for national investment.

51 For example, Complementary Medicines Australia and the National Institute of Complementary Medicine Health Research Institute (NICM HRI)

52 Hassoun A, Cropotova J, Trif M, Rusu AV, Bobiş O, Nayik GA, Jagdale YD, Saeed F, Afzaal M, Mostashari P, Khaneghah AM (2022) Consumer acceptance of new food trends resulting from the fourth industrial revolution technologies: A narrative review of literature and future perspectives. Frontiers in nutrition, 9, 972154.

53 Collins, J (2025) Feeding Australia: Albanese Labor Government's plan to secure our food future <https://minister.agriculture.gov.au/collins/media-releases/feeding-australia> (accessed 07 May 2025)

54 DCCEEW (2024a) National Waste Policy Action Plan 2024. Department of Climate Change, Energy, the Environment and Water, Canberra.

55 DCCEEW (2024b) Australia's Circular Economy Framework. Department of Climate Change, Energy, the Environment and Water, Canberra.

4 Opportunities for Australian agrifood

4.1 Opportunity identification methodology

To identify the top 30 preliminary opportunities (high volume and value by-product streams / bioactive combinations) for further analysis, a quantitative model was developed where:

- Data was drawn from the National Food Waste Baseline,[56] the Food Standards Australian New Zealand (FSANZ) Food Composition Database[57] and other literature.
- 30 by-product streams (i.e., the combined range of by-products generated at a single stage of production or processing) were selected for analysis based on their high volume or interest expressed from the agricultural and complementary medicines industries.
- Bioactive volumes were estimated for 22 bioactives of high global market size for each of the priority by-product streams (e.g., polyphenols in grape stems, marc and lees).
- Market wholesale prices were then applied to identify the top 30 opportunities (by-product stream / bioactive combination) by estimated supply value.

Each of the 30 opportunities were then explored further qualitatively through consultation with industry (see Appendix A) and desktop research to better understand their maturity, practicality and potential within the complementary medicines market (see Figure 6).

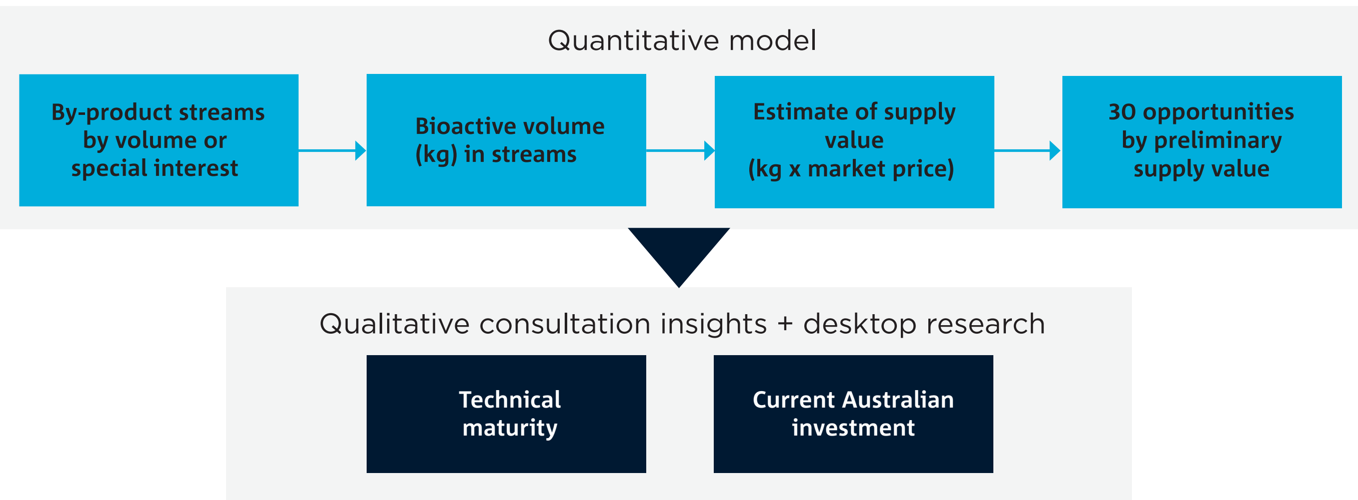
To prioritise prospective opportunities for potential further commercial validation, the following three preliminary opportunity analysis metrics were used:

- **Supply value –** the estimated Australian value of the bioactive volume across the specific by-product stream as determined by the quantitative analysis.
- **Technical maturity –** the current level of technical development of extraction practices for the opportunity across lab, pilot and commercial scales.
- **Current Australian investment –** the relative investment already given to various opportunities within Australia through research or commercial analyses for the complementary medicines industry or adjacent functional food industry.

This preliminary analysis was designed to take a data-driven approach to identifying potential areas of national strategic opportunity for further commercial validation, investigation and analysis. Due to data limitations, including the national level nature of the database and the use of proxies where specific values were not available, the analysis is not designed to identify niche (low volume, high value) opportunities, however examples of these opportunities were identified during consultation and are noted in section 4.4.

Further detailed description of the scope and methodology can be found in Appendix B.

Figure 6: Opportunity analysis methodology



56 FIAL (2021) National Food Waste Strategy Feasibility Study. – Final Report <https://www.fial.com.au/sharing-knowledge/food-waste> (accessed 1 April 2025)

57 Food Standards Australia New Zealand (2022). Australian Food Composition Database – Release 2. Canberra: FSANZ.

4.2 Key findings

Table 3 outlines the top 30 opportunities identified through this project. Key insights from this table include:

- The majority of the top 30 high-volume opportunities occur at the post-farmgate food processing stages. Only 5 identified opportunities are related to pre-farmgate losses.
- Despite inclusion of some niche lower volume/high bioactive concentration by-products streams, the top 30 were exclusively from high volume commodities. The majority of which were broadacre crops (22), followed by horticulture (5), livestock (2) and animal products (1).
- Numerous opportunities exist and are being developed for the functional foods segment, including protein, essential amino acids, or prebiotic (mainly dietary fibre) ingredients. This commercial interest contributes to strong global market sizes for these ingredients, for example, protein ingredients has the largest global market size of the bioactive categories examined (AU $37B) and attracts significant research and investment. In terms of expected future growth, the amino acid market has the fastest expected growth rate at 12.5% (CAGR 2022-2030), which may be reflective of demand in the protein industry.[58]
- Polyphenols command high prices and interest, however, may still require significant technical development to reach large scale commercial opportunities.
- Traditional complementary medicine bioactives, such as vitamins and essential minerals, have not demonstrated significant supply value to justify a national focus on extraction from agricultural by-product streams.

58 Frost & Sullivan (2023)

Value of bioactive supply within agricultural by-product stream

Green	Greater than $100 Million
Amber	Between $20 - $100 Million
Light grey	<$20 million

Technical maturity

Green	Bioactive extraction at pilot or commercial scale
Amber	Technical extraction of bioactive demonstrated and being optimised at laboratory scale
Light grey	Limited evidence of technical extraction
Dark grey	Not assessed

Current Australian investment

Green	Commercial research investment demonstrated for complementary medicines
Amber	Commercial research investment demonstrated in functional food industries
Light grey	Limited commercial investment in Australia
Dark grey	Not assessed

Table 3: Summary of 30 preliminary opportunities (*ordered by Australian supply value*)

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Canola	Primary processing (crushing)	Essential Amino Acids	$4,449	12.5%	**$3,422**	**Technical extraction demonstrated and undergoing optimisation.** Extraction methods are currently being developed through hydrolysing canola meal proteins at the laboratory scale.[60]	**Commercial investment into functional food industries.** Essential amino acid extraction receiving investment within the plant-protein efforts of the functional food segment.
Beef	Primary processing (slaughtering)	Collagen	$3,188	11.2%	**$3,052**	**Commercial extraction demonstrated.**[61] Existing industrial scale technology overseas and smaller providers in Australia.	**Commercial and technical elements well established in global industry.** Australian commercial research is being undertaken by Meat and Livestock Australia.[62]
Sugarcane	Primary processing (milling and refining)	Polyphenols^	$3,996	6.4%	**$1,482**	**Technical extraction demonstrated and undergoing optimisation.**[63] The extraction and benefits of sugarcane polyphenols has been widely researched. Reports of extraction from bagasse and molasses is limited to the research level. There are isolated reports of commercial polyphenol extracts from sugarcane being done internationally. This may indicate pilot or commercial levels.	**Limited commercial investment in Australia.** Stakeholders from agricultural and nutraceutical industries indicated commercial interest in ingredients from sugarcane/sugarcane products. Indicating a novel opportunity for Australian investment.

59 Frost & Sullivan (2023)

60 Warnakulasuriya SN, Tanaka T, Wanasundara JP (2024) Canola meal valorization via acid hydrolysis to generate free amino acids. Journal of the American Oil Chemists' Society, 101(1), 41-57.

61 Dobbrick F, Buckley M, Hendra A (2022) Hides to Riches Milestone 8 – Final Report Public. Meat and Livestock Australia. Prepared by Freeze dried industries. <https://www.mla.com.au/contentassets/e5b0a41776284b41b7f3957b66d0c9de/p.psh.1274-hides-to-riches---milestone-8-final-report_public.pdf>

62 As noted during consultations; Meat and Livestock Australia (2024) – see case study

63 Azlan A, Sultana S, Mahmod II (2023) Effect of different extraction methods on the total phenolics of sugar cane products. Molecules, 28(11), 4403; Hewawansa UH, Houghton MJ, Barber E, Costa RJ, Kitchen B, Williamson G (2024) Flavonoids and phenolic acids from sugarcane: Distribution in the plant, changes during processing, and potential benefits to industry and health. Comprehensive reviews in food science and food safety, 23(2), e13307

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Wheat	Secondary processing (milling)	Essential Amino Acids	$4,449	12.5%	**$1,235**	**Technical extraction demonstrated and undergoing optimisation.** Targeted extraction of amino acids from bran for the purposes of use in biotechnology have been explored.[64]	**Commercial investment into functional food industries.** Essential amino acid extraction receiving investment within the protein efforts of functional food segment.
Chicken	Primary processing (slaughtering)	Collagen	$3,188	11.2%	**$1,147**	**Commercial extraction demonstrated.** Well established commercial scale internationally.[65]	**Limited commercial investment in Australia.** Existing commercial interest and products. However, there are no reported chicken collagen extraction facilities in Australia. Indicating an opportunity for Australian investment.
Canola	Primary processing (crushing)	Protein Ingredients	$36,940	6.6%	**$825**	**Pilot scale extraction.** Commercial scale extraction from canola seeds demonstrated for the functional food industry.[66]	**Commercial investment into functional food industries.** Significant investment into plant protein opportunities from canola sources already underway in Australia.[67]
Sugarcane	Primary production	Polyphenols^	$3,996	6.4%	**$757**	**Technical extraction demonstrated and undergoing optimisation.**[68] The extraction and benefits of sugarcane polyphenols has been widely researched. Reports of extraction from tops and trash is limited to the research level. There are isolated reports of commercial scale extraction of polyphenol from sugarcane being done internationally.	**Limited commercial investment in Australia.** Stakeholders from agricultural and nutraceutical industries indicated commercial interest in ingredients from sugarcane/sugarcane products. Indicating a novel opportunity for Australian investment.
Wheat	Primary production	Essential Amino Acids	$4,449	12.5%	**$674**	**Laboratory characterisation only.** Targeted characterisation and quantification at laboratory level. Characterisation research noted wheat lacks certain essential amino acids like lysine, threonine, and methionine.[69]	

64 Hanstein, S (2024) Wheat bran extract as a source of amino compounds and sugar for biotech processes. Chemie Ingenieur Technik, 96(4), 440-445.

65 Technavio (2025) Global Collagen market 2025-2029. Market report.

66 Burcon (2024) Burcon Achieves First Run of Canola Protein isolate.< https://burcon.ca/2024/07/burcon-achieves-first-commercial-run-of-canola-protein-isolate/> (accessed 1 May 2025); Watson E (2022) 'A highly soluble, complete protein, with functional properties very close to whey protein...' DSM gears up to launch upcycled canola protein isolate. <https://www.foodnavigator-usa.com/Article/2022/03/14/A-highly-soluble-complete-protein-with-functional-properties-very-close-to-whey-protein-DSM-gears-up-to-launch-upcycled-canola-protein-isolate/> (accessed 01 May 2025)

67 Simons J (2022) GrainCorp, CSIRO and v2food partner on $4.4 million plant-based protein research. GrainCorp. <https://www.graincorp.com.au/graincorp-csiro-and-v2food-partner-on-4-4million-plant-based-protein-research/> (accessed 30 April 2025)

68 Azlan A *et al*. (2023); Hewawansa UH *et al*.(2024)

69 Khan MS, Ali E, Ali S, Khan WM, Sajjad MA, Hussain F (2014). Assessment of essential amino acids in wheat proteins: A case study. J. Biodivers. Environ. Sci, 4, 185-189.

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Wheat	Tertiary processing (Bakery and other manufacturing)	Essential Amino Acids	$4,449	12.5%	**$400**	**Laboratory characterisation only.** Targeted characterisation and quantification at laboratory level.[70] Characterisation lacks certain essential amino acids like lysine, threonine, and methionine.	
Barley	Primary production	Prebiotics	$3,405	7.3%	**$317**	**Technical extraction demonstrated and undergoing optimisation.** Extraction of prebiotic opportunities is occurring but is predominantly at low scale. Commercial extraction demonstrated for the functional food industry.[71]	**Commercial investment into functional food industries.** High dietary fibre/prebiotic barley is being developed and utilised to supplement foods.[72] However, consultations report limited interest in alternative plant prebiotic ingredients within complementary medicines industry.
Canola	Primary processing (crushing)	Polyphenols^	$3,996	6.4%	**$309**	**Technical extraction demonstrated and undergoing optimisation.**[73] Polyphenol extraction from canola meal limited to laboratory optimisation.	**Limited commercial investment in Australia.** Limited canola based complementary medicine products on the market. Indicating a novel opportunity for Australian investment.
Barley	Secondary processing (malting)	Essential Amino Acids	$4,449	12.5%	**$289**	**Laboratory characterisation only.**[74] Targeted extraction of amino acids is limited to protein extraction and characterisation.	
Wheat	Secondary processing (milling)	Protein Ingredients	$36,940	6.6%	**$274**	**Technical extraction demonstrated and undergoing optimisation.** Wheat germ protein peptides have been extracted, characterised and tested for physiochemical properties.[75]	**Commercial investment into functional food industries.** Commercial and technical elements of plant-based protein opportunity already receiving significant investment.
Barley	Tertiary processing (brewing)	Essential Amino Acids	$4,449	12.5%	**$234**	**Technical extraction demonstrated and undergoing optimisation.**[76] Extraction methods are currently being optimised at the laboratory scale engineering at the lab or pilot scale.	**Commercial investment into functional food industries.** Essential amino acid extraction receiving investment within the functional food segment.

70 Kowalska S, Szłyk E, Jastrzębska A (2022) Simple extraction procedure for free amino acids determination in selected gluten-free flour samples. European Food Research and Technology, 1-11.

71 CSIRO (2023) BARELYmax. <https://www.csiro.au/en/research/production/food/barleymax-bucase-study> (accessed 22 April 2025)

72 Kovačević Z, Strgačić S, Bischof S (2023) Barley straw fiber extraction in the context of a circular economy. Fibers, 11(12), 108.

73 Hussain S, Rehman AU, Luckett DJ, Blanchard CL, Obied HK, Strappe P (2019). Phenolic compounds with antioxidant properties from canola meal extracts inhibit adipogenesis. International journal of molecular sciences, 21(1), 1.

74 Neylon E, Arendt EK, Lynch KM, Zannini E, Bazzoli P, Monin T, Sahin AW (2020) Rootlets, a malting by-product with great potential. Fermentation, 6(4), 117.

75 Chin YL, Keppler JK, Dinani ST, Chen WN, Boom R. (2024). Brewers' spent grain proteins: The extraction method determines the functional properties. Innovative Food Science & Emerging Technologies, 94, 103666.

76 Jaeger A, Zannini E, Sahin AW, Arendt EK (2021)

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Wheat	Primary production	Protein Ingredients	$36,940	6.6%	**$155**	**Commercial extraction demonstrated for the functional food industry.** Wheat proteins are well known, ongoing research is being undertaken to characterise targeted proteins.[77]	**Commercial investment into functional food industries.** Commercial and technical elements of plant-based protein opportunity already receiving significant investment.
Wheat	Tertiary processing (Bakery and other manufacturing)	Protein Ingredients	$36,940	6.6%	**$109**	**Laboratory characterisation only.** Low volume extraction methods explored, for the purpose of characterisation.[78] Bread waste research focussing on use for fermentation or industrial feedstock.[79]	
Almonds	Primary process (hulling)	Prebiotics	$3,405	7.3%	**$97**	**Laboratory characterisation only.**[80] There is limited research into prebiotic extraction.	
Wine grapes	Secondary processing (Wine making)	Polyphenols^	$3,996	6.4%	**$85**	**Pilot-level extraction demonstrated.**[81] Technology for broader grapeseed oil extraction is being utilised.	**Commercial Australian investment is already occurring.** Stakeholders indicate commercial and technical research is already being undertaken in developing polyphenol extracts from viniculture wastes.[82]
Barley	Secondary processing (malting)	Prebiotics	$3,405	7.3%	**$81**	**Technical extraction demonstrated and undergoing optimisation.**[83] There is ongoing research into optimising extraction of prebiotics from malted barley residues.[84] Existing high prebiotic content barley products indicate commercial scale extraction in the functional food industry.[85]	**Commercial investment into functional food industries.** Commercial and technical development of plant-based prebiotics/ dietary fibre products have received significant investment for functional foods. However, consultations report limited interest in alternative plant prebiotic ingredients.

77 Szerszunowicz I, Kozicki S (2023). Plant-Derived Proteins and Peptides as Potential Immunomodulators. Molecules, 29(1), 209.

78 Kowalska S *et al.* (2022)

79 Dymchenko A, Geršl M, Gregor T (2023) Trends in bread waste utilisation. Trends in food science & technology, 132, 93-102.

80 Alasalvar C, Huang G, Bolling BW, Jantip PA, Pegg RB, Wong XK, Chang SK, Pelvan E, de Camargo AC, Mandalari G, Hossain A (2024) Upcycling commercial nut byproducts for food, nutraceutical, and pharmaceutical applications: A comprehensive review. Food Chemistry, 142222.

81 End Food Waste Australia (n.d.) From wine waste to high-value nutrient extracts. <https://endfoodwaste.com.au/from-wine-waste-to-high-value-nutrient-products/(accessed 22 April 2025)

82 End Food Waste Australia (n.d.)

83 Jaeger A, Zannini E, Sahin AW, Arendt EK (2021)

84 Fareed SZ, Tangjaidee P, Khumsap T, Klangpetch W, Phongthai S, Kanpiengjai A, Khanongnuch C, Unban K. (2025). Xylooligosaccharides from Barley Malt Residue Produced by Microwave-Assisted Enzymatic Hydrolysis and Their Potential Uses as Prebiotics. Plants, 14(5), 769.

85 Nutraceutical Business Review (2022) Golden Malt introduces prebiotic and gluten-free barleys <https://nutraceuticalbusinessreview.com/golden-malt-introduces-prebiotic-and-gluten-free-barleys-198189> (accessed 22 April 2025)

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59] MARKET SIZE (AU $M 2030)	GLOBAL BIOACTIVE MARKET [59] CAGR (2022-2030)	AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
Barley	Primary production	Protein Ingredients	$36,940	6.6%	**$72**	**Technical extraction demonstrated and undergoing optimisation.**[86] Barley-based protein supplements, protein concentrates, and other fortified food products indicate commercial extraction for the functional food segment.[87]	**Commercial investment into functional food industries.** Commercial and technical elements of plant-based protein opportunity already receiving significant investment.
Barley	Secondary processing (malting)	Protein Ingredients	$36,940	6.6%	**$71**	**Laboratory characterisation only.**[88] Malt barley characterisation and analysis for protein limited to use in brewing preparation.	
Almonds	Primary processing (hulling)	Essential Amino Acids	$4,449	12.5%	**$61**	**Laboratory characterisation only.** Focus on fortified food and animal feed.[89] Almond hull upcycling research in Australia currently focussed on bioenergy.[90]	
Milk	Secondary processing (cheese making)	Protein Ingredients	$36,940	6.6%	**$57**	**Commercial extraction demonstrated.**[91] Technical extraction is already established across broader proteins hydrolysates and for specialised targeted proteins (i.e. Lactalbumin).	**Commercial Australian investment already occurring.** Whey protein extracts and products are well established in global industry. Stakeholders indicate detailed protein characterisation and extraction has already been done, as such there is reduced commercial appetite for broader protein products.
Corn (Maize)	Secondary processing (milling)	Polyphenols^	$3,996	6.4%	**$48**	**Laboratory characterisation only.**[92] Most research is directed at improving the quality for animal feed, biomaterials or bioethanol manufacturing.[93]	

86 Houde M, Khodaei N, Benkerroum N, Karboune S (2018) Barley protein concentrates: Extraction, structural and functional properties. Food chemistry, 254, 367-376.

87 Emerging companies with barley protein products include AB InBev by Evergrain Ingredients. <https://www.evergrainingredients.com/>, Goodness Booster Flour by Grainstone <https://www.grainstone.com.au/>, Protein concentrates by Montana Microbial <https://www.montanamicrobial.com/>

88 Devnani B, Moran GC, Grossmann L. (2023) Extraction, composition, functionality, and utilization of brewer's spent grain protein in food formulations. Foods, 12(7), 1543.

89 Alasalvar C *et al.* (2024); Ollani S, Peano C, Sottile F (2024) Recent innovations on the reuse of almond and hazelnut by-products: A review. Sustainability, 16(6), 2577.

90 Circular Economy Business Innovation Centre (2023) Funded project – Innovative almond waste digestion systems for nutritional fertilizer production. <https://www.cebic.vic.gov.au/grants-funding-and-investment/funded-projects/almond-waste-to-nutritional-fertiliser> (accessed 22 April 2025)

91 Mehra R, Kumar H, Kumar N, Ranvir S, Jana A, Buttar HS, Telessy IG, Awuchi CG, Okpala CO, Korzeniowska M, Guiné RP (2021). Whey proteins processing and emergent derivatives: An insight perspective from constituents, bioactivities, functionalities to therapeutic applications. Journal of Functional Foods, 87, 104760.

92 Blandino M, Alfieri M, Giordano D, Vanara F, Redaelli R (2017). Distribution of bioactive compounds in maize fractions obtained in two different types of large -scale milling processes. Journal of cereal science, 77, 251-258. Alahmed A, Simsek S (2024) Enhancing Mechanical Properties of Corn Bran Arabinoxylan Films for Sustainable Food Packaging. Foods, 13(9), 1314.

93 Papageorgiou M, Skendi A 2018). Introduction to cereal processing and by-products. In Sustainable recovery and reutilization of cereal processing by-products (pp. 1-25). Woodhead Publishing.

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Lentils	Primary processing	Prebiotics	$3,405	7.3%	**$44**	**Technical extraction demonstrated and undergoing optimisation.** Extraction methods are being explored.[94]	**Commercial investment into functional food industries.** Commercial and technical development of plant-based prebiotics/ dietary fibre products have received significant investment for functional foods. However, consultations report limited interest in alternative plant prebiotic ingredients.
Olives	Secondary processing (crushing)	Polyphenols^	$3,996	6.4%	**$38**	**Commercial extraction demonstrated.** Olive pomace extracts are available at the commercial scale for nutraceuticals. Emerging technologies used in the olive oil industry. Ultrasound Assisted Extraction are now being piloted.[95]	**Opportunities for Australian investment.** Limited current investment. Existing commercial interest and products. However there has been limited investment into olive pomace sourced nutraceuticals. Indicating a novel opportunity for Australian investment.
Barley	Tertiary processing (brewing)	Protein Ingredients	$36,940	6.6%	**$32**	**Technical extraction demonstrated undergoing optimisation.** Research is focussing on optimisation of protein extraction methods for specific functional proteins and protein isolates.[96] Protein extraction from BSG (Brewers Spent Grain) for food grade protein products is at the commercial scale.[97]	**Commercial investment into functional food industries.**[98] Commercial and technical elements of plant-based protein opportunity already receiving significant investment. BSG-based upcycling into food products is a practice emerging in Australia.
Barley	Tertiary processing (brewing)	Polyphenols^	$3,996	6.4%	**$31**	**Technical extraction demonstrated and undergoing optimisation.**	**Limited commercial investment in Australia.** Indicating a novel opportunity for Australian investment.

94 Bautista-Expósito S, Vandenberg A, Dueñas M, Peñas E, Frias J, Martínez-Villaluenga C (2022). Selection of enzymatic treatments for upcycling lentil hulls into ingredients rich in oligosaccharides and free phenolics. Molecules, 27(23), 8458.

95 Rodríguez Ó, Bona S, Stäbler A, Rodríguez-Turienzo L (2022). Ultrasound-assisted extraction of polyphenols from olive pomace: Scale up from laboratory to pilot scenario. Processes, 10(12), 2481

96 Chin YL *et al.* (2024).

97 Jaegar A *et al.* (2021). Shoup ME (2022) EveryGrain starts commercial production of upcycled barley protein: 'The timing of us reaching scale couldn't be better' <https://www.foodnavigator-usa.com/Article/2022/07/07/EverGrain-starts-commercial-production-of-upcycled-barley-protein/#:~:text=Backed%20by%20a%20%24100m,formulators%20with%20a%20plant%2Dbase> (accessed 23 April 2025)

98 Burnett C (2020) Grainstone turns spent grain into flour. <https://brewsnews.com.au/grainstone-turns-spent-grain-into-flour/> (accessed 22 April 2025)

COMMODITY	PRODUCTION OR PROCESSING STAGE	BIOACTIVES	GLOBAL BIOACTIVE MARKET [59]		AUSTRALIAN SUPPLY VALUE (AU $ MILLION)	TECHNICAL MATURITY	CURRENT AUSTRALIAN INVESTMENT
			MARKET SIZE (AU $M 2030)	CAGR (2022-2030)			
Almonds	Primary processing (hulling)	Protein Ingredients	$36,940	6.6%	**$30**	**Laboratory characterisation only.**[99] Focus on fortified food and animal feed.[100] Almond hull upcycling research in Australia currently focussed on bioenergy.[101]	
Barley	Tertiary processing (brewing)	Prebiotics	$3,405	7.3%	**$11**		

Notes: Preliminary opportunities were assessed against the three metrics in the order of value of supply, technical maturity and current Australian investment. Opportunities with a supply value of <$20 million or technical maturity limited to laboratory characterisation, were filtered and further qualitative assessment was not undertaken. These opportunities will require greater supply, higher prices or further technological development for future consideration as a national-scale opportunity. All supply values should be considered as indicative only.

^Polyphenol content used the Total Phenolic Content of the by-products as sourced from public literature. Market size (2030) and (CAGR 2025-2035) sourced from Skyquest, Global Polyphenols Market[102]

99 Alasalvar C *et al.* (2025)

100 Ollani S *et al.* (2024)

101 Circular Economy Business Innovation Centre (2023)

102 Skyquest (2025)

4.3 Prospective opportunities

While all commodities highlighted in Table 3 represent potential opportunities to service the complementary medicine industry, AgriFutures Australia were interested in identifying those with comparatively untapped potential. Five were selected for profiling in this section (see Figure 7) which all have a high value in terms of potential bioactive supply (>$20 million), have demonstrated technical extraction in some capacity, and have had limited commercial investment within Australia. Priority was given to those where further commercial analysis would be valuable rather than duplicate existing analyses.

Prospective opportunities with pilot or commercial level extraction are closer to potential Australian commercialisation and may present nearer term opportunities. These include collagen from chicken trimmings, bones and offal and polyphenols from olive pomace. Alternatively, polyphenols from sugarcane by-products, canola meal and barley spent brewers grain all present potential longer-term opportunities due to lower levels of technical development.

Figure 7: Five prospective opportunities selected for further profiling and potential commercial viability analysis

Polyphenols from sugarcane, trash, bagasse and molasses

Collagen from chicken trimmings, bones and offal

Polyphenols from canola meal

Polyphenols from olive pomace

Polyphenols from barley via spent brewers grain

Polyphenols from sugarcane trash, bagasse and molasses

Australian bioactive supply value	Primary production: $757M Primary processing: $1,482M
Commodity by-product types	Trash, bagasse and molasses
Key growing regions	Coastal QLD (95%) and Northern NSW (5%).[103]

Description

Mechanised harvesting of sugarcane produces billets that are transported to local sugar mills. Sugarcane trash is a by-product of harvesting consisting of dry leaves (60%) and green tops (40%) and is either used as a trash blanket (mulch) or in some cases burnt before harvest.[104] Primary processing of sugarcane involves milling billets to produce sugar, which produces by-products including fibrous bagasse and molasses.

These by-products contain a variety of polyphenolic compounds such as flavonoids (e.g., catechin and quercetin), phenolic acids (e.g., ferulic acid and gallic acid), and lignin-derived polyphenols.[105] These can be used within the complementary medicines industry for their antioxidant functionality. Further, research reports that polyphenols from sugarcane bagasse exhibit activity that may support blood sugar management.[106] Australian institutions are researching and conducting clinical trials to investigate the medicinal benefits of sugarcane polyphenols, with emerging clinical research indicating prebiotic benefits of sugarcane extracts.[107]

Technical considerations

Extensive research has already characterised the composition and phenolic content of sugarcane by-products, with emerging research assessing and optimising efficiency of extraction techniques.[108] While pilot plants for sugarcane bagasse processing exist in Queensland, the function is directed at the generation of bioenergy products and bioplastics.[109] There are limited reported commercial or pilot scale plants for nutrient or bioactive extraction of sugarcane by-products.

Scaling bioactive extraction from bagasse and molasses to a commercial level will likely require integration of new technology into existing milling facilities and sugarcane networks to optimise existing assets and operations. Stakeholders highlighted the importance of ensuring future equipment is installed alongside existing infrastructure which are long standing investments from the sugarcane industry, such as rail supply systems designed to handle high volumes. There would be a preference for onsite bioactive processing, however it would be constrained to size limitations based on the footprint of the mill itself.

103 Department of Agriculture Fisheries and Forestry (n.d.) Sugar. Australian Government. <https://www.agriculture.gov.au/agriculture-land/farm-food-drought/crops/sugar> (accessed 22 April 2025)

104 Sukphun P, Wongarmat W, Imai T, Sittijunda S, Chaiprapat S, Reungsang A (2023) Two-stage biohydrogen and methane production from sugarcane-based sugar and ethanol industrial wastes: a comprehensive review. Bioresource Technology, 386, 129519.

105 Vijayalaxmi S, Jayalakshmi SK, Sreeramulu K (2015) Polyphenols from different agricultural residues: extraction, identification and their antioxidant properties. Journal of Food Science and Technology, 52, 2761-2769.

106 Zheng R, Su S, Zhou H, Yan H, Ye J, Zhao Z, You L, Fu X (2017) Antioxidant/antihyperglycemic activity of phenolics from sugarcane (Saccharum officinarum L.) bagasse and identification by UHPLC-HR-TOFMS. Industrial Crops and Products, 101, 104-114.

107 CASS Food Research Centre (n.d.) Power of Polyphenol Rich Sugarcane Extracts on improving the gut microbiome, mood and blood work. Deakin University. <https://www.cassfood.com.au/current_studies/power-of-polyphenol-rich-sugarcane-extracts-prses-on-improving-the-gut-microbiome-mood-and-blood-work/> (Accessed 22 April 2025); Tang C, Montoya JC, Fritzlar S, Flavel M, Londrigan SL, Mackenzie JM (2024) Polyphenol rich sugarcane extract (PRSE) has potential antiviral activity against influenza a virus in vitro. Virology, 590, 109969.

108 Azlan A, Sultana S, Mahmod II (2023) Effect of different extraction methods on the total phenolics of sugar cane products. Molecules, 28(11), 4403.

109 Groves M (2021) Pilot plant turning sugarcane waste into jet fuel, diesel, plastics prepares to flick switch. ABC news. <https://www.abc.net.au/news/rural/2021-10-15/pilot-plant-biorefineries-mackay-trial-renewables/100541364> (accessed 22 April 2025)

Preliminary commercial considerations

There are niche players within the market who are promoting polyphenol-rich sugarcane extract products, which may indicate a growing interest and potential for utilisation in the complementary medicines sector.[110] However, there are limited reports of the use of sugarcane by-products to create supplement products.

For primary production by-products, cost effective collection of trash is an important consideration. One study found that the lowest cost option is to collect trash during harvesting and separate it from cane prior to milling.[111] Further, any commercial opportunity would need to outweigh the benefits to farmers of retaining trash residues on the field, which include reducing losses of water, sediment, nutrients and pesticides, weed management and improving soil health.[112]

There is already substantial cross-sectoral interest for sugarcane by-products to be used for alternative functions which may compete with bioactive extraction opportunities. Bagasse reportedly has negligible waste management cost, as the sugarcane industry currently utilises 100% of the bagasse by-products to fuel boilers to generate power for mills, with excess electricity returned to the grid. There are also emerging competing options to use bagasse for the industrial production of construction materials, bioethanol and sustainable aviation fuel.[113] Availability of molasses for extraction will be determined by how much goes to new food production compared to the surplus volume being utilised as animal feed or into industrial chemical manufacturing.

110 NutraShure (n.d.) The Antioxidant Powerhouse Polynol · <https://nutrashure.com/polynol/> (accessed 22 April 2025); The Product Makers (n.d.) Polynol. <http://www.tpm.com.au/bio-activities/polynol/> (accessed 22 April 2025).

111 O'Hara I, Kaparaju P, Paulose P, Plaza F, Henderson C, Latif A, Zhang Z, Doherty W, Moghaddam L, Baker A, Renouf M, Mirskaya K, Ketsub N, Asad H. (2020) Biogas from sugarcane – Project results and lessons learnt. Queensland University of Technology. <https://arena.gov.au/assets/2021/05/utilising-biogas-in-sugarcane.pdf> (accessed 22 April 2025)

112 Queensland government (2018) Cropping – sugarcane trash. Australian Biomass for Bioenergy Assessment. <https://www.data.qld.gov.au/dataset/australian-biomass-for-bioenergy-assessment/resource/9e37e1ed-57aa-428b-a863-d1ad650ade7e> (24 April 2025)

113 Singh SP, Jawaid M, Chandrasekar M, Senthilkumar K, Yadav B, Saba N, Siengchin S (2021) Sugarcane wastes into commercial products: Processing methods, production optimization and challenges. Journal of Cleaner Production, 328, 129453.

Collagen from chicken trimmings, bones and offal

Australian bioactive supply value	$1,147M
Commodity by-product types	Trimmings, bones, skin, feet, offal, rendering products (i.e. protein meal)
Key growing regions	Outer areas of Sydney, Brisbane, Melbourne, Adelaide and Perth[114]

Description

The broiler chicken industry reports that 30% of its output from chicken processing plants are by-products such as trimmings, feathers, skin and offal, which are used for other products like pet foods.[115] Chicken is a commercial source of undenatured Type II collagen and hydrolysed collagen peptides which are increasingly popular in the complementary medicines industry. Further, chicken is also a rich source of types I-V collagens across various connective tissues such bone, cartilage, tendon and skin, especially around the neck, sternum and feet.[116]

Technical considerations

Chicken-derived collagen extraction methods are well-established, primarily using acid-solubilised and enzyme-assisted processes. While commercial scale techniques are available, extraction is still varied across collagen quality, extraction efficiency and scalability. Key challenges include improving yield and lowering processing costs.[117]

Preliminary commercial considerations

The global collagen market is well-established, with major international suppliers operating within the United States, Japan, China, United Kington and across the European Union. Market reports note that poultry collagen faces slower projected growth compared to other sources and remains the smallest source segment.[118] It competes directly with more dominant sources including porcine, bovine, and marine collagen, alongside growing consumer demand for halal and plant-based alternatives.[119]

Despite limited reports of Australian-made chicken collagen, an Australian Chicken Meat Federation submission to the Productivity Commission highlights an emerging industry focus on collagen extraction using rendering technologies.[120] The submission notes that the conversion of by-products into high value products can improve industry sustainability through the utilisation of existing systems.

An Australian industry for chicken collagen supply and additional upcycling of chicken by-products in Australia may benefit from the vertically integrated poultry industry across breeders and processers.[121]

114 Poultry Hub Australia (n.d) Meat Chicken (Broiler) Industry. <https://www.poultryhub.org/production/meat-chicken-broiler-industry> (accessed 22 April 2025)

115 Australian Chicken Meat Federation (n.d) What makes chicken Australian's favourite meat? <https://chicken.org.au/our-product/australian-chicken-meat/> (accessed 22 April 2025)

116 Abedin MZ, Riemschneider R. Chicken skin collagen. Molecular diversity and susceptibility to neutral proteinases. Pharmazeutische Industrie. 1984;46(5):532-5; Jayaprakash S, Razeen ZM, Kumar RN, He J, Milky MG, Renuka R, Sanskrithi MV (2024). Enriched characteristics of poultry collagen over other sources of collagen and its extraction methods: A review. International Journal of Biological Macromolecules, 133004.

117 Kıyak BD, Çınkır Nİ, Çelebi Y, Malçok SD, Koç GÇ, Adal S, Yüksel AN, Süfer Ö, Karabacak AÖ, Ramniwas S, Pandiselvam R (2024) Advanced technologies for the collagen extraction from food waste–A review on recent progress. Microchemical Journal, 201, 110404.

118 Technavio (2023) Global Collagen Market 2025-2029. Market Report.

119 Gunn B (2025) Recombinant Human Collagen: Plant-Based Production Addresses Growing Demand for a Vegan Option. BioProcess International. <https://www.bioprocessintl.com/emerging-therapeutics-manufacturing/recombinant-human-collagen-plant-based-production-addresses-growing-demand-for-a-vegan-option> (accessed 22 April 2025)

120 Australian Chicken Meat Federation (2024) Opportunities in circular economy. Letter to the Productivity Commission. <https://www.pc.gov.au/__data/assets/pdf_file/0009/387504/sub111-circular-economy.pdf> (accessed 22 April 2025)

121 Australian Chicken Meat Federation (2024) Our industry. <https://chicken.org.au/our-industry/industry-overview/> (accessed 22 April 2025)

Polyphenols from canola meal

Australian bioactive supply value	$308M
Commodity by-product types	Canola meal (traditional extraction by-product), Canola cake (mechanical extraction only)
Key growing and processing regions	Wheat belt and southern WA, Eyre Peninsula SA, Wheat belt VIC-NSW[122] Processing in VIC and NSW.

Description

Canola meal is the solid by-product from the oil extraction process of the canola rapeseed variety (which is specifically low-glucosinolate and low-erucic acid). It is produced at the end of the extraction process, alongside crude canola oil, and is predominantly used for animal feed.

Canola meal contains several antioxidant polyphenols, with the main compounds being sinapic acid (and its derivatives such as, canolol and sinapine), ferulic acid, caffeic acid and kaempferol derivatives.[123] While there is limited research for using canola-based polyphenols in complementary medicines, analysis of canola meal extracts report strong antioxidative properties and emerging research suggests potential anti-inflammatory and anti-diabetic activity.[124]

Technical considerations

Effective extraction of polyphenols from canola meal will be impacted by oil processing methods and variable content of residues. Different oil production methods result in canola meal with different residual oil content ranging from 1-20%.[125]

The most common method (traditional) involves heat treatment (toasting), crushing, mechanical pressing and chemical solvents for oil extraction, resulting in low oil content, defatted meal. The toasting step is used to remove anti-nutritional compounds such as glucosinolates and erucic acid, but will also degrade thermally sensitive polyphenols, and chemical solvent extraction may also lower the availability of lipophilic polyphenols.[126] Stakeholders suggest polyphenols may potentially be extracted from canola cake (the solid residue left after mechanical extraction that has not undergone solvent extraction), but would require amending industry standard production methods.

122 Australian Bureau of Statistics (2022) Canola, experimental regional estimates using new data sources and methods. First Release. Reference period 2019-20 financial year. <https://www.abs.gov.au/statistics/industry/agriculture/canola-experimental-regional-estimates-using-new-data-sources-and-methods/latest-release> (accessed 30 April 2025)

123 Hussain S, Rehman AU, Luckett DJ, Blanchard CL, Obied HK, Strappe P (2019) Phenolic compounds with antioxidant properties from canola meal extracts inhibit adipogenesis. International journal of molecular sciences, 21(1), 1.

124 Hussain S, et al. (2019); Hussain S, Rehman AU, Obied HK, Luckett DJ, Blanchard CL. (2022). Extraction, chemical characterization, in vitro antioxidant, and antidiabetic activity of canola (Brassica napus L.) meal. Separations, 9(2), 38.

125 Australian Export Grains Innovation Centre (n.d.) Australian canola meal for dairy cattle. < https://www.aegic.org.au/wp-content/uploads/2024/11/07-AEGIC-Australian-canola-meal-for-dairy-cattle.pdf> (accessed 30 April 2025)

126 Ye Z, Liu Y (2023). Polyphenolic compounds from rapeseeds (Brassica napus L.): The major types, biofunctional roles, bioavailability, and the influences of rapeseed oil processing technologies on the content. Food Research International, 163, 112282.

Canola meal from alternative processes that do not use heat treatment (such as cold press) or use chemical solvents (such as expeller press) may have higher polyphenol content as less polyphenols are degraded or extracted within the crude oil.[127] However, these processes are much less common in Australia, which may limit available feedstock.

Preliminary commercial onsiderations

Canola meal supply may be constrained by numerous factors including strong demand from animal feed industries across dairy, livestock and aquaculture, as well as growing interest for canola meal as an industrial biotechnology feedstock.[128] Furthermore, most of Australia's canola production is exported, with only a fraction directed to Australia's relatively small local canola crushing industry. Canola meal supply will also be susceptible to environmental changes, as well as pest and diseases that affect canola production.[129] Stakeholders suggest efforts to extract bioactives from canola by-products could also include unrefined crude oil as a feedstock, which also contains high levels of polyphenols, tocopherols and phytosterols.

There is increasing investment into improving Australia's canola crushing industry which may improve canola meal availability.[130] Furthermore, increased research into the use of canola by-products as an alternative protein source and development of high long chain omega-3 cultivars suggest there is a strong appetite to add and diversify value streams for canola in Australia. However, these efforts are in early development which may pull focus from other bioactive extraction research.

127 Chew, SC (2020) Cold-pressed rapeseed (Brassica napus) oil: Chemistry and functionality. Food Research International, 131, 108997.

128 CSIRO (2023) Future Canola. <https://www.csiro.au/en/work-with-us/industries/agriculture/Future-crops/Future-canola> (accessed 30 April 2025). Wongsirichot P, Gonzalez-Miquel M, Winterburn J (2022). Recent advances in rapeseed meal as alternative feedstock for industrial biotechnology. Biochemical Engineering Journal, 180, 108373.

129 CSIRO (2023) Future Canola. <https://www.csiro.au/en/work-with-us/industries/agriculture/Future-crops/Future-canola> (accessed 30 April 2025).

130 Alsop E (2024) Crushing investments point to confidence in canola. Grain Central. <https://www.graincentral.com/markets/crushing-investments-point-to-confidence-in-canola/> (accessed 30 April 2025)

Polyphenols from olive pomace

Australian bioactive supply value	$38M
Commodity by-product types	Solid pomace (olive pulp, may include skin and stones)
Key growing regions	North-Central VIC, Perth, WA[131]

Description

During olive oil production, large volumes of olive pomace are produced as a by-product. While pomace is often reprocessed to maximise oil yield, sizeable nutrient rich portions are still disposed.

Olive pomace contains significant amounts of antioxidant polyphenols, notably oleuropein, hydroxytyrosol and tyrosol, as well as other flavonoids and phenolic acids.[132] Studies report that olive pomace may yield higher polyphenol content than the refined olive oils, with 98% of the phenolic content going into byproduct streams during production.[133] Pomace is so high in phenolic content that it is considered phytotoxic and is an environmental burden.[134]

Technical considerations

Polyphenol extraction yield from olive oil production is highly influenced by the production method, with research reporting that modern 2 phase extraction of olive oil yields pomace with higher total phenolic content than the traditional 3 phase extraction.[135] Furthermore, research reports that the phenolic content found within the milling wastewater is higher than that of the solid pomace content, as such producers can also consider co-extraction to maximise polyphenol yield. The scale-up and viability of commercial olive pomace polyphenol extraction will also need to consider other factors including how to reduce high polyphenol degradation rates, and how to reduce reliance on using environmentally harmful solvents at large volumes.[136]

Preliminary commercial considerations

Extensive clinical research supports the health benefits of olive-based products, strengthening potential health claims that will support uptake in the complementary medicines industry.[137] There is a large existing market for olive leaf extracts, which may suggest consumer appetite for future olive-based supplements, however this will require further market testing. There is also existing interest and investment into olive oil by-product upcycling, such as into other food products, biofilms, soil additives and bioenergy.[138], [139] In Victoria, Boundary Bend Olives is undertaking research into the development of an olive waste processing facility to develop circular economy products.[140]

131 Australian Olive Association (2019) Australian Olive Oil – an overview 2019. <https://australianolives.com.au/australian-olive-oil-an-overview-2019/ > (accessed 24 April 2025)

132 Selim S, Albqmi M, Al-Sanea MM, Alnusaire TS, Almuhayawi MS, AbdElgawad H, Al Jaouni SK, Elkelish A, Hussein S, Warrad M, El-Saadony MT (2022) Valorizing the usage of olive leaves, bioactive compounds, biological activities, and food applications: A comprehensive review. Frontiers in Nutrition, 9, 1008349.

133 Nunes MA, Costa AS, Bessada S, Santos J, Puga H, Alves RC, Freitas V, Oliveira MB (2018) Olive pomace as a valuable source of bioactive compounds: A study regarding its lipid-and water-soluble components. Science of the total environment, 644, 229-236

134 Nunes MA *et al.* (2018)

135 Obied HK, Bedgood Jr DR, Prenzler PD, Robards K (2008) Effect of processing conditions, prestorage treatment, and storage conditions on the phenol content and antioxidant activity of olive mill waste. Journal of Agricultural and Food Chemistry, 56(11), 3925-3932.

136 Nunes, M. A., Pimentel, F. B., Costa, A. S., Alves, R. C., & Oliveira, M. B. P (2016) Olive by-products for functional and food applications: Challenging opportunities to face environmental constraints. Innovative Food Science & Emerging Technologies, 35, 139-148.

137 Mantzioris E (2025) Olive oil is healthy. Turns out olive leaf extract may be good for us too. The Conversation. <https://theconversation.com/olive-oil-is-healthy-turns-out-olive-leaf-extract-may-be-good-for-us-too-245941> (accessed 22 April 2025)

138 Barton J (n.d) Recycling Solid Waste from the Olive Oil Extraction Process. RIRDC Pub . No. 08/165. <https://australianolives.com.au/wp-content/uploads/2020/07/Charton-Bang-RIRDC-olive-waste-compost-plain-language.pdf> (accessed 22 April 2025) https://insights.figlobal.com/startups/making-clean-label-preservatives-from-olive-oil-pomace

139 Michail N (2022) Making clean label preservatives from olive oil pomace. Fi Global Insights. Informa markets. <https://insights.figlobal.com/startups/making-clean-label-preservatives-from-olive-oil-pomace> (accessed 22 April 2025)

140 Circular Economy Business Innovation Centre (2023b) Funded project – Building Australia's first zero waste hub for olive growers. <https://www.cebic.vic.gov.au/grants-funding-and-investment/funded-projects/zero-waste-olive-growers> (accessed 7 May 2025)

Polyphenols from barley spent brewers grain

Australian bioactive supply value	$31M
Commodity by-product types	Spent brewers grain
Key growing regions	VIC, NSW, QLD

Description

Spent Brewers Grain (SBG) is the primary by-product of the beer brewing process. It is a solid residue remaining after the fermentable sugars are separated from malted barley, and typically consists of the husk, pericarp and seed coat of barley grains. SBG accounts for 80-85% of the brewing industry's generated by-products.[141] Unprocessed SBG is occasionally used for low value applications such as for animal feed, composting or burning, but is often sent to landfill.[142]

SBG is nutritionally dense with high levels of functional protein, dietary fibres, lipids, vitamins and minerals.[143] Further, SBG also contains considerable levels of antioxidant polyphenols. These include ferulic acid, p-coumaric acid, caffeic acid, and sinapic acid.[144]

Technical considerations

SBG's high moisture content (up to 80%) makes it susceptible to spoilage and degradation of the bioactive compounds prior to extraction, posing challenges for storage and transportation.[145] Further, the polyphenolic compounds are usually encapsulated within the solid lignocellulosic material, which requires pretreatment to release phenolics for extraction, such as mechanical, chemical, thermal or enzymatic pretreatment.

Research notes that development of new or optimising pretreatment techniques will be required.[146] Traditional chemical or thermal extraction methods can produce high levels of polyphenols but are highly variable in efficiency, are high cost and are associated with negative environmental impacts.[147] Green extraction methods are emerging, however still require greater research and optimisation.[148]

Preliminary commercial considerations

There are ongoing efforts to repurpose SBG across industries; this includes as a source of nutrients for food and feed products, as well as further industrial processing converting SBG into biofuel, bioplastic production, construction additives, and biosorbents. This may present competition for supply.[149]

Beer consumption in Australia is declining, however, there is an increase in smaller breweries as consumer preferences move towards higher quality craft beers.[150] This trend may impact the sourcing of SBG as feedstock, requiring processors to aggregate supply from multiple dispersed sources to achieve volumes required for large extractions.

141 Singh SP, Jawaid M, Chandrasekar M, Senthilkumar K, Yadav B, Saba N, Siengchin S (2021) Sugarcane wastes into commercial products: Processing methods, production optimization and challenges. Journal of Cleaner Production, 328, 129453.

142 End Food Waste Australia (n.d.) SME Solutions Centre – Prioritisation of value-adding opportunities to upcycle brewing by-products. <https://endfoodwaste.com.au/sme-solutions-centre-prioritisation-of-value-adding-opportunities-to-upcycle-brewing-by-products/> (accessed 22 April 2025)

143 Fărcaş AC, Socaci SA, Chiş MS, Martínez-Monzó J, García-Segovia P, Becze A, Török AI, Cadar O, Coldea TE, Igual M (2022) In vitro digestibility of minerals and B group vitamins from different brewers' spent grains. Nutrients, 14(17), 3512. Chetrariu A, Dabija A (2023) Spent grain: A functional ingredient for food applications. Foods, 12(7), 1533.

144 Verni M, Pontonio E, Krona A, Jacob S, Pinto D, Rinaldi F, Verardo V, Díaz-de-Cerio E, Coda R, Rizzello CG (2020) Bioprocessing of brewers' spent grain enhances its antioxidant activity: Characterization of phenolic compounds and bioactive peptides. Frontiers in Microbiology, 11, 1831.

145 Terefe G (2022) Preservation techniques and their effect on nutritional values and microbial population of brewer's spent grain: a review. CABI Agriculture and Bioscience, 3, 51.

146 Lech M, Labus K (2022) The methods of brewers' spent grain treatment towards the recovery of valuable ingredients contained therein and comprehensive management of its residues. Chemical Engineering Research and Design, 183, 494-511.

147 Qazanfarzadeh Z, Ramu Ganesan A, Mariniello L, Conterno L, Kumaravel V (2023) Valorization of brewer's spent grain for sustainable food packaging. Journal of Cleaner Production, 385, 135726.

148 Macias-Garbett R, Serna-Hernández SO, Sosa-Hernández JE, Parra-Saldívar R (2021) Phenolic compounds from brewer's spent grains: Toward green recovery methods and applications in the cosmetic industry. Frontiers in Sustainable Food Systems, 5, 681684.

149 Lech M, Labus K (2022)

150 Wynne T (n.d.) Craft beer – Bucking the trend in Australia. The Agribusiness Bulletin. Deloitte. <https://www.deloitte.com/au/en/Industries/consumer-products/perspectives/craft-beer-bucking-the-trend-in-australia.html> (accessed 22 April 2025)

4.4 Other emerging opportunities

While quantitative modelling deliberately biased high-volume opportunities, niche commodities and bioactives could also present attractive opportunities at the individual company level. Table 4 lists examples of such opportunities that arose during the consultation process. Furthermore, Table 5 lists emerging agricultural sources highlighted during consultation as they may also be bioactive sources but would most likely be grown for a separate purpose and so not be considered by-products.

Aggregating high purity bioactives at lower volumes from various sources may present opportunities to consolidate lower volume by-products from within a region. However, stakeholders note the technical complexity required may greatly affect the capital expenditure required to establish infrastructure.

Table 4: Potential niche opportunities

COMMODITY	POTENTIAL OPPORTUNITIES FOR BIOACTIVES FROM BY-PRODUCTS
Farmed crocodile	Research is being undertaken to isolate and characterise collagen peptides from farmed crocodile by-products including cartilaginous material around the ribs and tail.[151] There is a growing farmed crocodile industry in the Northern Territory and north Queensland supplying a significant amount of the world's supply of crocodile skin and meat.[152]
Orange	Orange peel by-products are a rich source of bioactives which have been extensively characterised by research. These include phenolic acids (ferulic acid, caffeic acid, and p-coumaric acid), flavonoids (hesperidin, narirutin, eriocitrin), and over 20 types of carotenoids.[153, 154] There are large growing regions of oranges in the Murray Valley in Victoria, Riverina region of New South Wales, and the Swan Hill Riverland in South Australia.
Dragonfruit	While the bioactive composition of dragonfruit has been broadly characterised, there is limited research on Australian grown varieties. Dragonfruit skin is currently being explored for its polyphenols (flavonoids, phenolic acids and anthocyanins) and betalains.[155] Australian dragonfruit are predominantly grown in the Northern Territory and Queensland.[156]
Mango	Mango by-products include the peel and kernel. Mango peel contains phenolic acids (gallic acid, caffeic acid, and ferulic acid), flavonoids (quercetin, kaempferol, and mangiferin), and carotenoids like β-carotene. Mango kernels are a notable source of polyphenols, including rutin and penta-o-galloyl-glucoside, as well as tocopherols and phytosterols. Mango key growing regions are tropical and subtropical Northern Territory and Queensland, with varieties also grown in Western Australia and New South Wales.
Tomato	Ripe tomatoes are currently being used as a source for lycopene in the complementary medicines manufacturing industry.[157] Lycopene is the bright red pigment found primarily within the skin of the tomato.[158] Tomato peels and seeds are also abundant in phenolic compounds such as chlorogenic acid, rutin and naringenin. Seeds are also a notable source for phytosterols and tocopherols.[159] The majority of tomatoes are grown within Queensland (57%) and Victoria (28%).[160]
Capsicum	Capsicum skin and seeds are a valuable source of lycopene, other carotenoids, tocopherols and capsaicinoids.[161] Most capsicum is produced in tropical and sub-tropical areas, within Queensland, South Australia and Victoria.[162]

151 Strappe P, Wong R (2024) Isolation and characterisation of crocodile collagen peptides from farmed Australian saltwater crocodiles (Crocodylus porosus). AgriFutures Australia. <https://agrifutures.com.au/product/isolation-and-characterisation-of-crocodile-collagen-peptides-from-farmed-australian-saltwater-crocodiles-crocodylus-porosus/>

152 Crocodile Farmers Association of the Northern Territory (2024) Crocodile farming industry strategic plan 2024 to 2033 <https://dtbar.nt.gov.au/publications/strategies-and-plans/crocodile-farming-industry-strategic-plan>

153 Addi M, Elbouzidi A, Abid M, Tungmunnithum D, Elamrani A, Hano C (2022) An overview of bioactive flavonoids from citrus fruits. Applied Sciences, 12(1), 29. https://link.springer.com/article/10.1007/s11694-024-02779-1#Sec2

154 Nayana P, Wani KM (2024) Unlocking the green potential: sustainable extraction of bioactives from orange peel waste for environmental and health benefits. Journal of Food Measurement and Characterization, 18, 8145–8162.

155 Cheok A, Xu Y, Zhang Z, Caton PW, Rodriguez-Mateos A (2022) Betalain-rich dragon fruit (pitaya) consumption improves vascular function in men and women: a double-blind, randomized controlled crossover trial. The American Journal of Clinical Nutrition, 115(5), 1418-1431.

156 Northern Territory Government of Australia (n.d.) Pitaya: dragon fruit. <https://nt.gov.au/environment/home-gardens/growing-vegetables-at-home/pitaya-dragon-fruit> (accessed 22 April 2025)

157 Boulaajine S, Hajjaj H (2024) Lycopene extracted from tomato - A review. Food Science and Technology, 12(1), 1-14.

158 Agarwal S, Rao AV (2000) Tomato lycopene and its role in human health and chronic diseases. CMAJ, 163(6), 739-744.

159 Szabo K, Dulf FV, Teleky B-E, Eleni P, Boukouvalas C, Krokida M, Kapsalis N, Rusu AV, Socol CT, Vodnar DC (2021) Evaluation of the bioactive compounds found in tomato seed oil and tomato peels influenced by industrial heat treatments. Foods, 10(1), 110.

160 Hort Innovation (2019) Australian horticulture Statistics Handbook - Vegetables 2017/18. <https://www.horticulture.com.au/globalassets/hort-innovation/resource-assets/ah15001-australian-horticulture-statistics-handbook-vegetables.pdf> (accessed 22 April 2025)

161 Imran M, Butt MS, Suleria HAR (2018) Capsicum annuum bioactive compounds: health promotion perspectives. Bioactive Molecules in Food, Reference Series in Phytochemistry. Springer, Cham.

162 Capsicum case study from: Rural Industries Research and Development Corporation (2010) Pollination Aware. The Real Value of Pollination in Australia. <https://www.planthealthaustralia.com.au/wp-content/uploads/2024/01/10-114.pdf> (accessed 22 April 2025)

Table 5: Emerging bioactive sources

COMMODITY	POTENTIAL BIOACTIVES
Algae	Fish oil, containing omega-3 fatty acids
Cod	Cod liver oil and other fish oils, containing omega-3 fatty acids, vitamins A and D.
Australian native flora	Native plant extracts, containing phenolic compounds and vitamins.[163]

163 Mani JS, Johnson JB, Hosking H, Ashwath N, Walsh KB, Neilsen PM, Broszczak DA, Naiker M (2021) Antioxidative and therapeutic potential of selected Australian plants: A review. Journal of Ethnopharmacology, 268, 113580.

4.5 Industry development insights

Bioactive extraction from agricultural and food by-products is an early-stage emergent industry with very few commercial examples in Australia. The following section summarises industry development considerations and insights that were identified through consultation.

"

Any development needs to prioritise scale of supply, quality and price

While there is strong desire to source more complementary medicines ingredients locally, industry stakeholders have noted that the most important factors regarding any new Australian supply chains are that they are able to compete with incumbent international suppliers in terms of supply volumes and availability, as well as price and quality.

A staged approach may derisk scale-up

Industry stakeholders noted that a staged approach to reaching extraction and isolation of pharmaceutical-grade ingredients could help lower the risk and cost of specialised facilities and equipment. Early stages of the business model could focus on lower grade extracts for use in the functional and fortified food industry as a stepping stone towards higher value, higher purity extracts for complementary medicines. This could allow infrastructure and technical methodologies to develop over time and may derisk the long-term business case.

Market trends can be short lived but scaling-up production is a long game

While the complementary medicines market is experiencing broader growth, specific bioactive products are influenced by unpredictable market trends and can often follow short-lived hype cycles, which can make long-term investment challenging.

Collaboration is required across the future supply chain

Complementary medicines manufacturers require products made to specification and at appropriate scale before entering into offtake agreements. Bioactive extraction companies (e.g., vertically integrated primary production or processing, or new businesses established for purpose) need to understand these specifications and future demand before investing in building supply. Collaboration is essential to catalysing these activities and driving industry development.

Enabling policy considerations can drive development

Government can play a supportive role in enabling industry development. Stakeholders noted areas of focus include upskilling, financial incentives for sending by-products to circular uses (e.g., tax benefits), and developing a 'Brand Australia' presence in complementary medicine export markets to drive further growth.

Research and development is a priority

R&D is needed to ensure bioavailability of natural extracted forms of bioactives, as well as to support shelf-life claims for ingredients extracted from by-products. Alongside this, R&D is critical to informing the technical feasibility of extraction.

New businesses and business models may be needed

Farmers, food processors and complementary medicines manufacturers generally express a strong enthusiasm for an innovative Australian bioactive extraction industry. However, they are hesitant to take leading roles where this is not their core business, and they lack expertise and established capacity. While dedicated innovation business units are one option for larger companies, there may also be opportunities for new players, including cooperatives and grower groups, to establish themselves as bioactive extractors and drive industry growth in value-added supply chains.

Vitamins and essential minerals are readily available in cost effective synthetic forms

While important to the industry, commoditised ingredients generally do not represent valuable opportunities for Australia's food and agricultural sectors, as there is limited opportunity for a viable premium.

Nature-based risk assessments of supply chains may yield valuable opportunities

Industry stakeholders noted that climate-related disruptions are introducing supply chain vulnerabilities. For example, ocean warming and El Niño events are severely impacting the Peruvian anchovy industry,[164] a major source of fish oil, and threatening the stability of global fish oil supplies. The development of an Australian fish oil production industry utilising fishery by-products or sourcing from invasive cod species may be a valuable opportunity to adapt supply chains and minimise disruptions. Assessing supply chains for climate change vulnerabilities is important both in increasing industry resilience and in identifying potential opportunities for Australian production.

164 Mollinari C (2024) Peruvian anchovy executive warns about problems in a country's south fishing zone. Supply & Trade. Seafood Source. <https://www.seafoodsource.com/news/premium/supply-trade/peruvian-anchovy-executive-warns-industry-not-to-forget-about-the-country-s-south-zone> (accessed 22 April 2025)

5 Next steps

While 30 preliminary opportunities were identified in this report and five profiled, further analysis is required to validate commercial feasibility prior to investment. Critical to understanding commercial feasibility is collaboration within industries (for example, grower groups) and across supply chains. Conversations are required between suppliers and complementary medicine manufacturers to establish clear understandings around product specifications, scale of supply and regulatory requirements. Opportunity-specific analysis should also include the development of priority actions to unlock the new industry at the required scale.

Table 6 outlines the required activities and research questions that need to be explored to inform industry and government investment across a staged process. Many of these considerations have been informed by industry consultation.

Table 6: Next step activities and research questions

RESEARCH QUESTIONS	
Preliminary viability	1. **Practicality** – What practical considerations are relevant to the by-products and bioactives reported within this analysis and how do they impact commercial feasibility? For example, efficiencies from local clusters of by-products or growing regions, trade-offs from current by-product use pathways (e.g., animal feed or ground cover), considerations around the physical collection and aggregation of by-products (e.g., unharvested produce might require more labour or equipment, sanitation considerations), or technical isolation efficiency. 2. **Supply** – What are the preliminary estimates on extraction efficiency? What are the estimates on the volumes of supply of a bioactive each year? What is the minimum viable volume required to justify producing bioactives from this feedstock? How does this volume compare with the volume required by Australian complementary medicine manufacturers? How sensitive is pricing and supply to other external factors? Is this price competitive with other industries looking to utilise these by-products as feedstock? 3. **Price** – What is the pricing goal? Based on discussions with buyers, and preliminary data on supply and technology options, when might an ingredient reach price parity with incumbent suppliers? 4. **Quality** – What specification is required by the buyer? What extraction methodology is most suitable for the by-product streams proposed? What equipment is required to facilitate this?
STAGE GATE 1: PRELIMINARY VIABILITY	
Ecosystem analysis	5. **Partners** – What organisations already have relevant technical equipment, and can they be partnered with? What other organisations could be involved, either in supplying by-product streams or provision of services? 6. **Value chains** – What would new value chains need to look like? Are the logistics of aggregation viable? What relevant infrastructure (storage, processing, extraction, etc.) is already available in the applicable region and is additional infrastructure required for scaled operation? What (if any) new organisations would be required? Who are the key buyers/off-takers? 7. **International landscape** – Who is involved in similar extraction, in terms of input crops, output bioactives, and technical equipment requirements? What learning can be ascertained from their experiences?
STAGE GATE 2: ECOSYSTEM VIABILITY	
Business model innovation	8. **Scale-up** – What pilot and scale up studies are required to demonstrate technical feasibility? Are there lower value products (e.g., lower purity) along the same production trajectory that could be produced as a stepping stone towards high value ingredients to derisk scale up? 9. **Profitability** – is the modelled volume of output and supply price economically viable considering the projected costs of development? Where the opportunity used by-product streams from processing, are there mechanisms to ensure primary producers capture value? 10. **Regulatory considerations** – What regulations are applicable to the development of the opportunity and how does this impact feasibility?
Research priorities	11. **Research** – Is research required to build the clinical evidence base and support demand (e.g., bioavailability studies)? How can the research sector help industry develop new products (including shelf stability studies) and establish cost-effective scale-up?
STAGE GATE 3: BUSINESS MODEL VIABILITY AND SUPPORTING RESEARCH	

Appendix A – Consulted organisations

CSIRO would like to thank all consulted organisations for their contributions to this project through one-on-one videoconference interviews and document reviews. Tailored interview plans were developed for each interview, which sought to gather views on opportunities of untapped potential, key limitations, existing commercial examples of bioactive extraction, broader business impacts that bioactive extraction could pose on the organisation, and quantitative model assumptions.

The insights expressed throughout this report were developed by considering the collective views obtained alongside independent economic and qualitative research and may not always align with the specific views of one of the consulted individuals or organisations. Listed below are those organisations that consented to being named.

- Alkiira Therapeutics
- Australian Meat Processor Corporation (AMPC)
- AusVeg
- Avocados Australia
- Bega Group
- Blackmores
- Bowen Gumlu Growers Association (BGGA)
- CANEGROWERS
- Charles Darwin University
- Curtin University
- Extracta
- Grains Research and Development Corporation (GRDC)
- KPMG Australia
- Meat and Livestock Australia (MLA)
- Northern Territory Government - Department of Agriculture and Fisheries
- Queensland Government - Department of Primary Industries
- Sanitarium
- Swisse Wellness
- Vitex Pharmaceuticals

Appendix B – Supply value analysis methodology

Overview

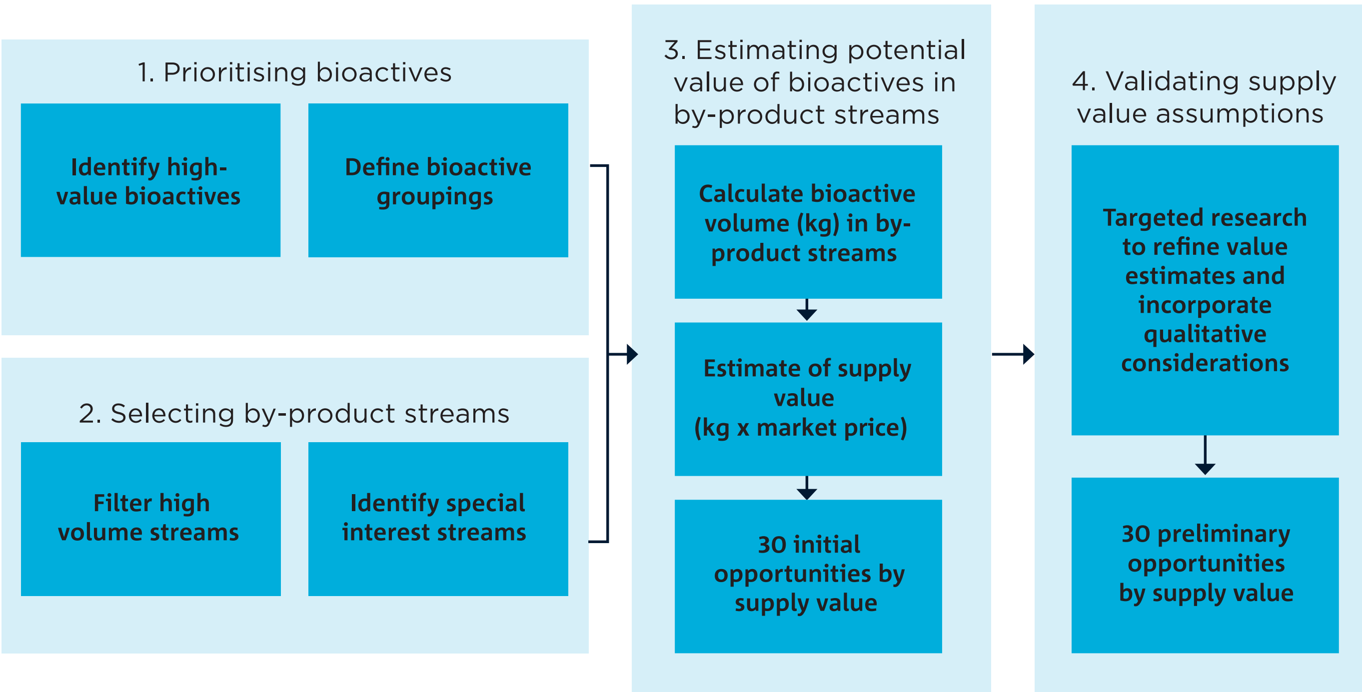
The objective of this analysis was to identify high-value sources of bioactives from agricultural by-product streams that may present significant market opportunities for an Australian raw ingredients extraction industry.

Given the wide range of agricultural by-product streams and bioactives in Australia, the analysis was conducted in multiple stages to narrow the focus and identify key opportunities. The process involved:

1. Prioritising bioactives
2. Selecting by-products streams
3. Estimating potential value of bioactives in by-product streams
4. Validating value assumptions

The resulting validated opportunities were then assessed and filtered based on their supply value, technical development and level of Australian investment. This process resulted in the development of Table 3: Summary of preliminary 30 opportunities which is intended to help identify opportunities for future commercial research and investment.

Figure 8: Supply value model methodology overview



Prioritising bioactives

The top 20 bioactives by global market size, reported in Frost & Sullivan's Global Nutraceutical Growth Opportunity (2023), were selected for analysis, excluding herbs and botanical ingredients (Table 7). This approach helped ensure that only bioactives with clear market demand and established applications were considered, providing greater confidence that any value derived from agricultural by-products would be commercially viable.

Stakeholders expressed strong interest in certain bioactives during consultations. These were added to the analysis, including: polyphenols, linoleic acid and broader carotenoids.

Some bioactives of similar nature were also grouped together to assess whether their combined potential value could be greater. This included grouping vitamins by solubility (water soluble vitamins B and C, and lipid soluble vitamins A, D, E), and grouping carotenoids (retinol, Alpha-carotene, Beta-carotene, Cryptoxanthin, Beta-carotene equivalents, and Xanthophyl).

Probiotics were excluded from analysis due to their live nature and requirements for further fermentation to reach ingredient volume needed for complementary medicines manufacturing.

Table 7: Top 20 bioactives by global market size, excluding herbal and botanical ingredients

BIOACTIVE INGREDIENTS	2030 ($AU MILLIONS)[165]	2022-2030 (CAGR %)
Protein Ingredients (Dairy and Plant)	36,940	6.60%
Vitamin C	8,559	7.30%
B Vitamins	8,286	8.79%
Lutein & Zeaxanthin	6,158	11.10%
Vitamin E	5,728	4.10%
Probiotics	4,802	5.80%
Amino Acids	4,449	12.50%
Calcium	4,252	4.30%
Iron	3,678	8.30%
Prebiotics	3,405	7.30%
Collagen Peptide	3,188	11.20%
Vitamin A	2,888	5.80%
Vitamin D	2,349	4.80%
Magnesium	2,343	6.09%
Zinc	2,034	8.10%
CoQ10	1,989	8.20%
Omega-3 Fatty Acids	1,982	2.50%
Melatonin	1,715	13.59%
Creatine	681	6.60%
Hyaluronic Acid	661	5.60%

Source: Frost & Sullivan, 2023

165 Converted using the average AUD/USD exchange rate for Q1 2023, as published by the RBA.

Selecting by-product streams

By-product streams represent the combine by-products generated at a single stage of production or processing. For example, the by-products of wine grape secondary processing (wine making) are stalks, marc, and lees; together constituting a single by-product stream.

The top 30 by-product streams by volume of low-value by-products were selected for analysis (Table 8). This step ensured that the by-product streams had sufficient volume to support the potential scaling up of the identified bioactive extraction opportunities.

Data was sourced and filtered from the Food Innovation Australia's National Food Waste Baseline (NFWB) database,[166] which includes information on nearly 500 agricultural by-products. The volume of low-value by-products was calculated by multiplying the total volume of a by-product stream (metric tonne) by the percentage that went to low-value destinations.[167]

Avocados, blueberries, broccoli/baby broccoli, coffee, and corn (maize) were included in the analysis due to special interest raised during stakeholder consultations.

Estimating the potential value of bioactives in by-product streams

This stage developed an estimate of the supply value of bioactives within each shortlisted by-product stream. This was approximated using the corresponding whole food[168] data in the Food Standards Australia New Zealand's (FSANZ) Nutrient database.[169] This was used to filter out bioactives which would be absent from the commodity or were found in trace amounts; too low to present a significant opportunity.

Further desktop research was conducted for bioactives not available in the FSANZ database, including linoleic acid, phenolic compounds, creatine, melatonin, CoQ10, and collagen. These bioactive amounts were then multiplied by the market price of each respective bioactive to generate an initial value estimate. The top 30 were selected for further validation of value estimates through desktop research.

166 FIAL (2021) National Food Waste Strategy Feasibility Study. – Final Report <https://www.fial.com.au/sharing-knowledge/food-waste> (accessed 1 April 2025)
167 Both the total by-product volume and the proportions directed to low-value destinations were taken directly from assumptions in the NFWB database.
168 e.g., using whole potato as a proxy for potato skin.
169 Food Standards Australia New Zealand (2022).

Table 8: Shortlisted by-product streams

COMMODITY	STAGE	BY-PRODUCTS	TOTAL VOLUME OF LOW-VALUE BY-PRODUCTS (MT)
Almonds	Primary process	Hull	178,750.00
Avocados	Primary production	Field losses	670.57
Avocados	Primary process	Off-spec products	8,906.92
Avocados	Secondary processing	Skins and nuts	1,362.69
Barley	Primary production	Primary production losses	88,189.45
Barley	Secondary processing	Malt combinings	198,934.26
Barley	Tertiary processing	Manufacturing losses	175,314.62
Beef	Primary process	Protein meal, Trimmings	1,020,039.11
Blueberries	Primary production	Field losses	216.00
Blueberries	Primary process	Off-spec products	2,148.18
Blueberries	Secondary processing	Offcuts	181.62
Broccoli	Primary production	Field losses	6,400.79
Broccoli	Primary process	Off-spec products	2,627.62
Broccoli	Secondary processing	Stalks, offcuts	671.92
Canola	Primary process	Meal	212,178.04
Cauliflower	Primary production	Field losses	52,809.47
Chicken	Primary process	Protein meal, Trimmings	450,895.84
Coffee	Primary production	Field losses	0.00
Coffee	Primary process	Hull	2,828.57
Coffee	Secondary processing	Chaff	3,860.21
Corn (Maize)	Primary production	Primary production losses	3,272.07
Corn (Maize)	Primary process	Lost grain	1,117.01
Corn (Maize)	Secondary processing	Hominy feed	38,704.37
Cottonseed	Primary process	Meal	249,664.51
Cucumbers	Primary production	Field losses	75,013.60
Lamb	Primary process	Protein meal, Trimmings	92,481.68
Lentils	Primary process	Leave, stems, empty pods, broken or discoloured bean	53,897.25
Mangoes	Primary production	Field losses	59,935.20
Milk	Secondary processing	Cheese scraps, Whey, Butter, Buttermilk powder, Processing loss, other manufacturing losses	2,547,903.15
Oats	Secondary processing	Oat husks	78,434.16
Olives	Secondary processing	Pomace	100,995.09
Oranges	Secondary processing	Pomace	107,524.94
Pork	Primary process	Trimmings, Protein meal	97,880.51
Potatoes	Primary production	Field losses	64,204.00
Potatoes	Primary process	Off-spec products	53,689.71
Potatoes	Secondary processing	Skins, offcuts, etc	207,827.77
Sugarcane	Primary production	Primary production losses	285,857.69
Sugarcane	Primary process	Bagasse, molasses	9,148,743.72
Sweet potatoes	Primary production	Field losses	53,171.31
Tomatoes	Primary production	Field losses	201,084.86
Watermelons	Primary production	Field losses	114,904.00
Wheat	Primary production	Primary production losses	175,904.52
Wheat	Secondary processing	Bran, Germ	406,396.78
Wheat	Tertiary processing	Bakery waste	187,751.44
Wine grapes	Secondary processing	Stalks, Marc, Lees	102,249.01

Validating value assumptions

This stage focused on refining the initial value estimates for the top 30 by-product streams and bioactive combinations with the highest potential bioactive value. Some production data was updated using more recent sources,[170] such as ABS and ABARES, and averaged across three years to provide a more reliable forecast of potential production. Waste data continued to be based on assumptions from the NFWB, with some exceptions where specific assumptions were updated to reflect more current or relevant information.

A literature review was also conducted to assess the specific bioactive content of each by-product, replacing earlier estimates that used whole food proxies. Where available, bioactive content was cross-checked across multiple sources to improve accuracy. In cases of wide variation, the most reliable source with values aligned to the most frequently reported range in the literature was used.

The pricing data used to determine supply value was based on wholesale prices sourced from the public domain. Pricing will be greatly influenced by intrinsic product properties such as the chemical form and formulation, purity level, manufacturing method and source, external economic factors, and geopolitical trends. While prices were cross-checked with key industry users of these ingredients and found to be within reasonable ranges, exact figures could not be provided due to commercial confidentiality. As such, all values should be considered as indicative.

Data limitations and scope exclusions

Commodities and by-products excluded from the analysis include:

- non-food agricultural commodities such as forestry products and industrial hemp;
- potential bioactive sources that were grown for use such as some algae and seaweeds; and
- those with limited characterisation or volume data availability. For these, it is recommended that future research and modelling be undertaken when data is made available.

Opportunities were based on potential extraction directly from a by-product. Where by-products could be used as feedstock for the generation of bioactives through alternative methods such as microbial fermentation, these were not included for analysis.

Bioactive content can vary based on growing region, seasons, environmental conditions, and agricultural practices. While Australian research was used where available, most data was sourced from international publications due to limited local studies.

Bioactive content was expressed as the total amount present in each by-product, which may differ from the amount that can be extracted, as extraction efficiency depends on the specific technology and methods used.

170 The NFWB used data from pre-2021 and may still reflect the impacts of COVID-related disruptions.

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