



Australia's National
Science Agency

Edible insects

A roadmap for the strategic growth
of an emerging Australian industry

April 2021



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CSIRO foreword

The global population will reach 9.7 billion by 2050, fuelling the demand for protein.

The world will need to produce more protein into the future in a way that is more sustainable and from diversified sources, not only to meet global demand, but also the changing dietary patterns of the modern health and ethically conscious consumer.

In the 2019 *Growth Opportunities for Australian Food and Agribusiness* report, we at CSIRO estimated a \$4.1 billion AUD domestic and \$2.5 billion AUD export opportunity for alternative proteins by 2030. In our 2020 *COVID-19: Recovery and Resilience* report, we identify alternative protein sources and their export potential as a key opportunity for the Australian food and agribusiness sector over the medium term. Insect-based ingredients and animal feeds were identified as favourable science and technology enablers within a suit of complementary sources, including novel protein extraction processes, ongoing improvements in aquaculture production systems, and plant-based proteins.

So important is this chance created by the world's growing demand for high quality protein that CSIRO, along with collaborators, is developing a Future Protein Mission to help seize the spoils of the protein boom by supporting new Australian industries through science, innovation and technology. These missions will tackle Australia's big challenges and focus on the issues that matter the most, for our quality of life, the economy, and the environment.

The developing Future Protein Mission will help industry explore conventional protein areas, enabling a shift from commodity to high value plant protein products, to protect and grow sustainable animal protein production, and to support emerging protein production industries such as insects.

Insects have been part of many cuisines around the world for millennia, including Australian First Nations Peoples, and are promising, if not necessary, enablers allowing us to diversify our diets into the future. This report explores the potential of edible insects as an alternative protein source in the Australian context by laying out a detailed and comprehensive plan for this emerging industry. Alternative protein industries could play an important role in Australia, contributing to regional and national prosperity, and will be fundamental to meeting shifting global food demands.

Professor Michelle Colgrave

Future Protein Lead
CSIRO



IPAA foreword

Two years ago, academics, farmers, processors, chefs, students and stakeholders met at CSIRO in Brisbane to share ideas and discuss the Australian edible insect protein industry. Attendees brought a broad scope of perspectives from across all aspects of the supply chain for an industry that, at the time, had only eight insect farms and four companies selling products for human consumption. They were joined by leading international researchers supporting edible insect policy and industry in Europe, which is several years ahead in market acceptance and research and development when compared to Australia. The most inspiring part of the symposium was the overwhelming participation and willingness to collaborate, share and engage with each other to move the industry forward.

It is true that the current Australian insect protein industry is small and emerging, however, it consists of determined and passionate professionals with a variety of expertise collectively focused on the use of insects for food and animal feed. Our members are pushing boundaries, looking for new insect species to adopt, raising robust and healthy colonies from limited seed stock, creating products, recipes and systems, not to mention farming and utilising insects that only exist here in Australia.

Our country is ancient, with a long history of utilising insects as food. There is a unique and powerful opportunity for our industry to learn from and be led by First Nations Peoples in understanding Australian insects and supporting the education of Western cultures in adopting and accepting insects as food. Across the world, less than five species of insect are commonly farmed by the largest insect companies often reported in the news. This report identifies more than 60 insect species native to Australia that have commonly been eaten by and are deeply connected to First Nations Peoples. An industry that would be uniquely Australian, built and developed in collaboration with First Nations People, is an incredible and compelling distinction of our industry operating in the global market.

As I write this, three months into 2021, the world is in the fight for its life to mitigate supply chain disruptions caused by climate change and the COVID-19 pandemic, and develop new ways to increase protein production to feed the anticipated population of 2050. The energised insect protein industry of Australia finds itself with several members already receiving venture funding, developing novel products and processing techniques, and selling products on the shelves of big brand Australian supermarkets. Noticeably, we are poised ready to grow as new insect farmers and producers are joining the industry each year.

It is meaningful, therefore, that this report is a formative document for the Australian insect protein industry. It provides a clear roadmap to navigate the next meaningful steps forward and guidance on the research priorities that will contribute to the commercialisation and positive outcomes for the emerging industry. I look forward to seeing its recommendations in action as insects become a more sustainable and high-value part of the modern Australian diet well into the future.

Olympia Yarger

Chair, Insect Protein Association of Australia





Executive summary

Current food systems cannot meet the global challenge of producing enough nutritious, high-protein food for the world's growing population.

Conventional farmed animals, such as cattle, pigs, and poultry, are currently the largest source of protein worldwide, and account for more than 30% of all calories consumed by humans. Increased production of conventional animal protein would be expensive, pose high environmental costs, and would be restricted in scale by the availability of natural resources. Diversifying global food supply chains will be essential to building more resilient food systems capable of withstanding increased disruptions caused by climate change, environmental damage, and emerging diseases.

The global edible insect industry is growing fast, with the worldwide market expected to reach \$1.4 billion AUD in value by 2023. More than 2,100 insect species are currently eaten by two billion people from 130 countries, including 60 native insect species traditionally consumed by First Nations Peoples in Australia. Insects have high-value nutritional profiles, and are rich in protein, omega-3 fatty acids, iron, zinc, folic acid and vitamins B12, C and E. Commercial insect farming is considered to have a low environmental footprint, requiring minimal water, energy, and land resources.

Europe and the United States of America are the leading edible insect markets in the Western World today, with more than 400 edible-insect-related businesses in operation. In Australia, early adopting start-ups and entrepreneurs have recognised the potential of a national edible insect industry. Currently, 14 insect-based businesses operate in Australia, including farmers, producers, product developers, chefs, and consultants. The Australian insect industry is expected to grow into a \$10 million AUD industry annually in the next five years. However, scalability is limited by a lack of automation, limited research in the local sector, and the current state of consumer attitudes.

This report identifies the challenges and opportunities for the Australian edible insect industry. It provides a useful framework for First Nations initiatives, start-ups, insect businesses, researchers, policy makers, and members of the general public who are considering engaging with the emerging industry. Australia is well positioned to leverage its agricultural innovation, knowledge of biodiversity, research capabilities and industry experience to take advantage of developing opportunities in the edible insect sector and deliver insect products to the well-established export markets. In order to advance the Australian industry, we must:

- forge new collaborative partnerships among First Nations Peoples, researchers, industry, and government bodies to advance our knowledge, procedures and policies
- co-develop First Nations owned and led initiatives, improve Western perceptions of insect consumption, and create new Australian-branded products and food experiences that will promote traditional usage and market acceptance
- identify and incorporate native insect species already adapted to the Australian environment into low-impact farming practises to encourage an ecologically sustainable industry
- produce new edible insect foods that are delicious, nutritious, and easy to access to help improve the Australian diet.

Through increased investment, ongoing collaboration, as well as foundational research and development, Australia can become a leading international player in producing nutritious, sustainable, and ethical Australian-branded edible insect products that will contribute to meeting the global challenge of achieving food security.



Introduction



Limitations of global food production systems

The need to upscale global agricultural systems sustainably is one of modern societies' biggest challenges. Our current arable land and water resources used for agriculture are finite¹ and not enough to produce the 69% increase in food required to feed the expected global population of 9.7 billion people by 2050². Globally, conventionally farmed animals such as cattle, pigs and poultry are the major sources of protein in our diets, as 30% of all human calories consumed are derived from meat products³. Although vegetarianism is becoming more common in Western countries, the average consumption of animal protein per capita continues to increase⁴, driven by the increasing global population and improved socioeconomic growth of people from developing nations. Influencing consumers to adopt a reduced meat diet is often difficult because of cultural, societal and personal associations with meat consumption⁵.

The effects of the COVID-19 pandemic, particularly border closures, physical distancing, shortages of workers and prolonged lockdowns, are posing immediate challenges to global food supply chains. Not only is the current pandemic making people more conscious about the link between the environment, food and health, it is also increasing the demand for fresh, healthy, additive-free food with traceable origins, and facilitated by food e-commerce^{6,7}.

Existing food production systems and supply chains are likely to be challenged by increasing rates of environmental destruction, land mismanagement, changing climates and emerging pandemics. These risks, combined with agricultural intensification and the consumption and trafficking of wildlife not only increase the rate of global biodiversity loss, but also new pandemics, as wildlife, livestock and humans are forced closer together, facilitating transmission of pathogenic microbes or virus between species and their spread throughout the world through globalised trade routes⁸ (Figure 1).

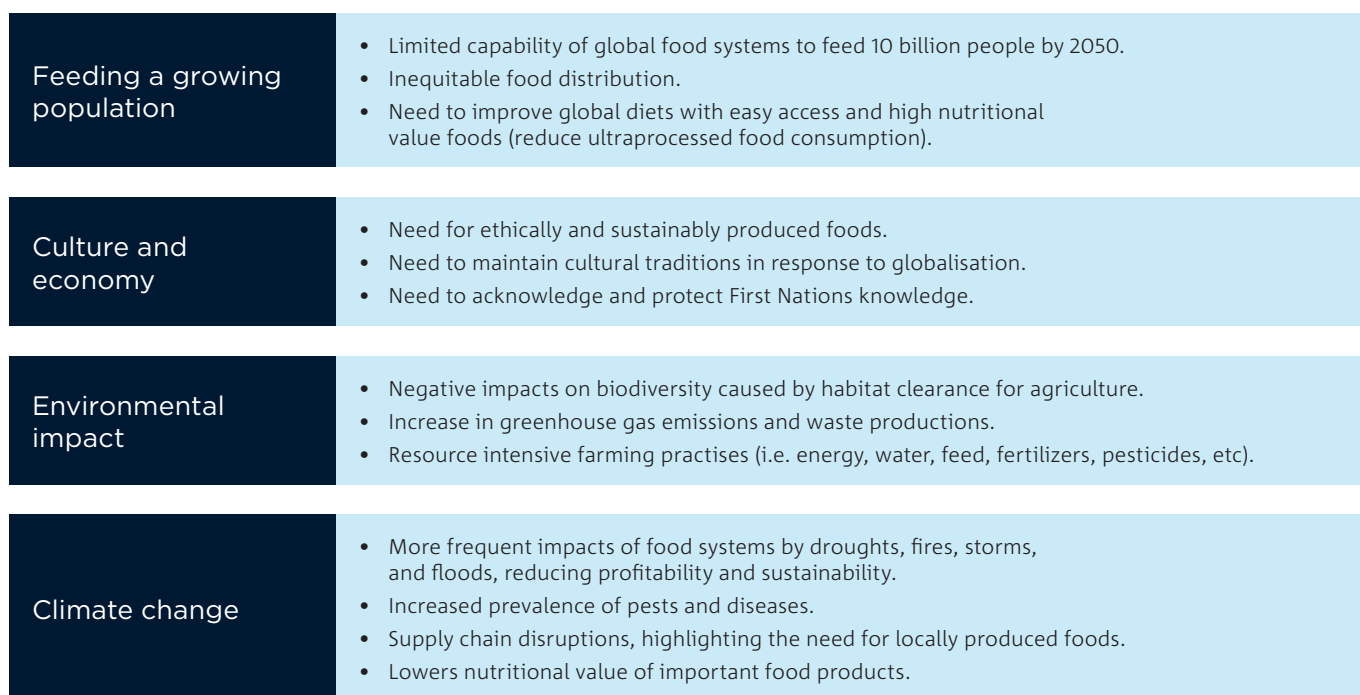


Figure 1: Triggers for the development of an alternative protein industry.

1 <https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/>

2 Ranganathan, J., Vennard, D., Waite, R., Dumas, P., Lipinski, B., & Searchinger, T. (2016). Shifting diets for a sustainable food future. In *Creating a Sustainable Food Future* (Vol. 11, Issue April).

3 Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods* (Basel, Switzerland), 6(7), 53. <https://doi.org/10.3390/foods6070053>.

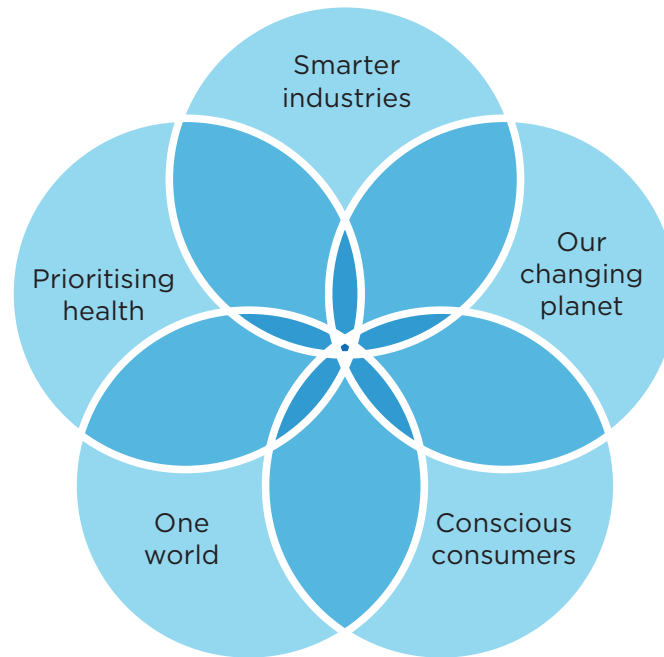
4 <https://ourworldindata.org/meat-production#meat-production-by-animal>

5 Alexander, P., Brown, C., Arneith, A., Dias, C., Finnigan, J., Moran, D., & Rounsevell, M. D. A. (2017). Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? *Global Food Security*, 15, 22–32. <https://doi.org/10.1016/j.gfs.2017.04.001>

6 CSIRO Futures (2020) COVID-19: Recovery and resilience, CSIRO, Canberra

7 How COVID-19 is accelerating the food transformation | Deloitte Netherlands. <https://www2.deloitte.com/nl/nl/pages/consumer/articles/food-covid-19-accelerating-food-transformation.html>

8 IPBES. (2020). Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services. IPBES Secretariat. <http://agriculture.kzntl.gov.za>



Smarter industries

The rise of digital technologies, artificial intelligence and robotics is driving more efficient value chains. It is impacting production (i.e. upscale) to the way consumers purchase and receive food (i.e. e-commerce).

Prioritising health

With COVID-19, the already growing consumer focus on health and wellbeing is accelerating. Aging populations, rise in chronic illnesses, such as diabetes and heart disease, and increasing social awareness for improved health and wellbeing support this trend. There has also been a broader global consumer trend of caution and preference towards brands that demonstrate purpose, transparency and alignment with their values.

One world

A globalised world promotes greater exposure to foods from different regions and cultures. This opens the markets to new opportunities locally and abroad, but also introduces new threats. Increased competition will make differentiating products more important than ever before.

Conscious consumers

As the climate changes, so does the mindset of consumers. Increase in wealth, social awareness of personal wellbeing and the ethical treatment of animals are all giving rise to an environmentally conscious consumer willing to switch from a conventional meat-based diet to a flexible diet of alternative and less processed proteins to minimise their environmental footprint.

Our changing planet

Producing food using conventional methods is becoming more challenging, with the rise of unprecedented droughts, fires, storms and floods due to the changing climate, environmental stress, biodiversity loss, pest outbreaks and reduction of arable land. Additionally, these factors impact on the quantity and quality of the food produced. Therefore, the food industry must think of innovative solutions to continue to feed the growing population.

Figure 2: Megatrends driving the need for alternative proteins, such as insect protein.

For emerging industries to succeed, they must anticipate and adapt to global megatrends and substantial shifts in social, economic, environmental, technological and/or geopolitical conditions that may reshape the way a sector operates in the long term⁹ (Figure 2).

Alternative plant proteins is an example of a successful new industry that has become more mainstream with an expected market value of \$21.1 billion AUD by 2023¹⁰. This rapid expansion is largely attributed to the rise of environmentally conscious consumers, innovation around food production and co-investment by multinational companies to reinforce their social licence to operate.

9 Hajkowicz, S. (2015). Global Megatrends - Seven Patterns of Change Shaping Our Future (Issue 3).

10 Technavio (2017) Global plant-based protein products market 2019-2023

Edible insects as a promising industry

Edible insects may help us feed the growing population in the face of climate change, disruptions to food production systems, and the rise of the conscious consumer.

Edible insects are the fastest growing alternative protein market in the world¹¹. The global edible insect industry is expected to reach a total value of \$1.4 billion AUD by 2023¹² and grow 44% annually by 2025¹³. More than 2,100 recognised¹⁷ insect species have been eaten by two billion people in 130 countries around the world¹³. The main insect orders eaten globally are

beetles (Coleoptera), followed by ants, bees and wasps (Hymenoptera), crickets and grasshoppers (Orthoptera), moths and butterflies (Lepidoptera) and termites (Isoptera) (Figure 3). Interestingly, one of the world's most used natural food dyes is derived from carmine obtained from the bodies of female cochineal insects.

Insects have largely been excluded from becoming fully developed into a staple of the Western diet. The modern way of life, including competition of convenience food and people who are time poor, combined with a lack of technological development in insect farming and food production systems, have hindered the uptake of insect consumption. A developed edible insect industry has the potential to address 10 of the 17 Sustainable Development Goals¹⁴ established by the United Nations¹⁵, aiming to a 'better and more sustainable world'.

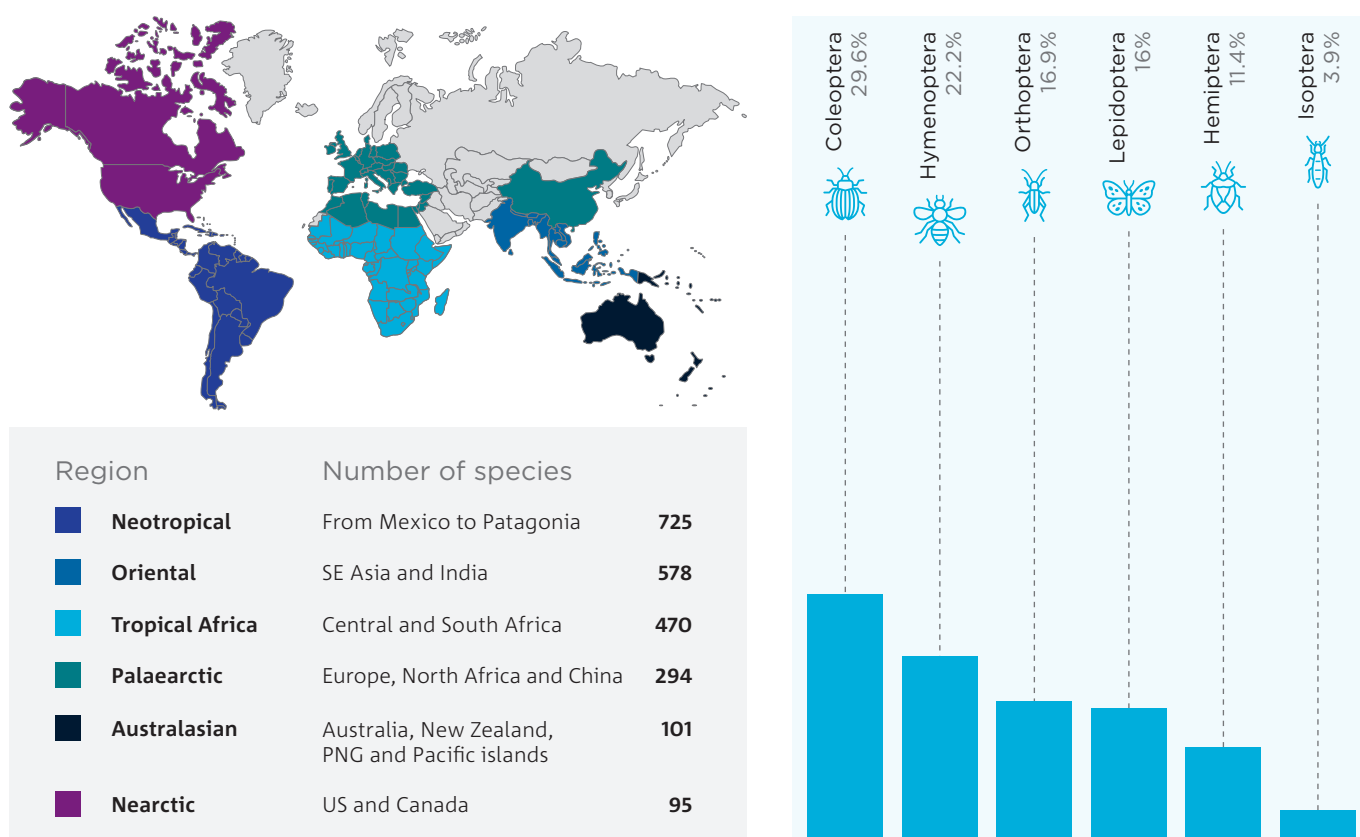


Figure 3: Number of insect species consumed around the world (left) and percentage of species consumed per insect order (right)¹⁷.

11 FIAL. (2019). Protein market: size of the prize analysis for Australia. https://fial.com.au/Protein_Report_2019

12 Food and Agriculture Organization of the United Nations. (2013). Edible insects. Future prospects for food and feed security. In Food and Agriculture Organization of the United Nations (Vol. 171).

13 Barclays. (2019). Insect protein: bitten by the bug. Barclays, June. <https://www.investmentbank.barclays.com/our-insights/insect-protein-bitten-by-the-bug.html>

14 Helping to end poverty in all forms everywhere (UN Goal 1); working towards zero hunger (2); ensuring healthy lives and promoting well-being for all ages (3); promoting inclusive and sustainable economic growth, employment and decent work for all (8); building resilient infrastructure, promoting sustainable industrialisation and fostering innovation (9); reducing inequality within and among countries (10); making cities inclusive, safe, resilient and sustainable (11); achieving responsible consumption and production (12); taking urgent action to combat climate change and its impacts (13), and; sustainably managing forests, combating desertification, halting and reversing land degradation, and halting biodiversity loss (15).

15 <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

16 <https://golden.com/wiki/Entomophagy-REDPV4>

17 Jongema, Y. (2017). Worldwide list of recorded edible insects. In Wageningen University (pp. 1–100). Department of Entomology, Wageningen University & Research. <https://www.wur.nl/en/Research-Results/Chair-groups/Plant-Sciences/Laboratory-of-Entomology/Edible-insects/Worldwide-species-list.htm>



Edible insect products available globally¹⁸



Foods

- protein bars
- breads
- burger patties
- crackers
- chips
- falafel
- flours
- granola
- alternative meats
- pastas and noodles
- sausages



Beverages

- beers
- milks
- milkshakes
- soft drinks
- spirits and alcohol
- protein enriched/
fortified drinks



Confectionary*

- candies and lollies
- chocolates
- ice-creams
- cookies

*Including insects in confectionary products might facilitate their initial uptake, however, it could offset their nutritional benefits. Food Manufacturers would need to ensure that they are delivering a healthy product, not just more protein.



Other

- bitters
- butters
- oils
- pesto
- spices and seasonings

Figure 4: Types of edible insect products available globally.

¹⁸ <https://www.bugburger.se/guide/the-big-list-of-edible-insect-products/#beer>

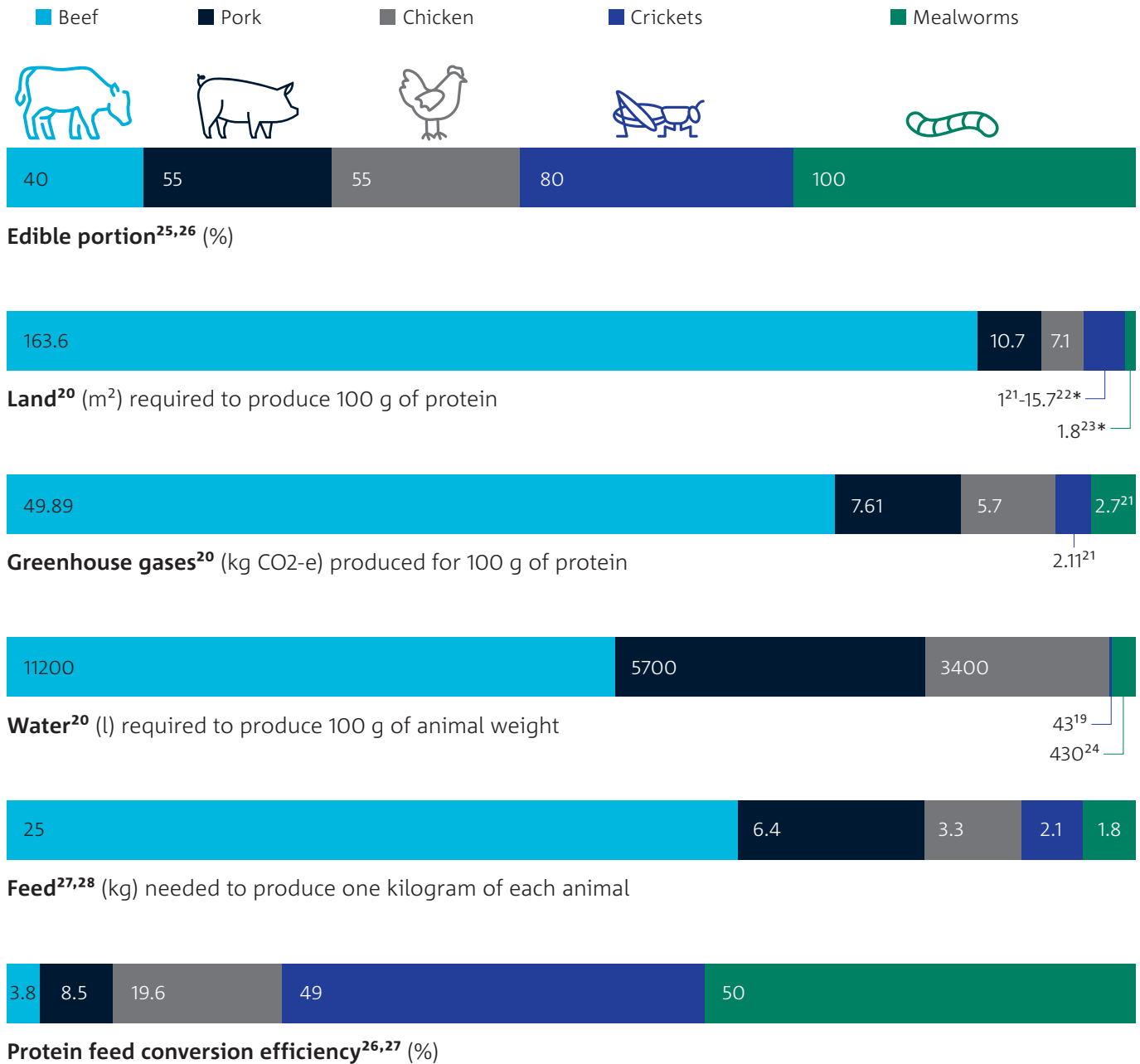


Figure 5: Environmental footprint of crickets and mealworms compared to conventional farmed animals.

*Land usage for crickets and mealworms is much lower than conventional farmed animals, since they can be stacked vertically other in industrial warehouses.

19 Halloran, A., Hanboonsong, Y., Roos, N., & Bruun, S. (2017). Life cycle assessment of cricket farming in north-eastern Thailand. *Journal of Cleaner Production*, 156, 83–94. <https://doi.org/10.1016/j.jclepro.2017.04.017>

20 Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987 LP – 992. <https://doi.org/10.1126/science.aag0216>

21 Nadeau, L., Nadeau, I., Franklin, F., & Dunkel, F. (2015). The Potential for Entomophagy to Address Undernutrition. *Ecology of Food and Nutrition*, 54(3), 200–208. <https://doi.org/10.1080/03670244.2014.930032>

22 Suckling, J., Druckman, A., Moore, C. D., & Driscoll, D. (2020). The environmental impact of rearing crickets for live pet food in the UK, and implications of a transition to a hybrid business model combining production for live pet food with production for human consumption. *International Journal of Life Cycle Assessment*, 25(9), 1693–1709. <https://doi.org/10.1007/s11367-020-01778-w>

23 Oonincx, D. G. A. B., & de Boer, I. J. M. (2012). Environmental Impact of the Production of Mealworms as a Protein Source for Humans - A Life Cycle Assessment. *PLoS ONE*, 7(12). <https://doi.org/10.1371/journal.pone.0051145>

24 Miglietta, P. P., De Leo, F., Ruberti, M., & Massari, S. (2015). Mealworms for Food: A Water Footprint Perspective. In *Water* (Vol. 7, Issue 11). <https://doi.org/10.3390/w7116190>

25 Alexander, P., Brown, C., Arneith, A., Finnigan, J., & Rounsevell, M. D. A. (2016). Human appropriation of land for food: The role of diet. *Global Environmental Change*, 41, 88–98. <https://doi.org/10.1016/j.gloenvcha.2016.09.005>

26 Halloran, A., Roos, N., Eilenberg, J., Cerutti, A., & Bruun, S. (2016). Life cycle assessment of edible insects for food protein: a review. *Agronomy for Sustainable Development*, 36(4), 57. <https://doi.org/10.1007/s13593-016-0392-8>

27 Alexander, P., Brown, C., Arneith, A., Finnigan, J., Moran, D., & Rounsevell, M. D. A. (2017). Losses, inefficiencies and waste in the global food system. *Agricultural Systems*, 153, 190–200. <https://doi.org/10.1016/j.agsy.2017.01.014>

28 Bawa, M., Songsermpong, S., Kaewtapee, C., & Chanput, W. (2020). Effect of Diet on the Growth Performance, Feed Conversion, and Nutrient Content of the House Cricket. *Journal of Insect Science (Online)*, 20(2). <https://doi.org/10.1093/jisesa/ieaa014>



Edible insects in Australia

Entomophagy (the eating of insects) has been practised in Australia for tens of thousands of years by many First Nations Peoples communities. Out of the 62,000 insect species native to Australia²⁹, more than 60 species^{30,31,32}, have been documented to be traditionally eaten by First Nations Peoples, including iconic species such as the witjuti grubs, bogong moths and honey pot ants. This unique cultural knowledge held by different First Nations communities could boost traditional ownership of bush food businesses, many of which have the potential to be co-developed into innovative businesses producing Australian branded products for the international market.

The Australian insect industry (including insects for human food, animal feed and upcycling of waste streams) is still considered as an emerging industry with a potential to reach or exceed \$10 million AUD per annum in the next five years based on a recent evaluation by AgriFutures Australia³³. Many early adopting insect start-ups, farmers and businesses have already established small scale insect farming processes and began developing entry-level food products made available to consumers online or in Australian grocery stores. The Insect Protein Association of Australia (IPAA) is currently the peak body representing the Australian insect industry, which is largely focused today on using insects for animal feed and upcycling of waste streams.

Australian consumer acceptance is currently low, which is expected for an emerging industry. Australian insect businesses have attempted to diversify revenue streams by exploring parallel markets, including the use of insects for human and pet consumption, production of alternative animal feed and the upcycling of food waste. However, growth of the Australian industry is slow as few businesses have reached commercial scale, and out of those selling edible insect products, most available products are derived from only crickets or mealworms. Therefore, a step change is needed to expand the market and realise the full potential of the emerging Australian edible insect industry.

Edible insects would complement, not completely replace, conventional animal proteins in modern diets.

2 billion people in 130 countries already eat insects.

The edible insect industry is well established and rapidly growing in Europe and North America. Close to 400 edible-insect-related businesses are operating in the western world¹⁶, producing a variety of products ranging from flavouring, confectionary, beverages and more substantial foods (Figure 4). Despite the global biodiversity of insects, with more than 1 million species occurring worldwide, only two types of insects have been successfully commercialised for human consumption: crickets and mealworms.

Farming insects has the potential to become a sustainable protein source (Figure 5). Insects are highly efficient in converting feed into food, with a conversion rate of approximately 50%, which means that they need about 2 kg of food to produce 1 kg of protein. At least 80% of the insect is edible, and they require reduced food and water inputs and the waste associated with farming insects is little¹². Although detailed information about the sustainability of insect production systems is scarce, early results are promising. Compared to mealworms, chickens require three times more land and emit 50% more greenhouse gases, and beef requires almost 10 times as much land and produces 18 times more greenhouse gases¹⁹. Furthermore, crickets can be reared in very small spaces (1 kg in 10 m²) and emit a similar amount of greenhouse gas emissions as mealworms. Compared to beef, both crickets and mealworms require less than a tenth of the feed needed for beef farming to produce the same amount of protein²⁷.

29 <https://www.environment.gov.au/science/abrs/publications/other/numbers-living-species/executive-summary>

30 Yen, A.L. 2009. Edible insects: Traditional knowledge or western phobia? *Entomol. Res.* 39(5), 289–298

31 Yen, A.L. 2005. Insect and other invertebrate foods of Australian Aborigines. In M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 367-387. Enfield, NH, USA, Science

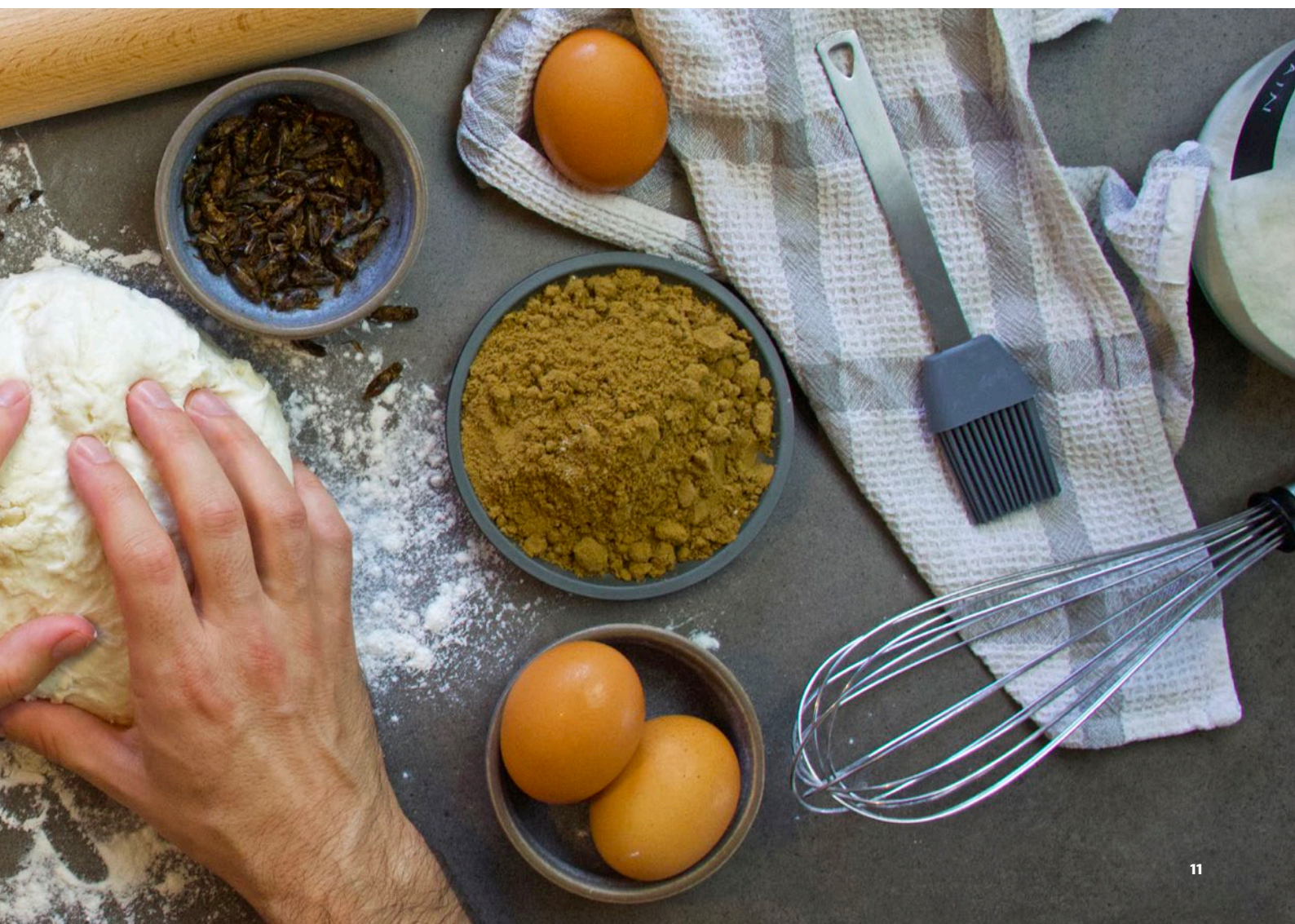
32 Yen, A.L., Gillen, J., Gillespie, R., Vanderwal, R. & the Mutitjulu Community. 1997. A preliminary assessment of Anangu knowledge of Central Australian invertebrates. *Memoirs of the Museum of Victoria*, 56: 631-634.

33 AgriFutures (2020) *Catalysing a \$10M Australian Insect Industry: an industry-led RD&E plan* AgriFutures Australia Publication No. 20-059



The Vision

To advance an inclusive, viable and sustainable Australian edible insect industry that supports the global market by forging new collaborations, sharing knowledge, delivering innovative processes and offering delicious Australian-branded insect products.



This roadmap intends to explore the current state of the Australian edible insect industry and required steps to achieve the proposed vision of a successful future industry.

The emerging edible insect industry provides us with a unique opportunity to strengthen Australia's position as a significant contributor to both the national and global food sector. Australia can elevate the industry to become more sustainable, strengthen cultural connections and contribute to improve modern diets by developing healthy, high quality and innovative, Australian-branded edible insect products. Co-developing First Nations Peoples owned and led initiatives will be critical to the success of the industry that has the potential to become a leader in creating new businesses that nurture people, land and culture, while helping to address the global challenge of achieving food security.

Call to action

Establishing new collaborations among First Nations Peoples and the research, government and industry sectors will help to overcome current global challenges and drive the edible insect market forward. In the past, such collaboration was usually represented with a 'Golden Triangle' symbolising the coming together of industry, government, and academia. However, to allow the emerging industry to succeed, it will be crucial to include First Nations Peoples throughout the entire process, from farming to commercialisation. Therefore, we propose the 'Golden Diamond' to include First Nations Peoples. Broadening inclusivity as part of a wholistic industry will enable each party to work together and contribute unique insights, areas of impact and solutions to the emerging industry to help solve some of the biggest global challenges, such as food security (Figure 6).



Figure 6: Call to action.

The ideas expressed here represent views collected during the ‘Developing Australia’s edible insect research and industry to improve environmental, health and cultural outcomes’ Cutting-Edge Symposium that ran from 28-30 August 2019 in Brisbane. The symposium brought together First Nations Peoples, insect farmers, edible insect product developers, researchers, and government workers to identify the key science, technology and business enablers, discuss current and emerging trends, and ascertain market opportunities and challenges.

We identified four impact areas in response to Australia’s competitive advantage in the emerging edible insect market (Figure 7):

1. strengthen culture
2. achieve sustainability
3. towards a healthier diet
4. support industry and decision makers.

To capitalise on these opportunities, businesses and the supporting food and agriculture ecosystem (industry bodies, suppliers, research, education, investors, and government) will need to invest in a variety of science, technology and business enablers to mobilise and elevate the national industry.

To maximise the benefit to Australia and the global market, we will need to develop new foods that are sustainable and highly nutritious, incorporate native species with a deep cultural value and long practise of being eaten by First Nations Peoples, and take full advantage of the technological advances and momentum already generated by the global industry.

The aim of this report is to catalyse new discussions, collaborations and actions among First Nations Peoples, and the research community, industry and government sectors to forge an inclusive, growth-oriented, and resilient Australian edible insect industry.

Impact area	Industry opportunity	Pathways to success
<p>Strengthen culture</p> <p>Co-develop First Nations Peoples initiatives and improve Western perceptions of edible insects to promote and advance the market.</p>	<ul style="list-style-type: none"> • Increase First Nations Peoples owned and led business initiatives. • New flavours, textures, and products. • Food experiences and culinary innovation. 	<ul style="list-style-type: none"> • First Nations enterprise collaboration. • Commercial insect farmers. • Consumer and marketing surveys. • Positive media engagement.
<p>Achieve sustainability</p> <p>Identify native insect species with minimal environmental footprints and develop low impact farming processes to create a truly sustainable industry.</p>	<ul style="list-style-type: none"> • Resilient and sustainable farming. • Native species developed into Australian branded products for national and global markets. • New foods for conscious consumers. 	<ul style="list-style-type: none"> • Develop native species already adapted to Australian climate. • Generate environmental footprint data for farmed species. • Monitoring and optimisation of farming practises.
<p>Towards a healthier diet</p> <p>Develop and incorporate easy to access and nutritious insect-derived foods into the Australian diet.</p>	<ul style="list-style-type: none"> • New alternative protein sources with high-value micronutrients. • Natural and nutritious food. • Supplements and fortified meals. 	<ul style="list-style-type: none"> • Nutritional data for native species. • Product development. • Consumer testing.
<p>Support industry and decision makers</p> <p>Forge new partnerships among First Nations Peoples and the research, industry, and government sectors to advance knowledge, procedures and policies and strengthen the industry.</p>	<ul style="list-style-type: none"> • Farming automation and upscaling. • Develop novel supply chains and species farmed. • International export of Australian products. 	<ul style="list-style-type: none"> • Collaborations among First Nations Peoples, researchers, industry, and policy makers. • New automated infrastructure and blockchain technologies for farming. • Standardise policies and guidelines. • Peak body to represent industry.

Figure 7: Impact areas, opportunities, and pathways to success for Australia’s maturing edible insect sector.



The Australian edible insect industry

Australia is well positioned to leverage its knowledge of biodiversity, research capabilities and industry experience to take full advantage of the emerging opportunities of the edible insect market.



Australia is presented with a tangible opportunity to become a key player in the global international edible insect market, offering innovative Australia-branded products and services. In addition to Australia’s favourable climatic conditions for insect farming, we have strong agricultural research capabilities, effective biosecurity measures and support of industry incubators and accelerators. Now more than ever is the time for Australian businesses, in conjunction with First Nations Peoples, researchers, industry and government to identify and invest proactively in new resilient markets, processes and products (Figure 8). Failing to do so could limit the economic value, job creation and global reputation of the Australian agricultural sector.

To become a successful industry, the sector must take a synergistic approach of developing a new generation of collaborative and shared business frameworks that are sustainable, ethical, and inclusive. By combining First Nations and Western knowledge, the industry will be able to share knowledge and develop best practices to protect First Nations intellectual property (IP) and create benefits for all involved.

Australia can leverage its iconic native species, First Nations Peoples led initiatives, agricultural innovation, and proximity to the Asian export markets to quickly expand the national market and support the global industry (Figure 9). To achieve this, foundational research is required to increase our



knowledge of the nutritional profiles of native species, environmental footprint of farming, and consumer attitudes, and innovate upscaled farming practices to drive consumer demand and build more resilient supply chains. By recognising risks and turning weaknesses into strengths, the sector can work together to create an inclusive, high growth and resilient industry (Figure 10).

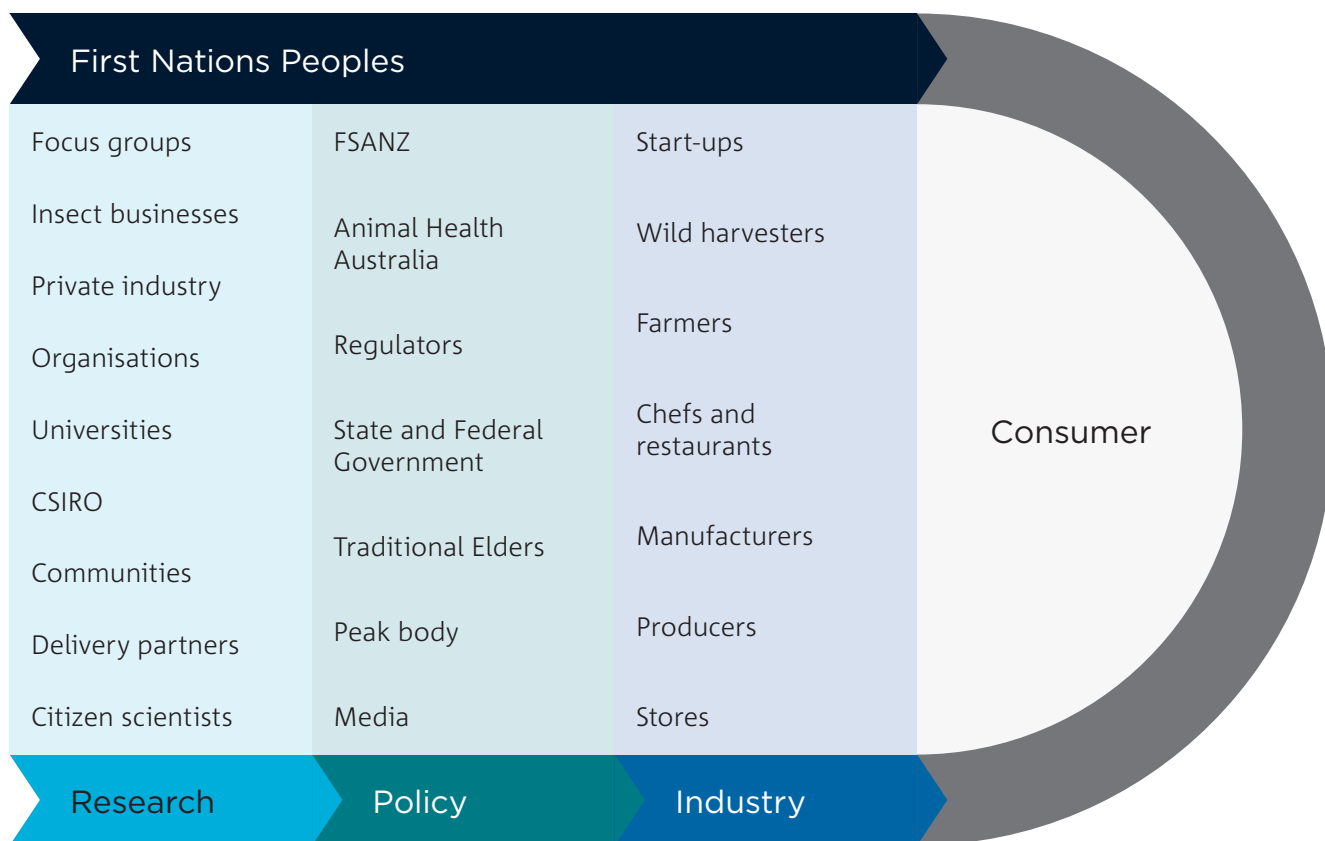


Figure 8: Ecosystem map of the Australian edible insect sector.

Australian insects are on track to become a

\$10M AUD

per year industry³³.

Edible insect products

are currently available at major Australian supermarket stores.

60+

native insect species are traditionally consumed by First Nations Peoples.

20%



of surveyed Australians would eat witjuti grubs³⁴.

Younger Australians

are more likely to eat edible insects³⁵.

54%

of Australians are worried about climate change³⁵.

In the last 20 years, growth in meat consumption

by 54% in China and 89% in Indonesia³⁶.

14 insect-based businesses already operate in Australia, including:

farmers

product developers

consultants

producers

chefs and restaurants

The average Australian eats more than

110 kg

of animal protein each year, including poultry, beef, pork, fish and sheep³⁷.

Figure 9: Australian edible insect sector snapshot.

34 Rich, B. R. (2006). A feasibility study into the commercialisation of Wichetty Grubs. A Report for Rural Research and Development Corporation. RIRDC Publication (Issue 06/109).

35 Sogari, G., Bogueva, D., & Marinova, D. (2019). Australian consumers' response to insects as food. *Agriculture (Switzerland)*, 9(5). <https://doi.org/10.3390/agriculture9050108>

36 Euromonitor 2018 The Rise of the Ethical Consumer

37 <https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/meat-consumption>



Green tree ants (*Oecophylla smaragdina*).

Strengths	Weaknesses	Risks
<ul style="list-style-type: none"> • Traditional usage by First Nations Peoples and biodiversity of Australian insects. • World class research and infrastructure in agriculture and biodiversity sectors. • Momentum created by ambitious early adopting insect businesses and farmers. • Global market demand for alternative proteins. • Agricultural innovation and proximity to Asian export market. • Ability of edible insects to withstand global disruptions in the food supply chain. 	<ul style="list-style-type: none"> • Limited knowledge on biology, nutrition, farming, production, and safety of native species. • Australian population may be too small to support industry itself. • Neophobia (fear of new foods) and misguided public perceptions of insects. • Current insect food product costs are considered expensive due to high labour costs. • Lack of farming automation limits scalability of industry. • Limited funding to advance industry. 	<ul style="list-style-type: none"> • Potential allergic reactions and sensitivities to shellfish and insect products³⁸. • Insects might carry biological and chemical contaminants or act as physical hazards affecting consumer's health³⁹. • Lack of funding, resources and buy-in from researchers, industry, and governments. • Potential for alternative plant-based foods preferred over insect derived products. • Media and community perpetuating insect stereotypes.

Figure 10: Summary of Australia's key current strengths, weaknesses, and risks in the emerging edible insect market.

38 Bose, U., et al. 2021. "Protein Extraction Protocols for Optimal Proteome Measurement and Arginine Kinase Quantitation from Cricket *Acheta domesticus* for Food Safety Assessment." *Food Chemistry* 348: 129110. <https://doi.org/https://doi.org/10.1016/j.foodchem.2021.129110>.

39 FAO. 2021. Looking at edible insects from a food safety perspective. Challenges and opportunities for the sector. Rome.

Australian insect collections as resourceful infrastructure

The CSIRO Australian National Insect Collection (Canberra, ACT) is the world's largest holding of Australian insects and other invertebrates. It houses more than 13 million research specimens and grows by more than 100,000 specimens each year. The collection is a critical resource of authoritatively named specimens used for species identification and molecular diagnostics, taxonomy, evolutionary biology, biogeography, ecology, natural resource management and biosecurity by its staff, Australian and international researchers, industry, government and university students. Each year, specimens are digitised and databased, with digital records served online through services such as the Atlas of Living Australia, and new species added the Australian Faunal Directory national species list. The Australian National Insect Collection joins other state entomological collections such as the Australian Museum, Museum Victoria, Queensland Museum, South Australian Museum, Tasmanian Museum and Art Gallery, and the Western Australian Museum working to strengthen our understanding of Australian biodiversity.



Challenges and opportunities

Strengthen culture

Co-developing First Nations Peoples owned initiatives, improving Western perceptions of edible insects, and developing innovative Australian-branded products and food experiences will be essential to drive the industry forward.

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SNAPSHOT

- Entomophagy has been practised by First Nations Peoples in Australia for tens of thousands of years.
- As younger Australian's become more worried about climate change, edible insects have the potential to become an environmentally sustainable and secure food source.
- Disruptions due to COVID-19 and climate change have raised awareness about the relationship between the environment, health, and food.
- Native edible insect species can inspire new and exciting Australian-branded food products co-developed by First Nations led initiatives.
- Positive stories about insect foods in media may assist to change consumer attitudes and incorporate edible insects into the Western diet.



The name **witjuti grub** (also spelled **witchetty** or **wichety**) is derived from the Pitjantjatjara language and has been loosely applied to more than 20 different species of moths and beetles³⁴.

Like many Western cultures, there is a growing disconnection between the way food is produced and the point of consumption. This is largely attributed to people becoming more time poor, industrialisation of food production, urbanisation and globalisation, as food items become more conveniently purchased from supermarkets instead of being sourced from where they are produced. Most Western cultures have developed an aversion for insects, perpetuated by stereotypes of insects being dirty, pests, dangerous, only eaten in times of desperation or having an inherent “yuk” factor. Therefore, one of the biggest opportunities in the industry will be changing the narrative about eating insects⁴⁰ by embracing untold stories of cultures where entomophagy is considered mainstream.

Native insects can provide new flavours, ingredients, and experiences for consumers with an increasing appetite for alternative, healthier and more sustainable foods.

As Australia’s first agricultural scientists, First Nations Peoples have a rich history of farming and harvesting native animal and plant species, including insects. Entomophagy by some First Nations communities is deeply linked to ancient cultural practises, as well as specific insect species such as bogong moths. Historically, up to 700 First Nations Peoples would gather during the summer in the mountain ranges of the Australian Capital Territory (Brindabella Ranges), New South Wales (Mt Kosciuszko, Bogong Peaks and Tinderry Mountains) and Victorian alps for the bogong moth harvest season. The bogong moths were harvested, roasted on hot ashes, and eaten by the communities, which enabled intertribal corroborees, feasts, marriages, meetings, and trades⁴¹.

Unfortunately, the increased adoption of Western diets by First Nations communities has led to the decline of traditionally practised entomophagy³⁰, which is often seen as outdated by the younger generations. Creating new First Nations led initiatives may be a way of ensuring that the cultural practises of entomophagy continue into the future.

Prioritising First Nations Peoples owned and led initiatives will improve knowledge and benefit sharing which will contribute to building an inclusive industry.

Embracing native species and establishing more First Nations owned and led initiatives is an exciting opportunity for Australia. By co-developing the emerging industry, we can create new Australian-branded food products and celebrate the long-practised tradition of eating insects to inspire more people to put insect on their plates. Any research and business development in this space will need strong First Nations leadership and guidelines to recognise traditional ownership of culturally eaten insect species and guarantee knowledge and benefit sharing of First Nations intellectual property. This can be done through the development of co-research agreements between First Nations leaders and collaborators, as well as working within the Nagoya Protocol to prevent biopiracy⁴².

The emerging industry should be at the forefront of protecting First Nations culture and ensuring that First Nations Peoples have tangible opportunities to lead business enterprises in a way that benefits communities and protects insect species with cultural significance.



The Bogong moth (*Agrotis infusa*).

40 Deroy, O., B. Reade, and C. Spence. (2015). “The Insectivore’s Dilemma, and How to Take the West out of It.” *Food Quality and Preference* 44: 44–55.

41 Warrant et al. 2016. The Australian Bogong Moth *Agrotis infusa*: A Long-Distance Nocturnal Navigator. *Frontiers in Behavioral Neuroscience* 10 (77) 1-17. <https://doi.org/10.3389/fnbeh.2016.00077>

42 <https://www.cbd.int/abs/>

CASE STUDIES

Traditional Owned Bush Products

Building the Traditional Owner-led Bush Products Sector in Northern Australia

Building the Traditional Owner-led Bush Products Sector in Northern Australia is a recent project funded by the Cooperative Research Centre for Developing Northern Australia and led by a First Nations Steering Committee. It provides a strategic framework to increase First Nations Peoples bush food initiatives in northern Australia, aiming to develop culturally appropriate business models to meet the needs of First Nations Peoples and secure co-benefits for commercially developed enterprises.

csiro.au/en/Research/LWF/Areas/Pathways/Sustainable-Indigenous/Indigenous-bush-products

Shared patents

Chuulangun Aboriginal Corporation

The Chuulangun Aboriginal Corporation and University of South Australia is a modern example for joint ownership of novel patents and products co-developed between First Nations Peoples enterprises and universities. Both parties were awarded a patent for the co-development of novel medicine derived from traditionally used plants. This patent protects First Nations intellectual property and ensures sharing of commercial benefits, as the Kuuku l'yu Northern Kaanju traditional owners are leading partners on the research and help decide how their knowledge is commercialised.

ipaaustralia.gov.au/tools-resources/case-studies/chuulangun-aboriginal-corporation-and-university-south-australia

Biodiscovery policy

Queensland Biodiscovery Act 2004

Queensland was the first Australian state to establish a Biodiscovery Act, which regulates the taking, analysing and use of native biological material. However, in its original form, it did not cover traditional knowledge and neglected First Nations Peoples from benefit-sharing negotiations. Therefore, it did not meet all the requirements established in the Nagoya Protocol, as only biological material from state land or waters were regulated. The Queensland Government recently acknowledged those deficiencies and reformed the Biodiscovery Act after widely consulting with First Nations Peoples, scientists and experts on intellectual property and First Nations rights.

Under the revised law, anyone engaging in biodiscovery must take all reasonable measures to form an agreement with the First Nations custodians of the traditional knowledge being used, including a benefit-sharing agreement. The Act now aligns to the Nagoya Protocol which is beneficial for those wanting to export products to Europe, where the protocol has been ratified.

The Queensland Government is also designing a “Traditional Knowledge Code of Practice” in consultation with First Nations communities and other experts to help the biodiscovery industry work more inclusively with traditional knowledge custodians.

First Nations initiatives

Aboriginal and Torres Strait Islander communities have strong connections to country and totemic relationships with certain plants and animals. In the last two hundred years, many native plants, animals, and other biological materials, along with traditional knowledge, have been taken without the consent of First Nations Peoples who rarely benefited from their development into commercial products. Such inappropriate usage may also lead to considerable spiritual harm of certain communities and perpetuate the social and economic injustices of colonisation. The emerging industry must set an example by honouring and collaborating with First Nations Peoples to strengthen knowledge and benefit sharing by developing First Nations owned and led initiatives, patents, and products to benefit all involved. In turn, First Nations Peoples long tradition of eating insects may help inspire the Western community to embrace edible insects as mainstream.

Western perceptions

Although entomophagy is well established in African, Asian, and Latin American countries, most Western countries seem to be more neophobic and hesitant towards eating insects. Australian insect businesses currently operating believe that: the industry is a long play and that entomophagy will become more mainstream in 10 years' time; edible insects should complement, not replace, modern Western diets, and; the gradual introduction of edible insect foods is expected to be the most successful way to increase consumer adoption.

Media and marketing

Positive and far reaching media strategies are needed to inspire new consumers to try insects and promote the emerging market. Future campaigns should adopt global trends (i.e. growing appetite for alternative proteins), promote the many cultural, nutritional and environmental attributes of the industry, and teach customers how to cook with insects as everyday ingredients. In order to avoid consumer confusion and highlight the diversity of products on offer, Australian edible insect businesses agreed that the sector should adopt a standardise terminology by: avoiding the term "bug" which may have negative connotations of disease, and; marketing products specific to the insect origin, similar to the meat industry's marketing of chicken, beef or pork products (i.e., cricket powder, roasted mealworm, black soldier fly oil etc.). Until consumer attitudes improve and the industry goes mainstream, some Australian insect businesses are focusing on promoting their own story, minimising insects in their promotional material or packaging. Servicing the export market may be an opportunity to rapidly grow the industry, as well as positioning insects as a natural complimentary animal protein food or ingredient (i.e. kangaroo and cricket meat sausages). Foundational research is needed to identify target demographics, consumer attitudes and optimal marketing strategies to influence consumer behaviours for positive change.

- Loss of traditional practises.
- Variable success in harvesting seasonal species.
- Limited engagement with industry.
- Uncertainty around implementation of Nagoya Protocol.
- Limited examples of knowledge and benefit sharing.
- Risk of cultural appropriation.

- Loss of connection with food origins.
- Changing consumer attitudes based on assumptions (i.e., taste, masculinity, neophobia, food conspiracy, and disgust).
- Australian consumer attitudes largely untested.

- Overcoming negative consumer attitudes and stereotypes perpetuated by media.
- Generalised terms often confuse consumers (i.e., word "bug" usually associated with disease).
- Addressing consumer concerns of food safety, taste, price, and access to products.

OPPORTUNITIES NOW (2021-2024)

- Involve First Nations Peoples at all stages.
- Model new co-developed enterprises on existing programs (i.e. Kakadu Plum).
- Provide training in business management to grow First Nations initiatives.
- Create First Nations owned trademarks.
- Strengthen knowledge of native species by bridging the gap between First Nations and Western science.
- Co-develop native species into new farmed lines and products.
- Develop framework to ensure First Nations IP is protected and guarantee benefit sharing.

- Identify target customers for all demographics (i.e., age, culture, religion, social background).
- Test public perceptions and experiences.
- Diversify edible insect products (i.e., snacks to staple meals).

- Refine messaging and adopt standardised terminology.
- Leverage consumer demand for products with environmental and health benefits.
- Deliver positive media campaigns featuring influencers (i.e. chefs and celebrities).
- Incorporate other native Australian ingredients and flavours (i.e., lemon myrtle).

OPPORTUNITIES AHEAD (2025-2030)

- Successful First Nations owned and led businesses delivering to a global market.
- Innovative native species-based food products.
- Strengthen linkages, knowledge and benefit sharing among Golden Diamond members.
- Promote respect for First Nations traditions and cultures.
- Diversify income for regional areas.
- Develop better legal protections for traditional knowledge.

- Edible insects become a staple of the Australia diet.
- New Australian-made products exported globally.
- Improve consumer connection to food origins.
- Embrace consumer feedback to create new and exciting products and food experiences.

- Drive culinary innovation by incorporating insects into high-value food.
- Foster public acceptance and positive experiences.
- Increase market share of Australian made and owned products.
- Expand First Nations owned products inspired by culture and regions.

Questions and considerations going forward

- Identify First Nations communities willing to participate, provide business management training and co-develop and promote First Nations owned and led initiatives.
- Identify native edible species recognised by both Traditional and Western science.
- Work with First Nations Peoples and advisors to adopt best-practise for communication, outreach, marketing, and business management.
- Conduct foundational research on consumer attitudes for all demographics to identify key target markets.
- Use consumer data to focus efforts in creating promising new foods (i.e., whole insects vs. incorporating insects into existing foods like burger patties, flours etc.).
- Create dynamic stories about insect foods and businesses that can be widely communicated via popular media.

Challenges and opportunities

Achieve sustainability

Identifying and developing native insect species already adapted to the Australian environment into low impact farming processes will achieve a truly sustainable industry.

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SNAPSHOT

- Our unique insect biodiversity can inspire a variety of new Australian edible insect products.
- Insects can help transform our existing food systems to become more sustainable overall.
- Farmed insects should have low environmental footprints and high nutritional values, including micronutrients not supplied in other animal or plant-based diets.
- Importation of foreign insect products may increase the carbon footprint but also pose a biosecurity risk to Australia.
- The true sustainability of the global industry is largely unknown due to significant knowledge gaps in life cycle analyses for farmed and native species.



The environmental footprint of a food product quantifies the amount of natural resource inputs, greenhouse gases emitted, and waste produced, from farm to fork.

Australia is a drought prone continent, as more frequent and extensive fire seasons are making it more difficult and expensive to produce conventional animal protein. Moreover, our current food systems are a major contributor to large environmental impacts, including biodiversity loss, greenhouse gas emissions, contamination and shortages of water, largescale ecosystem pollution, and land degradation. Climate change is also impacting on the quality and quantity of agricultural produce resulting in economic and humanitarian crises.

A sustainable food system ensures food security and nutrition for all, without compromising the economic, social, and environmental needs of future generations. However, our current food production systems and supply chains are not sustainable nor resilient. Resilient food systems have the capacity to achieve this same objective in the face of various and unforeseen disturbances including environmental (i.e., climate change), socio-political (i.e., pandemics) or economic shocks (i.e., global recessions).

To transform our existing food system to become more resilient and sustainable, we need to reduce the environmental footprint of our food products without losing nutrients. One way to achieve this is by diversifying our diets and maximising the consumption of foods with lower footprints. Insects are more effective at converting feed to body mass compared to conventionally farmed animals since they are poikilothermic or 'cold-blooded' animals. Producing insect protein usually requires less water, land and energy than producing a similar amount of other animal protein. Insects are high in protein and contain many other nutrients suitable for human food and animal feed. They can also be reared in small spaces, like industrial warehouses, so more protein can be farmed in urban areas closer to consumers.

Insects have been largely heralded as environmental saviours to the agricultural industry, however, there is limited knowledge regarding the life cycle assessments of commercially farmed¹² or native species. Of the two most globally farmed insect species, crickets appear to be more sustainable in terms of greenhouse gases emissions and lower feed, land and water inputs compared to chicken, pork or beef. Mealworms require less land and produce less greenhouse gases than chicken, however, both have a similar environmental footprint for feed, water and energy usage. Some insects are also known producers of methane⁴³, like cockroaches, termites, and scarab beetles, however, their energy inputs for

commercial farming (i.e., room temperature/humidity control) are unknown. Therefore, more foundational research is needed to assess the environmental footprint of each species being farmed to ensure a truly sustainable industry. Such assessments will be critical for the industry going forward to measure the environmental impacts along the supply chain and certify the sustainability of this industry.

Foundational research is crucial to assess the environmental footprint of Australian insect farms to build a truly sustainable industry.

One way of further minimise the environmental footprint of the industry is to use insects to upcycle clean waste streams that would otherwise go to landfill, thereby providing successful waste management solutions. Some insect species can be reared on pre-consumer organic waste to produce nutritious food and feed, however, such processes must meet state and federal regulations to prevent any potential contamination³² in humans and animals.

Insect species should be sustainably farmed instead of wild harvested, the latter of which may negatively contribute to biodiversity loss. It is imperative that farmed species are accurately identified by entomologists using reference insect collections (i.e., the CSIRO Australian National Insect Collection, Canberra, ACT). Each species has unique biology and energy requirements for farming, nutritional profiles for product development, and bioavailability of commercially desirable compounds for pharmaceutical development. The application of wrong species data may result in unwanted colony collapse, incursions of biosecurity threats and/or financial loss.

Certifying the sustainability of the edible insect industry will add value across the entire supply-chain, promote greater business differentiation and build resilience in times of uncertainty. This certification can be based on standardised life cycle assessments that are comparable between conventional and alternative foods. A life cycle assessment evaluates the environmental impact of a product throughout its entire life cycle: from the production of inputs (i.e. feed) to the agricultural farming process, consumption in homes or restaurants and finally waste disposal. These assessments are widely recognised and used for most food products and supply chains around the worlds²⁶. The following table summarises the challenges and opportunities that were considered as crucial to advance the Australian edible insect industry.

With more than 62,000 insect species formally described in Australia, there is an enormous potential to develop new edible insect species into Australian-branded products.

43 Hackstein, J.H. & Stumm, C. K. (1994). Methane production in terrestrial arthropods. *Proceedings of the National Academy of Sciences of the United States of America*, 91(12), 5441–5445.

CASE STUDIES

Native biodiversity

Rebel Food Tasmania

Rebel Food Tasmania are food industry innovators, playing on the consumers familiarity of existing products, such as peanut butter, and adding crickets, mealworms, or native cockroaches (marketed as 'woodies') to increase the protein content. The company aims to develop new ways to farm different insects with minimal environmental impacts by feeding them seasonal vegetables and clean pre-consumer food waste obtained from local farms and commercial kitchens.

rebelfoodtasmania.com

Environmental certification

ENTOTRUST

ENTOTRUST is an independent organisation that certifies the quality, safety and environmental footprint of edible insect food and beverage products. It provides international certification on the origin, sustainability, safety, and social fairness of edible insect products sold. Certified products are labelled with a seal of endorsement to indicate that the producer was able to satisfy a high level of standards. This model provides an existing framework that Australia could adopt to ensure that local insect producers are committed to reducing their environmental footprint, and in turn, promote a sustainable and equitable industry to consumers.

entotrust.org



Waste management

Goterra



Goterra is the first Australian company to employ automated insect farming to address waste management. By developing an automated and scalable system of modular insect farms, the company can process waste quickly and close to where it is being produced, therefore reducing transportation costs. Black soldier fly (*Hermetia illucens*) larvae are used to upcycle waste streams into high protein commercial animal stock feed (insect powder for non-ruminant farm animals) and high-quality soil conditioner (frass). In addition, Goterra is partnering with researchers to develop new methods of reducing plastic waste using black soldier flies.

goterra.com.au

Pest management

Pakistan Hi-Tech Feeds

Pakistan recently endorsed a plan to implement and expand a locust-based development project to several regions of the country where villagers are paid to collect, dry and shred swarming pest locusts devastating agricultural crops. Pakistani regions that were identified as being pesticide-free were selected for this program to ensure that the locusts were safe for consumption. The wild harvested locusts went to Hi-Tech Feeds, Pakistan's largest animal-feed producer, which substituted 10% of the soybean in its chicken feed with the insects. This project was based on a project in Yemen, where the government encouraged the community to eat the locusts.

CHALLENGES

Biodiversity

Australia is one of the most biodiverse countries in the world, with more than 62,000 insect species formally described. Many native species have the potential to be developed into new edible products, in addition to the 60 species already traditionally eaten by First Nations Peoples. However, there are still many knowledge gaps in terms of the number of edible species, their life cycle assessments, molecular identification, nutritional and safety data, and optimal farming conditions. New research in this area should be developed following the Nagoya protocol, to ensure a fair and equitable share of the discoveries' potential benefits with Traditional Owners.

Environmental footprint

Currently, the global environmental footprint of the livestock industry is high. In Australia, 55% of the land is used for grazing⁴⁵. Pastures and crops use about 90% of all agricultural water extracted⁴⁶ and contributes to 11% of the total national greenhouse gas emissions⁴⁷. From the 30 million tonnes of organic waste generated in Australia yearly, more than a third is livestock manure⁴⁸. Therefore, edible insects provide a unique opportunity to contribute to a more sustainable food value chain by reducing the environmental impact of food products.

Pest species

Incursions of pest insects, including the Australian locust or cotton armyworm, can negatively impact agricultural land and native biodiversity. Recurrent invasions of pest species are facilitated by increasing changes caused by climate, land-use and ineffective pest management. Farming pest or foreign species that are not yet established is undesirable as it threatens Australian biosecurity. However, wild harvesting established pest species that are safe to eat for humans and animals may be a novel, economically viable and chemical free approach to pest control.

- Less than 0.1% of native insect species are recognised as edible.
 - Few native species have known nutritional profiles.
 - The conservation status of many native species are unknown.
 - Limitations for wild harvested species due to complex life cycles and potential impact to populations.
 - Variation of Australian state biosecurity regulations.
 - Uncertainty of enacting the Nagoya Protocol across states.
-
- High environmental costs of farming and transportation of conventional meat products.
 - Conventional protein production is a major driver for deforestation, habitat loss and water consumption.
 - Agricultural systems may be threatened by climate change, animal feed shortages and pandemics.
 - Strain on waste management systems due to increase of organic waste produced by agriculture, hospitality, and households.
-
- Uncertainty of predicting pest invasions.
 - Short time frames to manage pest incursions before they become established.
 - Lack of knowledge of safety of consuming pest insects (i.e., heavy metals, pesticides, etc.).

44 Woodward, E., Hill, R., Harkness, P. and R. Archer (Eds.) 2020 Our Knowledge Our Way in caring for Country: Indigenous-led approaches to strengthening sharing our knowledge for land and sea management. Best Practice Guidelines from Australian Experiences. NAILSMA and CSIRO, Cairns, Australia

45 <https://www.agriculture.gov.au/abares/aclump/land-use>

46 <https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/latest-release>

47 <https://www.agric.wa.gov.au/climate-change/reducing-livestock-greenhouse-gas-emissions>

48 <https://www.environment.gov.au/protection/waste/food-waste/recovering-organic-waste>

OPPORTUNITIES NOW (2021-2024)

- New research to identify and develop native species feasible for commercialisation.
- Create a public database of native species authorised to be farmed or traded in Australia.
- Engage with Food Standards Australia New Zealand (FSANZ) to register commercially grown native insects.
- Improve state import and export regulations.
- Engage with First Nations communities to develop best practices for farming native species⁴⁴.

- Potential for insects to alleviate conventional animal supply chain disruptions.
- Reduce habitat clearing and lower transport footprint by developing new urban insect farms.
- Use standard life cycle assessments to quantify environmental impact of farming native insects.
- Reduce input costs by optimising farmed insect feed based on clean pre-consumer food waste streams.
- Implement best practises to minimise waste and pollution outputs.

- Develop more accurate models to predict pest invasions.
- Use cost-effective artificial intelligence and image-based technology to rapidly identify species.
- Invest in scalable, automated pest collection methods.
- Confirm safety of species by conducting chemical composition analyses.
- Investigate potential bioaccumulation of pesticides and heavy metals in pest insects and food derivatives.
- Operate within established biosecurity protocols (i.e., Department of Agriculture, Water and Environment - Biosecurity Act 2015).

OPPORTUNITIES AHEAD (2025-2030)

- Optimise and upscale production of native insects to develop new edible insect products.
- Build smarter value chains using DNA-testing and blockchain technology to trace products origin and protect from potential fraud.
- Work towards implementing the Nagoya protocol at a federal level.
- Ensure survival of threatened native species through controlled mass rearing.

- Build knowledge of life cycles and resource usage for farmed species.
- Shift to urban insect farms for food production, reducing land clearing rates and allowing us to rewild and restore native habitats.
- Develop assessment tools to compare environmental footprints and production costs of insects versus other foods.
- Lower agricultural sector's environmental footprint by encouraging the use of renewable resources.
- Reinforce a circular economy and improve waste management by upcycling clean food waste as insect feed.

- Automate detection, collection and testing of pest species for nutritional and safety profiling.
- Develop novel pest management systems that are effective and support economic growth.

Questions and considerations going forward

- Insects are currently exempt from ethics approval for research; however, this could change in the future if regulations are updated.
- Social and ethical considerations of potentially exploiting easy to access food sources for lower income communities (i.e., avoiding a similar situation with quinoa, where local communities could not afford the product after being sold to higher income countries).
- Foundational research needed on the environmental footprint of each edible insect species, including: resource usage (i.e., land, water, energy and feed); greenhouse gas emissions and waste production; amount of protein and nutritional composition by yield under differing feed inputs, environmental variables etc., and; production costs.
- How do improvements on the sustainability of beef production (i.e., feeding cattle seaweed to reduce methane production) compare to rearing insects?
- Determine what percentage of the protein in our diet can be derived from insects?
- Explore and incentivise the use of insects for waste management, including researching waste types (i.e., pre-consumer agricultural waste) that could be safely fed to insects, aiming to encourage circular insect farms, as well as alternative insect-derived bioproducts (i.e. biogas extracted from black soldier flies fed waste streams).

Challenges and opportunities

Towards a healthier diet

Edible insect foods that are delicious, nutritious, and easy to access will increase market uptake and help improve the Australian diet.

DRIVERS Prioritising health | Conscious consumers



SNAPSHOT

- Poor diets are causing many Australians to experience high rates of preventative diseases like obesity, diabetes, and cardiovascular disease.
- Eating insects could help combat human health issues, as insects offer unique nutritional attributes.
- Insects have the potential to be developed into new medicines.
- Whole insects and their derived products can contribute to a healthier, more balanced, and diverse diet.
- Edible insects can replace highly processed, low nutrient and high calorie discretionary foods.



Traditional diets are being replaced by modern diets, as they adapt to available foods and cultural practises in a particular region.

In many modern diets, the quality and diversity of food is often replaced by convenience, as we eat more refined sugars, fats, salts and processed meats than ever before.⁴⁹ This can result in preventable health issues such as malnutrition, obesity, diabetes and cardiovascular disease. Some existing public health problems have become exacerbated by the COVID-19 pandemic. For example, people with obesity and/or cardiometabolic diseases have shown higher fatality rates from the virus compared to people without⁵⁰.

Lifestyle change is the primary method for weight control, as obesity increases the risk for diabetes and cardiovascular disease. Research shows a moderate amount of protein

Edible insects and derived products can improve diet and reduce preventable health risks.

incorporated into every meal will help muscle metabolism and potentially make weight loss easier⁵¹. Integrating insects in the modern Australian diet has the potential to improve the intake of high-quality protein and other essential nutrients. Insects could also facilitate an even distribution of protein intake during the day, instead of concentrating most protein in one meal (i.e., protein consumption is usually low at breakfast and high at dinner).

The need for protein around the world varies depending on the region: low income countries need more protein to combat malnutrition, while high income countries like Australia need protein from healthier and more sustainable sources. A recent report⁵¹ on the Australian diet showed that most of our calorie and protein intake comes from discretionary food that are high in calories, but low in nutrients.

Australia can create new, exciting, and healthy insect-based foods inspired by our diverse traditional First Nations and multicultural diets.



49 <https://ourworldindata.org/diet-compositions>

50 de Frel, D. L., Atsma, D. E., Pijl, H., Seidell, J. C., Leenen, P. J. M., Dik, W. A., & van Rossum, E. F. C. (2020). The Impact of Obesity and Lifestyle on the Immune System and Susceptibility to Infections Such as COVID-19. In *Frontiers in Nutrition* (Vol. 7, p. 279). <https://www.frontiersin.org/article/10.3389/fnut.2020.597600>

51 Noakes, M, (2018) Protein Balance: New Concepts for Protein in Weight Management; CSIRO, Australia

CASE STUDY

Research consortium

GREEiNSECT (Denmark)

GREEiNSECT is a collaborative research consortium of universities and private partners aiming to mass produce selected insect species into a nutritious and protein rich food source for humans and animals. They investigated the technical aspects of developing insect mass-rearing systems in Kenya, their applications to food, nutrition, and feed security, and their economic and social impacts and acceptance.

One project in Kenya, Kenya, led by Dr Carolyne Kipkoech, explored the use of edible crickets to improve nutrition and health in children. Foundational research was conducted on the nutrient composition at different insect life stages, prebiotic potential of chitin from farmed crickets, and their effectiveness to improve human growth and haemoglobin and fatty acid levels. Results indicated that crickets harvested at 9-11 weeks of maturity had optimum nutritional profile, therefore these were used to enrich porridge and biscuits fed to children aged 3-5 years old children. It was found that not only did the children willingly eat the insect porridge, but their health improved overtime.

greeinsect.ku.dk



Integrating insects could improve the modern Australian diet and potentially contribute to better health outcomes, especially if edible insects replace discretionary food and other highly processed products. Insects are distinguished from other animal protein sources by having many unique nutritional attributes. Insects are high in quality protein with a full set of amino acids, omega-3s and 6s fatty acids, micronutrients (i.e., copper, iron, magnesium, manganese, phosphorous, selenium and zinc), and vitamins (i.e., ascorbic acid, riboflavin, pantothenic acid, biotin, and in some cases folic acid)⁵². Pilots studies have shown promising additional health benefits of eating insects, such as improved gut health by promoting growth of beneficial gut bacteria⁵³. New research is also exploring the use of insects as medicinal food provided under medical supervision for the dietary management of a specific disease, disorder, or medical condition⁵⁴.

Eighty percent of modern drugs are derived from or inspired by nature⁵⁵. Insects themselves are known to contain important substances with pharmaceutical potential⁵⁶. New research has shown that some grasshopper species have higher concentrations of antioxidants than in orange juice⁵⁷. Therefore, insects may be an untapped source for new drugs, supplements and desirable biocompounds such as enzymes and/or antimicrobials. However, there are still many knowledge gaps in terms of the nutritional profiles, medical potential and safety of most species, shelf-life of insect products, and digestibility studies and clinical research in humans.

The main challenges and opportunities to advance this industry are summarised in the following tables.

52 Rumpold, B.A. & O.K. Schlüter (2013) Nutritional composition and safety aspects of edible insects; *Mol. Nutr. Food Res.*, 57, pp. 802-823

53 Stull, V. J., Finer, E., Bergmans, R. S., Febvre, H. P., Longhurst, C., Manter, D. K., Patz, J. A., & Weir, T. L. (2018). Impact of Edible Cricket Consumption on Gut Microbiota in Healthy Adults, a Double-blind, Randomized Crossover Trial. *Scientific Reports*, 8(1). <https://doi.org/10.1038/s41598-018-29032-2>

54 Jeong, H., & Shin, K. (2020). What is required for edible insects to become medical food? From a health professionals and caregivers' perspective. *Insects*, 11(6), 1–15. <https://doi.org/10.3390/insects11060388>

55 Li, J. & Vederas J.C. 2009. Drug Discovery and Natural Products: End of an Era or an Endless Frontier? *Science* Vol. 325, Issue 5937, pp. 161-165 DOI: 10.1126/science.1168243

56 Roos, N., & van Huis, A. (2017). Consuming insects: Are there health benefits? *Journal of Insects as Food and Feed*, 3(4), 225–229. <https://doi.org/10.3920/JIFF2017.x007>

57 Di Mattia, C., N. Battista, G. Sacchetti, M. Serafini. Antioxidant Activities in vitro of Water and Liposoluble Extracts Obtained by Different Species of Edible Insects and Invertebrates. *Frontiers in Nutrition*, 2019; 6 DOI: 10.3389/fnut.2019.00106

Protein in the Australian diet

Most proteins currently consumed by Australians come from processed cereals (i.e., bread) and discretionary food sources (i.e., cakes, biscuits and pastries) instead of more nutritious and less processed options (i.e., dairy, eggs and meat). Many of these are not high in protein per se, but their protein contribution is significant because they are eaten in large quantities.

Nutrients and digestibility

Significant knowledge gaps exist on the nutritional profile of insects which vary depending on species, developmental stages, sex, diet, growth environment, and the analysis methods used. On average, the protein content of insects is higher than plant protein sources, including cereal, soybeans, and lentils⁵⁹. Some insects, such as, grasshoppers, crickets, and locusts, are particularly rich in protein, exceeding conventional meat and eggs⁶⁰.

Health

Some cultures around the world associate edible insects with health benefits beyond nutrition. Recent studies in China and Korea identified a blood-glucose-lowering compound in silkworm (*Bombyx mori*), which was recently developed into a medicine to treat diabetes. Similarly, new studies have shown that the wax moth (*Galleria mellonella*) and yellow mealworm (*Tenebrio molitor*) can both influence blood pressure⁶³, while some crickets and grasshoppers are high in antioxidants⁶⁶. Regarding traditional Chinese medicine, termites (*Macrotermes annandalei*) are thought to strengthen the immune system⁶⁴, with potential for Australian species to be developed for the export market. More research is needed to assess the medical potential of Australian native insects with co-involvement from First Nations Peoples.

Food safety

Allergens

For some people, insects can cause allergic reactions or sensitivities through contact, inhalation, and ingestion, potentially affecting consumers and insect producers. Insect allergens are currently considered similar to shellfish allergies and labelled as such on products sold to consumers. Grasshoppers, moths and silkworms are also known to cause respiratory sensitisation for some insect farmers.

Microorganisms and toxicity

Edible insects can act as vectors of microorganisms. Most of these are insect-specific and pose no serious risk to human health, however, some are pathogenic (i.e., *E. coli* or *Salmonella*). Potential outbreaks within farmed colonies are likely to increase with improper handling of insects or storage of products below optimal conditions. This can largely be avoided by following current hygiene, rendering and food processing standards to ensure that the edible insect products are safe to eat. Under state and federal regulations, it is prohibited to feed food waste to insects that are destined for human consumption, as these substrates may contain environmental contaminants (i.e., heavy metals, pesticides, and restricted animal material).

- Risk of not producing enough quality protein.
- Consumer attitudes are binary (i.e., conventional vs alternative protein eaters).
- Neophobic consumers unwilling to try alternative proteins.
- Current alternative protein products are highly processed and sodium rich.
- Exoskeletons contain a high proportion of chitin which is difficult to digest.
- Nitrogen content of chitin may lead to the overestimation of crude protein reported⁶¹.
- Conflicting reports on the health benefits of chitosan, a polysaccharide derived from chitin (i.e., indigestible antinutrient⁶² vs antioxidant and prebiotic that improves human gut microbiota⁵³).
- Limited knowledge of biochemical properties of insects for potential medical application.
- High cost and slow turnover for developing new medicines.
- More research is needed to identify and confirm the benefits of insects as health foods or medicines.
- Knowledge gaps on specific allergens and sensitivities caused by insects.
- Limited studies on microbial toxicity and bioaccumulation of pesticides and heavy metals for insects and feed sources.
- Lack of knowledge on the safety of native insects for food and feed.
- Need for standardised food safety and quality control aligned to existing government legislation⁶⁵.
- Lack of systematic work to guarantee safety and shelf-life of products⁶⁶.
- Some insect species act as intermediate hosts for parasites that may be potentially pathogenic to humans⁶⁷.

58 <https://www.eatforhealth.gov.au/guidelines/australian-guide-healthy-eating>

59 Bukkens SG. The nutritional value of edible insects. *Ecol Food Nutr.* 1997;36:287–319. doi: 10.1080/03670244.1997.9991521

60 Mlcek J, Rop O, Borkovcova M, Bednarova M. A comprehensive look at the possibilities of edible insects as food in Europe—a review. *Pol J Food Nutr Sci.* 2014; 64:147–157. doi: 10.2478/v10222-012-0099-8

61 Boulos, S., Tännler, A., & Nyström, L. (2020). Nitrogen-to-Protein Conversion Factors for Edible Insects on the Swiss Market: *T. molitor*, *A. domesticus*, and *L. migratoria*. *Frontiers in Nutrition*, 7. <https://doi.org/10.3389/fnut.2020.00089>

62 Schlüter, O., Rumpold, B., Holzhauser, T., Roth, A., Vogel, R. F., Quasigroch, W., Vogel, S., Heinz, V., Jäger, H., Bandick, N., Kulling, S., Knorr, D., Steinberg, P., & Engel, K. H. (2017). Safety aspects of the production of foods and food ingredients from insects. *Molecular Nutrition and Food Research*, 61(6). <https://doi.org/10.1002/mnfr.201600520>

63 Cito, A., Botta, M., Francardi, V., & Dreassi, E. (2017). Insects as source of angiotensin converting enzyme inhibitory peptides. *Journal of Insects as Food and Feed*, 3(4), 231–240. <https://doi.org/10.3920/JIFF2017.0017>

64 Kim, T. K., Yong, H. I., Kim, Y. B., Kim, H. W., & Choi, Y. S. (2019). Edible insects as a protein source: A review of public perception, processing technology, and research trends. *Food Science of Animal Resources*, 39(4), 521–540. <https://doi.org/10.5851/kosfa.2019.e53>

65 Han, R., Shin, J. T., Kim, J., Choi, Y. S., and Kim, Y. W. (2017) An overview of the South Korean edible insect food industry: challenges and future pricing/promotion strategies. *Entomological Research*, 47: 141–151. doi: 10.1111/1748-5967.12230.

66 van Huis, A. (2016). Edible insects are the future? *Proceedings of the Nutrition Society*, 75(3), 294–305. <https://doi.org/doi:10.1017/S0029665116000069>

67 Gatecki R, Sokoł R (2019) A parasitological evaluation of edible insects and their role in the transmission of parasitic diseases to humans and animals. *PLoS ONE* 14(7): e0219303. <https://doi.org/10.1371/journal.pone.0219303>

OPPORTUNITIES NOW (2021-2024)

- Identify nutritional profiles and desirable biomolecules of insect species.
 - Optimise combinations of nutrients and create new products optimised for health.
 - Conduct clinical trials to test health benefits of eating insects.
 - Develop and promote recipes to facilitate mainstream uptake of insects.
-
- Identify protein and amino acid composition for insect species.
 - Isolate and test beneficial compounds to develop fortified foods enriched by insects.
 - Identify optimal human digestibility of insects (i.e., whole, powdered or protein isolates).
 - Remove exoskeletons during processing to increase digestibility.
-
- Identify medicinal properties of insects and their impact on human health.
 - Develop functional foods based on edible insects.
 - Conduct research on health benefits of chitin-derived products to potentially improve human gut microbiota.
 - Determine optimal microbial and insect species to improve gut health.
-
- Identify allergens and effect of food processing on allergenicity.
 - Investigate similarities in insect and shellfish allergies to improve product labelling.
 - Explore cost-effective and viable pathways to remove allergens.
 - Evaluate safety of consuming native insect species.
 - Identify and remove potential pathogenic microorganisms to ensure food safety.
 - Update product labelling and conform to FSANZ guidelines to enhance food safety.
 - Optimise hygiene safety practises for farming insects.
 - Explore development of using clean pre-consumer food waste as feed for insects destined for human consumption.

OPPORTUNITIES AHEAD (2025-2030)

- Improve health by incorporating nutritious insect-derived products into the Australian diet.
 - Encourage different ways to eat insects (i.e., whole foods, complementing ingredients or supplements).
 - Include insects in staple products and promote consumption in the Australian Guide to Healthy Eating⁵⁸.
 - Personalised nutrition of insect-based diets to meet dietary and health needs of patients.
-
- Better understanding of insect protein and species nutritional profiles.
 - Develop new tasty products with improved health attributes.
 - Create nutritious fortified foods and supplements enriched with edible insects.
 - Improve the quality of protein consumed by Australians.
-
- Investigate impact of edible insects in the public health space.
 - Evaluate optimum prebiotic/probiotic ratio for insect products.
 - Develop new insect-derived pharmaceutical products to improve human health.
-
- Identify hypoallergenic insects and develop them into new products with reduced allergenic potential.
 - Improve farming practices to reduce potential allergies and sensitivities.
 - Boost consumer confidence by standardising safety regulations to ensure the quality of insect products.
 - Increase knowledge of microbial and toxicity accumulation across all stages of product development.

Questions and considerations going forward

- Reform of Health Star Rating labelling scheme, which currently disadvantages insects despite health benefits (i.e. Marco cricket powder is only rated 2.5/5 stars, despite being 65.6% protein and high in vitamin B12, Iron and Zinc and very low in sugars < 1%).
- Identify contaminants in food waste streams and explore potential of creating safe edible insect products feed pre-consumer food waste.
- Work with pharmaceutical sector to develop new medicines, probiotics and nutritional supplements derived from insects.

Challenges and opportunities

Support industry and decision makers

Forging new collaborative partnerships among First Nations Peoples, researchers, industry, and government bodies will advance our knowledge, procedures and policies to strengthen the industry.

DRIVERS Smarter industries | One world | Our changing planet



SNAPSHOT

- In the next five years, the Australian insect farming is estimated to be worth \$10 million AUD per annum³³.
- Fourteen insect-based businesses, farmers and producers are currently operating in Australia.
- Most existing insect businesses service the animal feed market worth \$875 million AUD annually in Australia³³.
- Covid-19 has impacted some insect businesses and potentially slowed market growth.
- New Australian-branded insect products will value add to Australia's current \$69 billion AUD in agricultural, fisheries and forestry production exports⁶⁸.

⁶⁸ Jackson, T, Zammit, K & Hatfield-Dodds, S 2020, Snapshot of Australian Agriculture 2020, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra. CC BY 4.0. <https://doi.org/10.25814/5e3a4ad8f80e7>



The world is constantly and rapidly changing. Understanding and making strategic decisions based on long-term fluctuations in the global market is critical for the success of new industries. At the same time, agile and flexible business plans to adapt to short-term variations in consumer preferences is also important.

Today, insect farming in Australia is in its early stages, with only a handful of insect farmers growing insects for human and animal food. Most insect farmers use manual processing techniques with high labour costs, which are reflected in the final cost of products that are considered too expensive for some consumers. This lack of automation prevents the industry from scaling up and becoming more affordable for mainstream adoption.

Developing automated farming will allow the industry to scale up, reduce labour costs and make products more affordable to help consumers incorporate edible insects into their existing diets.

Australian insect businesses are keen to turn native insect species into new and exciting edible products.

Modernisation of the agricultural sector has improved with automation and provenance tracking of farmed goods. These innovative technologies can be readily applied to Australian insect farming to upscale the industry and reduce costs to meet growing consumer demand. The new industry can also support, not compete with, existing supply chains (i.e. manufacturing, transportation etc.) developed by the conventional meat industry to enhance the agricultural sector.

Australia currently lags behind the European Union in terms of adopting and reforming policy to govern the insect industry. Australian state and federal policies are often variable and should be standardised to better reflect the nuances and needs of the Australian industry.

Under the current Australian novel food legislation (i.e., FSANZ), native insect species with a history of traditional usage are not considered novel or non-traditional food, and therefore may be fast-tracked for development. In other countries, novel foods may limit their market adoption as they require a slow, in depth and costly process to prove that the species has been used before and is not novel.



Farming black soldier flies (*Hermetia illucens*).

As more edible insect products are developed overseas and become mainstream, Australia is presented with a unique opportunity to co-develop native insect species with First Nations initiatives into new, high-quality Australia-branded products for the global market. Currently, there are no patents registered in Australia for edible insects.

The new industry will add value to Australia’s economy by generating new diversified revenue streams for insect-derived products, including new foods, pharmaceuticals, nutritional supplements, alternative animal feed and upcycling of food waste. Implementing the use of clean pre-consumer waste streams as feed input for farmed insects may become a viable, cost-effective, and sustainable action that saves the Australian economy \$20 billion AUD per year⁶⁹. This will allow Australia to become a major global player in promoting a circular economy.

Sustained investment will be essential throughout the supply chain to support new First Nations initiatives and other start-ups, farmers, producers, and researchers. These funds should support new staff, branding refinement, and innovative research and development to optimise insect farming, manufacturing, and product development. The industry must work together to proactively secure funding and/or in-kind support from investors, philanthropists, delivery partners (i.e. supermarkets and multinational food companies), organisations (i.e. the CSIRO) and government bodies to grow the national industry.

Future growth in a sustainable and high-value edible insect industry will be dependent on a whole of sector approach, combining First Nations Peoples, researchers, industry, and government sectors to drive the market forward. Fortunately, several platforms already exist to enable the timely dissemination of information, including general meetings of the Insect Protein Association of Australia and the peer reviewed Journal of Insects as Food and Feed.



Processing crickets (*Acheta domesticus*).

New products and services derived from edible insects

Farmed animal feed*

Nutritional supplements

Upcycling food waste

Increased entomology services

Reduction of plastic waste

Fertilisers

Bio-derived pharmaceuticals

Alternative pet food

Organic insect farms

*Note: current state and federal government restrictions prevent use of insects as feed for ruminant animals due to concerns of restricted animal material.

69 <https://www.environment.gov.au/protection/waste/publications/food-waste-factsheet>

CASE STUDIES

Everyday foods

Circle Harvest

Circle Harvest (formerly Edible Bug Shop) was established in 2007 by Skye Blackburn (Sydney, New South Wales) and is Australia's first insect farm for human consumption. The company farms and processes insects and creates edible insect products sold online and through commercial supermarkets, including Macro Cricket Powder available at Woolworths supermarkets. Skye and Circle Harvest are active in educating the general public on the benefits of insects as food through school visits, cooking demonstrations and media appearances.



Products sold: cricket (*Acheta domesticus*) corn chips, roasted crickets and mealworms (*Tenebrio molitor*), cricket and mealworm chocolates, cricket protein powder, cricket pasta, cricket dukka, granola with cricket powder, and ant (*Iridomyrmex rufoniger*) candy.

circleharvest.com.au

Protein

Grilo Protein

Grilo was established in 2015 by CEO Lucas Becker (Byron Bay, New South Wales) and focused on creating new cricket-based products marketed towards the lifestyle and health conscious consumer. Products were available online or sold in local Independent Grocers of Australia supermarkets in the Byron Bay area. Due to the limited availability of farmed insects in Australia, cricket (*Gryllobates sigillatus*) powder was imported from overseas suppliers. In January 2021, Grilo announced its decision to close the business to pursue other ventures.

Products sold: roasted crickets, cricket powders, seasonings and protein bars.

griloprotein.com.au

Restaurant provider

GrubsUp

GrubsUp was established in 2016 by Paula Pownall (Pinjarra, Western Australia) and sells edible insect products online and supplies ingredients to a range of cafes, restaurants and street foods in the Perth and regional Western Australian areas. Most insects sourced are imported from international suppliers (i.e., crickets).



Products sold: roasted crickets, roasted crickets in salt and pepper grinders, cricket dukkha, cricket powders and roasted mealworms.

grubsup.com.au

Traditional flavours

Something Wild Australia

Something Wild Australia was established in 2016 by the Motlop family of the Larrakia People, and is one of the first national Traditionally owned business supplying native plants and meats to restaurants and consumers around Australia, including lemon myrtle, wattleseed, kakadu plum and green tree ants (*Oecophylla smaragdina*). As the general manager and part-owner, Daniel Motlop and his team fosters positive working relationships by employing First Nations harvesters and staff.

Products sold: Something Wild collaborated with Adelaide Hills Distillery to create an award winning Australian gin infused with green tree ants wild harvested from the Northern Territory and other traditionally eaten plants like finger lime, lemon myrtle and native juniper (Boobialla).

somethingwild.com.au

Pet food

BuggyBix

BuggyBix was established by Shaun Eislars (Milsons Point, New South Wales) and is the largest provider of insect-derived products for the Australian pet food market, especially dogs. The main ingredients are black soldier flies (*Hermetia illucens*) and mealworms sourced from local Australian insect farmers, with products sold online.

Products sold: black soldier fly biscuits, mealworm biscuits, and kelp and black soldier fly or mealworm protein supplements.

buggybix.com.au



Nutrition consultation

Bug Me

Bug Me Entomophagy Nutrition Consulting Services is run by Nicole Senior and Jane Marriott who are two accredited nutritionists and practising dietitians. They offer consultation services to the community on incorporating edible insects into the diet and combine knowledge of nutritional science and culinary arts to promote edible insects.

Services offered: nutritional advice, technical and regulatory compliance, research, and recipe development.

bugme.com.au



Funding and policy

Australian insect businesses currently have limited resources and require seed funding, government grants and venture capital investments to create business plans and build capacity in farming, production, product research, development, and market analysis. Most farmers service the farm feed sector, considered an easy entry point, allowing businesses to build insect farming infrastructure that can be modified in the future when the edible insect market becomes mainstream. Current business efforts largely conform with existing state and federal policies that have been retrofitted for the agricultural use of insects (i.e., feed). Recently, Animal Health Australia worked with researchers, industry bodies and state governments to produce an updated national guideline to the use of farmed insects as livestock feed. Additional resources will be required to grow the Australian market, as well as standardising state and federal policies to regulate the industry.

Farming

Since there are only a few operating insect farmers in Australia, most insect producers and product developers import non-Australian insect species ingredients from overseas, including mealworms and crickets. Although this can be more cost-effective and takes advantage of species already successful internationally, importing foreign species may increase potential biosecurity risks and the carbon footprint of products, contradicting the sustainable image of the industry. Australian businesses are excited for the opportunity of developing native species into new products with lower environmental footprints, reduced biosecurity risk and high export potential. Some businesses are already sourcing wild harvested native green tree ants and cockroaches to create products available on the market. The current cohort of Australian insect businesses believe that there is room for more entrants to participate in the industry, due to the diversity of products, services, branding and personal stories.

Manufacturing

To seamlessly integrate into the existing food market, insect producers have been following current food safety protocols, including product processing, manufacturing and labelling (i.e., FSANZ), to ensure quality and safety. Many policy guidelines may need to be standardised at the state and federal levels of government. A major concern from businesses is that the edible insect market will not become mainstream until advances are made in production, product innovation and updating regulations to meet industry needs.

Marketing

The emerging industry must meet consumer expectations of being a healthy and sustainable market. Australian insect businesses currently implement unique marketing strategies to target different consumer demographics (i.e., adventurous, novelty eaters, “foodies” looking for a unique experience, or conscious of sustainability, nutrition and health and fitness). Most agree that their customers are more affluent who can afford the higher prices of introductory products. One business is differentiating itself by targeting the pet food market, selling a variety of black soldier fly and mealworm-based biscuits for dogs. Some businesses say that it is easy to get products in stores, but harder to get new customers to buy the products. Other businesses feel that to achieve growth in the market, insects must be downplayed in their packaging and marketing, which some interpret as a potential lack of pride in the industry. There also must be a clear differentiation for the use of insects for human food, animal feed and upcycling of food waste, to remove any negative connotations from the edible insect market. Wide reaching media campaigns, celebrity endorsements and advocacy by social influencers will help grow public interest in the market.

- Limited funding available for staff recruitment, infrastructure, and product development.
- Low investor confidence for businesses unable to measure production capacity, project yields or ability to generate new patents or IP.
- State and federal regulations need to be updated for insects as food and feed.
- Importing foreign species increases the carbon footprint and potential biosecurity risks.
- Limited knowledge of farming native species.
- Need for automation as costly production leads to expensive products.
- Unreliability of insect farming and potential financial loss (i.e., colony collapse).
- Need for improved knowledge sharing to support the industry, especially start-ups.
- Potential risk of contamination by microorganisms and heavy metals.
- Potential allergy concerns for people with sensitivities to shellfish.
- Market demand for biodegradable packaging without risk of product spoilage.
- Consumer confusion caused by mixed narratives of insects for food, feed and reducing food waste, with the latter two perceived as ‘dirty’.
- Most businesses minimise insects in product marketing, conforming to unconscious bias of consumers.
- Limited reach of grass-roots promotional campaigns by smaller businesses.
- Narrative that insects will replace conventional farmed animals may perpetuate perceived rivalry between industries.

OPPORTUNITIES NOW (2021-2024)

- Create new collaborative networks among Golden Diamond to advance investment, knowledge, procedures and policies.
- Attract funding for research and development, business development and improving infrastructure.
- Develop methods of estimating projected farming yields and costs to attract investors.
- Expand crowd funding opportunities.

-
- Document and characterise native species using national resources and research infrastructure (i.e. insect collections).
 - Establish native species for farming and product development.
 - Support conventional animal farmers by diversifying their business by including rearing insects.
 - Assemble a peak body to improve knowledge sharing and represent the industry to policy makers and media.
 - Develop automation to upscale, secure supply chains and drive consumer demand.
 - Enrich farmed species diets to optimise desirable nutritional properties (i.e., omega fatty acids, vitamins and protein).

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- Implement food safety and farming hygiene guidelines (i.e., International Platform of Insects for Food and Feed).
 - Consult with state and federal government to regulate industry.
 - Create effective biodegradable packaging to meet consumer demand and enhance sustainable image of industry.

-
- Promote insects as safe to eat and differentiate insect markets for human food, pet and animal feed, and upcycling food waste.
 - Develop products for all consumer access points (i.e., snacks for first time exposure to main dietary staples).
 - Target key consumer demographics (i.e., health and fitness minded, environmentally conscious, adventurous eaters, and early adopting younger generations).
 - Supply high value insect products and ingredients to producers, restaurants and chefs.
 - Create crowdfunded farming kits of edible species to encourage consumers to grow insects at home.
 - Aim for insects to complement, not replace, other farmed animals and support existing food supply chains.

OPPORTUNITIES AHEAD (2025-2030)

- A multidisciplinary market uniting First Nations Peoples, researchers, industry and government sectors.
- Creation of new jobs and maintained need for entomologists.
- Australian farming innovation of sustainable food production systems.
- Resilience of global food supply chain powered by insects.

-
- Upscale farming through automation to make products more affordable.
 - Industry adoption of native insects to expand product diversification with First Nations involvement.
 - Foster industry collaboration and growth to increase number of Australian insect farms.
 - New Australian made products for global export.
 - Build resilience in the agricultural sector by including insects in the food supply chain (for food and/or feed).

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- Diversification of affordable food products to consumers.
 - Drive innovation and adoption of novel Australian farming technology and sustainable packaging.
 - Take advantage of artificial intelligence, robotics, and e-commerce to improve productivity and reduce costs.

-
- Promote First Nations initiatives and co-developed native species products.
 - Drive market adoption by promoting key messaging around environmental and health benefits of edible insects.
 - Increase accessibility of high-quality insect products widely available in restaurants, supermarkets and online.
 - Move from edible insects as gimmick-based snacks to mainstream staples of the Australian diet.
 - Boost sales by promoting unique Australian made and owned products for global export.

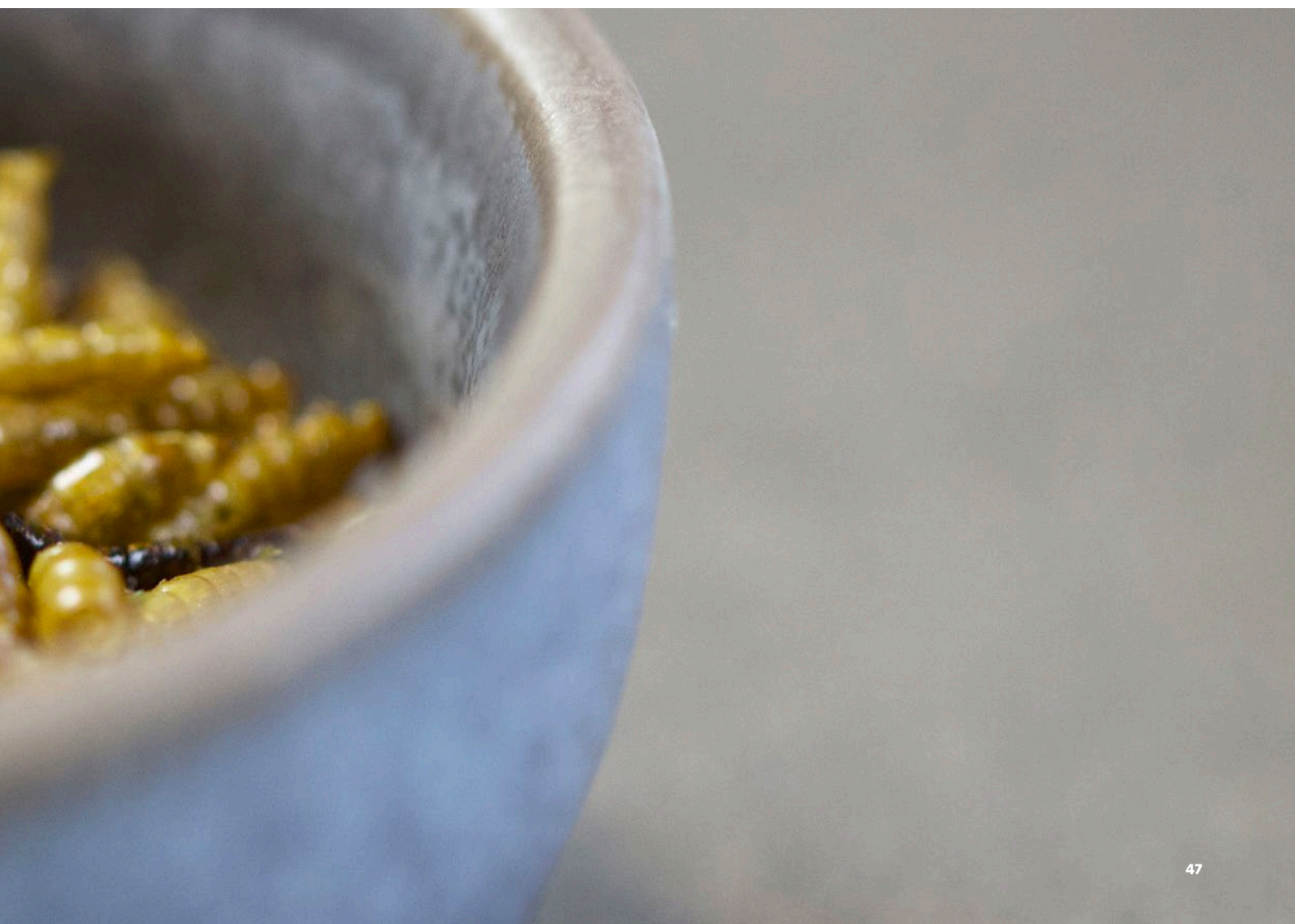
Questions and considerations going forward

- As the industry rapidly expands, so do the opportunities to develop insects into a diverse range of innovative products and services complimentary to food for human consumption. The ability for insect businesses to deliver into alternative sectors will increase market share and help to build resilience in times of uncertainty.



Enabling growth

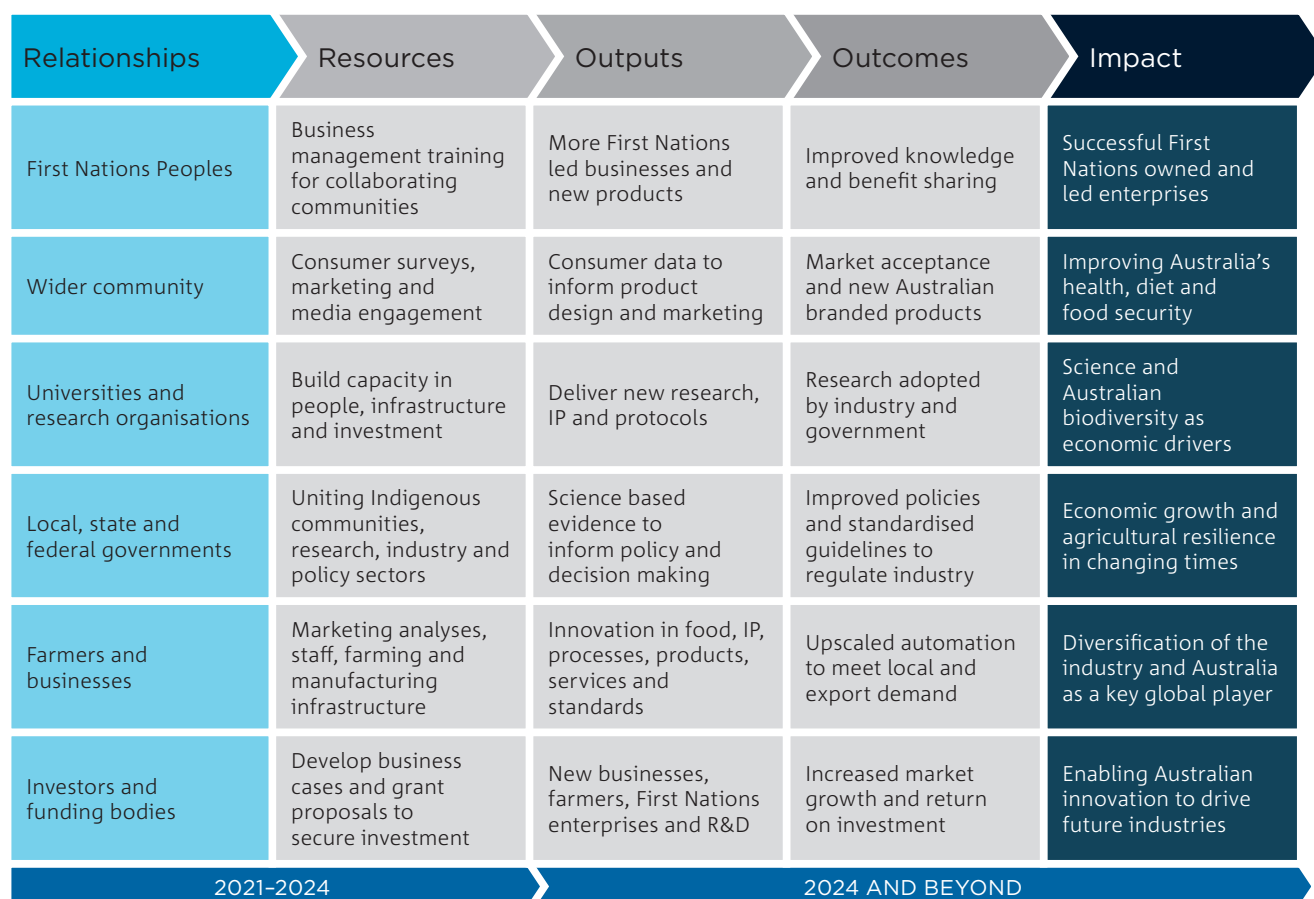
By leveraging collaborative relationships, securing investment and building capacity, Australian edible insect production and farming will grow to become a legitimate, economically viable and environmentally sustainable industry.



To enable strategic growth and create a diversified edible insect industry, collaboration and support among First Nations Peoples and the research, industry and policy sectors will be essential. Each sector will benefit from increased investment to expand industry infrastructure and staffing resources, ongoing promotion of the industry through wide reaching positive media campaigns,

and updated state and federal policies to create consistent, best-practise operating frameworks to strengthen the industry. As Australia embarks on this new frontier, the current energy and excitement shared by the industry will be advantageous to create exciting new products, processes, and policies for a sustained and resilient market.

The impact pathway to a resilient and sustainable edible insect industry in Australia



SUCCESS INDICATORS	ASSUMPTIONS	RISKS
Australian research output on edible insect industry.	Developing the market will drive consumer acceptance.	Consumers may prefer other alternative protein sources (i.e., plant-based).
Increased number of insect farmers and native insect species eaten.	The insect industry may be seen as a competitor to the conventional meat industry.	Local supply chains may not be robust enough to meet consumer demand and compete with cheaper imported products.
Increased number of outlets selling products.	Insects are more nutritious, sustainable, and cost-effective than conventional farmed animals.	Unexpected economic shocks may affect global supply chains, consumer attitudes and market uptake.
Increased number of food industries and products incorporating insects in their products.	Farmers will readily transition to farming insects.	Delay in automation may prevent upscaling and affordability of products.
Increase percentage of Australian's eating insects.	Continued growth in the agricultural export market.	International export relationships may be weakened in the future.



Actions

To achieve the desired impact and advance the cultural, environmental, health and diet, and commercialisation benefits of the emerging edible insect industry, Australia must commit to the following three actions:

- 1 Enabling science and technology**
Develop innovative multidisciplinary research and technology to enhance our knowledge.
- 2 Supporting industry**
Grow insect businesses that adopt new research, processes and technology to upscale production and drive market growth.
- 3 Informing policy action**
Provide science-based evidence to inform decision making to standardise regulatory processes and safeguard the quality of the market.

Strengthen culture

Enabling science and technology	Supporting industry	Informing policy action
<p>Linking First Nations initiatives and Western science. We must protect First Nations cultural IP and move beyond species identification by First Nations People to co-develop an inclusive industry. By developing enabling pathways involving ethics and patenting, better benefits will be gained for traditional knowledge sharing of culturally used species and practises of farming or harvesting species.</p> <p>Insights gained from focus groups. Conduct consumer research for each major demographic to identify the target market and help inform product development and marketing strategies. Focus groups will also help identify the most consumer-friendly language to use when describing and promoting products.</p>	<p>Co-develop the industry with First Nations Peoples. Establish new First Nations owned and led enterprises to foster an inclusive industry.</p> <p>Outreach and education. Promote outreach activities to educate school children, consumers, and hospitality professionals on the benefits of eating insects, including how to cook and prepare them. This will increase public acceptance and ultimately support market growth.</p> <p>Product development. Market diversification will be driven by competition among businesses as they look to differentiate themselves.</p> <p>Collaborate with influencers. Promoting edible insect with the support from celebrity chefs, fitness spokespeople, and other influential personalities.</p> <p>Australian-made native species. Leverage Australia's iconic branding by developing and promoting new native species and products for the national and export markets.</p> <p>Embrace market drivers. Promote the multi-faceted benefits of edible insects, including Australian made products for the export market, health benefits for wellbeing and fitness conscious consumers, and environmental benefits for sustainability minded consumers.</p> <p>Promote market through advertising. Once funded, the peak body (i.e., IPAA) should coordinate strategic advertising campaigns to widely promote the industry (akin to the viral lamb campaigns ran by Meat & Livestock Australia).</p>	<p>Establish new Australian networks. Foster knowledge sharing among First Nations Peoples, researchers, industry members, policy advisors and the general public through collaboration, conferences and public events⁷⁰.</p> <p>Establish collaborative workgroups. Forge new collaborative task forces among First Nations Peoples, researchers, industry leaders and policy makers to update current regulations to encourage a supportive and dynamic market.</p>

⁷⁰ Such as: IPAA AGM; AES; Insects to Feed the World Conference 2020 Canada, Journal Farm & Feed, Insetec 2019 FIST Brazilian Conference on EI Nov 6-8 2019.

Achieve sustainability

Enabling science and technology	Supporting industry	Informing policy action
<p>Increase investment and funding opportunities. Secure additional investment to fund co-developed First Nations initiatives, and start-ups, insect businesses and researchers to conduct novel research to fill knowledge gaps.</p> <p>Determine true sustainability. Increase value proposition by measuring the environmental footprint (i.e., methane and nitrous oxide production, water, and electricity usage), protein conversion rates, and climatic suitability of native species compared to other foods.</p> <p>Opportunities in pre-consumer food waste. New research is needed to determine if there are environmental, health and cost benefits of feeding farmed insect clean pre-consumer food waste destined for human consumption.</p>	<p>Develop resilient native species. Native species are already adapted to Australia's unique climate, have a suspected lower carbon footprint, and may not pose as high a biosecurity risk compared to importing products containing exotic species. Farming native insects is expected to be resilient during increased prevalence of droughts and pandemics, helping to secure the supply chain.</p> <p>Incentivise farmers and businesses. Increase funding and support for insect businesses, start-ups and farmers adopting more sustainable agriculture practices (i.e., solar energy, pre-consumer food waste, etc.).</p> <p>Collaboration with developers. Explore possibility of mechanically collecting pest insects during an incursion to be used as food or feed and contribute to novel economically viable pest species management.</p>	<p>Reward environmentally friendly farms. Create accreditation models rewarding farmers committed to lowering the environmental footprint of insect farming, reflected on product labelling (i.e. similar to the ENTOTRUST initiative).</p> <p>DNA based identification and blockchain technologies to certify and trace product origins. Adopting these technologies will help maintain a centralised register to identify species and trace their origins to combat fraud, mislabelling and species substitution in food safety surveillance systems.</p> <p>Towards meeting national environmental targets. Policy and decision makers should support research and farming optimisation for innovative food systems with low environmental footprints and promote their uptake by Australians to help meet national sustainability goals.</p>

Towards a healthier diet

Enabling science and technology	Supporting industry	Informing policy action
<p>Determine nutritional profiles. Most nutritional profiles of edible insects are based on foreign species. For this reason, new research initiatives would benefit by determining nutritional profiles of native species to identify highly nutritious candidates for farming.</p> <p>Quantify secondary compounds. New research is needed to quantify the bioavailability of desired minerals, vitamins and fatty acids in insects, as preliminary evidence suggest that insects are high in vitamins, omega fatty acids and antioxidants. Native species considered for farming should be profiled for such desirable and marketable compounds.</p> <p>Conduct digestibility and microbiome studies. It is currently unknown how much fibre is found in native insect species. New research on the digestibility of native species should be conducted to determine if their products can promote natural gut health.</p> <p>Monitor safety of products. Conduct research on potential bioaccumulation of contaminants in farmed insect lines (i.e. heavy metals, pathogenic microorganisms and antinutritional compounds).</p> <p>Enrich insect diets to optimise our own. New research and farming trials are needed to explore potential fortification of farmed insect diets to enrich for desirable and marketable characteristics for human consumption.</p>	<p>Lean into food trends. Increase market share of new products aligned to growing trends (i.e. alternative proteins, free from gluten, sugar free etc.).</p> <p>Combat malnourishment. Provide affordable supplements and fortified food products including protein, vitamins and minerals derived from insect products.</p> <p>New medicines and pharmaceuticals. Explore native insect species as a potential resource for new drugs, nutrients, and other desirable pharmaceutical compounds.</p> <p>Ensure quality control and standardised testing. Identify and adopt best food practises to test quality and potential contamination of insect derived products along the supply chain.</p>	<p>Update policies and regulations. Reform state and federal guidelines to include insects for human consumption. A new taskforce is recommended to identify the current knowledge gaps to improve existing state and federal policies for the anticipated rise of edible insect products for human consumption.</p> <p>Reform product labelling. Working closely with current labelling authorities (i.e., FSANZ and Health Star Rating scheme) to improve edible insect product labelling and advance market adoption.</p> <p>Develop best practice guidelines. Following a Hazard Analysis Critical Control Points (HACCP) plan to ensure processing and storage of insects and their products follow the same health and sanitation regulations for other foods to ensure microbiological and chemical safety. Due to the known allergic potential of insects, allergies and sensitivities should also be considered.</p>

Support industry and decision makers

Enabling science and technology	Supporting industry	Informing policy action
<p>Explore native species. By identifying and characterising their nutritional profiles and farming potential, novel species may be commercialised and brought to market.</p> <p>Prioritise knowledge gaps. Identify and prioritise key areas in need of research and development to improve farming processes, manufacturing, and production.</p> <p>Develop new ways to measure farming outputs. Creating new tools to predict farming yields will help insect farmers secure investment by venture capitalists and other funding bodies.</p>	<p>New standards for new species. Establish new farming practises for native species for commercial farming, including the transition from wild caught to farmed stock, growth optimisation and automated upscaling.</p> <p>Consistent farming guidelines. Create shared best practise guidelines and safe operating procedures on how to farm insects, allowing start-up businesses to easily enter the market.</p> <p>Securing accountability and transparency using blockchain technology. Assure traceability, quality, sustainability, and provenance of the industry by adopting blockchain technologies, especially for wild harvested species (i.e., ensuring First Nations involvement and protection of species populations).</p> <p>Knowledge sharing. Establish collaborative networks to share technical processes, IP, R&D, and funding opportunities, as well as providing staff training.</p> <p>Improve representation. Advance the current peak body (i.e., IPAA) to lead communication, information sharing and representation of First Nations Peoples initiatives, insect farmers, producers, sellers, researchers, and policy makers.</p> <p>Upscale farming to reduce cost. Artificial intelligence and automation of farming procedures will reduce costs and drive market growth.</p> <p>Value adding to other sectors. Allow the edible insect market to value add to existing agricultural sectors, including support to the conventional meat industry supply chain by using existing manufacturing and transport infrastructure, or as an alternative feed for farmed animals in times of drought or conventional feed shortfalls.</p>	<p>Update guidelines and regulations. Current regulations on the use of insects as livestock feed vary from state to state, with some jurisdictions allowing insect products to be fed to aquaculture and poultry, but not ruminant animals due to concerns of restricted animal material. These regulations are currently based on the European Union and will need to be modified to better reflect the Australian industry.</p> <p>Improve export regulations. Update regulations to improve understanding of restrictions for importing and exporting insect-based products across state and country boundaries.</p> <p>Provide new funding schemes. Expand government grant schemes and/or creating new funding opportunities to encourage start-ups and new businesses to enter the market and drive jobs and economic growth.</p>

CASE STUDY

The Insect Protein Association of Australia as a peak body

The Insect Protein Association of Australia (IPAA) is the national peak body for insect farming and promotes the use of insects predominantly for conventional animal feed. With more than 140 members, the IPAA provides a forum for collaborative networks among the insect industry and relevant stakeholders, including insect farmers, producers, sellers, researchers, and businesses. It provides support and advocacy for businesses interested or currently engaged in insect farming, establishes best working practises, and liaises with policy makers to provide evidence to inform state and federal standards and regulations. The IPAA offers open membership and shares information through its virtual annual general meeting, social media channels (Twitter @insect_au), website (insectproteinassoc.com) and popular media campaigns.



Insect Protein Association of Australia

Challenges

Like most associations, the IPAA would like to increase its membership and collaboration between members. The IPAA does not represent all insect farmers, as some do not see the value in joining the Association and remain “invisible” to the national insect sector. The Association is currently operated voluntarily or with in-kind support of staff provided by their respective businesses. Investment is sought to increase staffing resources to steer the Australian industry, run administration tasks, lobby governments, fund annual meetings, provide support for members and start-ups, secure grants and scholarships, and advertise to promote and expand the industry.

Moving forward

During the CSIRO Cutting-Edge Symposium, it was discussed whether the national insect industry be divided into separate markets of insects for human consumption, animal feed and upcycling of food waste. It was overwhelmingly agreed that the markets be unified under the existing IPAA, instead of forming a separate peak body for the edible insect industry. Some participants found the word “protein” in the name of the Association could limit future opportunities, and to better reflect the diversity of the industry, it was suggested that the name be changed (for example, the Insect Association of Australia). To demonstrate integrity with the Australian farming industry, it was suggested that the Association and insect farmers join the National Farmers’ Association to improve business operations of the animal food supply chain throughout Australian States and Territories.



Conclusion

Australia is presented with a unique opportunity to leverage its proven track record in innovation and agricultural success to strengthen collaborations among First Nations Peoples, researchers, industry, and the government to become a global player in the edible insect market.

First Nations owned and led initiatives will be vital to improve knowledge and benefit sharing, foster an inclusive industry, and co-develop native species into new Australian-branded products. Science and technology will be important enablers to upscale farming processes to meet market demand, reduce product costs and create exciting new products for global export. By building resilience, the edible insect industry will strengthen food supply chains throughout Australia and the world to help achieve food security in a time of changing climates, food shortages and emerging health crises.

Identifying market trends, consumer attitudes and key demographic targets will be essential for businesses to encourage consumers to adopt edible insects as part of the Australian diet. This will be achieved through ongoing education, positive media campaigns and foundational research to identify the nutritional and health benefits of eating insects, such as their use in combating malnutrition and other dietary-related diseases.

Insect farming will be vital to establish a truly sustainable and innovative protein supply chain with unique insect-derived nutrients that require minimal energy, water and land requirements compared to today's conventional food production systems. Foundational research on native insects will not only help improve our knowledge and the management of Australia's unique biodiversity, but also strengthen our national biosecurity.

Through collaboration, research and development, and further investment, insect businesses will be able to enhance their value propositions and develop innovative Australian-made products, processes, and services to successfully contribute to a growing, diverse and successful market.

This roadmap will help mobilise the emerging Australian edible insect industry by energising First Nations Peoples, researchers, insect businesses and policy makers to work together and drive the industry forward. By developing inclusive collaborative relationships, securing investment, and planning strategically, an innovative, resilient, and celebrated Australian edible insect industry will become a reality.

Participants

This roadmap would not have been possible without the invaluable input from the participants.



Participants of the CSIRO 'Developing Australia's edible insect research and industry to improve environmental, health and cultural outcomes' Cutting-Edge Symposium. Guests were encouraged to continue their discussions on social media using the hashtag #EatBugsAU.

Of the participants involved, the following people agreed to be personally acknowledged for contributing to this research:

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