Final Report

A scoping study to review fungi-based innovations to inform product development opportunities

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Project code:

MU20004

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A scoping study to review fungi-based innovations to inform product development opportunities (MU20004)

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Summary

Consumer interest in sustainable agriculture and plant-based dietary patterns, such as vegan, vegetarian and flexitarian diets, is growing. As a result, food product innovators and food manufacturers are increasingly investing in the development of meat-alternative product innovations that are appealing both environmentally and from a health perspective. To this end, mushrooms are uniquely positioned to address both key drivers, as their umami flavour has been shown to mimic that of meat, and mushrooms are one of the most sustainably farmed foods globally. In 2022 and beyond, the Australian mushroom industry has a great opportunity to consider engagement in plant-based food product innovation and other value adding activities with commercial benefits. However, in the current market, mushroom growers are predominantly focused on putting "fresh" mushrooms on Australian supermarket shelves, with only a few growers having experience in commercializing early-stage innovations, adopting novel technologies, or experimenting in businesses outside commercial mushroom farming.

In light of this, informing mushroom growers of existing global value-adding product opportunities that may unlock potential revenue streams and raise profit margins, in conjunction with raising per capita mushroom consumption, is an important step for the industry broadly. Hence, this project, utilising predominantly desk-top review methods and industry engagement, aimed to (i) identify "commercially ready" fungi-based global innovations and product development for Australia, from both waste and non-waste streams; (ii) better inform the industry of new market opportunities and their potential viability and feasibility in the Australian context.

This project yielded the following key outputs:

(1) A mushroom product compendium of over 180 products across 13 categories that can be used to inform the mushroom industry of the range and types of commercially available products, as well as highlight the key food categories where mushroom innovation is most active and by which major companies.
(2) Three deep explorations (case studies) of novel mushroom-based food innovation activities were conducted, identified to be of potential interest to mushroom growers by an Australian Industry Engagement Group consulted in the project. These case studies were as follows; powdered products, mycelium-based products, and the design of value-added products emerging from the FUNGUSCHAIN Project in Europe. FUNGUSCHAIN provided a platform for a range of mushroom functional bioactive components extracted through a cascading series of processing methods.
(3) For each case study, key insights and considerations for Australian mushroom growers were offered, encompassing technology, business, nutritional composition, food regulation and intellectual property issues where appropriate.
(4) Three novel food product concepts using *Agaricus bisporus* mushrooms to inspire mushroom growers interested in further exploring food innovation for their business.

Final recommendations for Australian mushroom growers who wish to explore value-add opportunities in the food innovation space, include:

1) Conduct innovation in the right way by engaging a multidisciplinary team that provides the necessary expertise and experience; involve funders who understand their own risk appetite, and who know how to mitigate project risk; and ensure a well-defined innovation process is followed.

2) Share commercial and financial risk through careful fostering of partnerships (public and private).

3) A key pillar of any future industry-focused or organisational decision-making should be based on comprehensive and up-to date information, hence it is strongly recommended that the mushroom-based

food product compendium is held in a central repository that is accessible to industry for use and that it is updated regularly.

Keywords

Mushroom; fungi; Agaricus bisporus; product innovation; product development; commercial opportunities; commercialisation; value addition; value added products; plant-based, vegan, vegetarian, meat-alternative, sustainable.

Introduction

Plant-based dietary patterns, characterised by higher amounts of whole grains, vegetables, fruits, legumes and lower levels of meat, are associated with reduced risk of developing chronic diseases such as heart disease, diabetes, and certain types of cancer [1]. Driven by these perceived health benefits, there is a rapidly growing consumer movement towards plant-based diets, both in Australia and globally [2]. This trend is contributing to a wider expansion of the global health food market, with plant-based food innovators now paying closer attention to nutritional quality and diversification of product offerings that can, in particular, replace meat in the diet [3]. As a result, meat-alternative product innovations are expanding and according to the latest Food Frontier report, *Meat the Alternative*, the alternative protein sector in Australia is expected to achieve $3billion in domestic sales by 2030 [4]. Consumers who are interested in plant-based eating are typically also concerned about environmental sustainability and sustainable food systems. Agricultural and processing methods that have fewer negative impacts on the environment are key to achieving greater environmental sustainability, and reducing waste is therefore paramount. Mushrooms are uniquely positioned to address both key drivers, as their umami flavour has been shown to mimic that of meat [5], and mushrooms are one of the most sustainably farmed foods globally [6].

These inter-linked trends, between health and environment, may present an opportunity for the Australian mushroom industry to engage in new product development utilising mushrooms, notably *Agaricus bisporus* (the most common variety in Australia, including the button mushroom, larger field mushrooms, Portobello and Swiss brown). According to the Australian Guide to Healthy Eating (AGHE, 2013) [7], mushrooms are classified as a vegetable, and thereby are considered to confer similar health benefits to plant foods in general, yet mushrooms are not found in a broad range of products on supermarket shelves.

In Australia, there are approximately fifty *Agaricus bisporus* mushroom producers who currently grow over 70,000 tonnes of mushrooms annually with a farm gate value of more than 440 million AUD [8]. The industry also produces approximately 20,000 tonnes of edible mushroom waste which is currently of negligible value and often bears a cost to the grower in its disposal [8]. Industry estimates suggest that 60% of mushroom biomass is left behind to be disposed of as compost material [9]. Moreover, there is negligible utilisation of mushroom off-cuts (such as stipes) in food products currently available on the market. The high cost of production, especially labour and compost inputs, represents a major cost driver for mushroom producers who have the same goal in mind: to maximise yield and raise profit margins. However, in the current market, mushroom growers are predominantly focused on putting “fresh” mushrooms on Australian supermarket shelves, with only a small number of growers having experience with the full scope of the commercialisation pipeline.

Informing mushroom growers of existing global value-adding product opportunities that may unlock potential revenue streams and raise profit margins, in conjunction with raising per capita consumption, is an important step for the industry broadly. The Australian mushroom industry has a great opportunity to engage in novel plant-based food product innovation and other value adding activities with commercial benefits.

Hence, this project aimed to:

1. identify “commercially ready” fungi-based global innovations and product development for Australia, from both waste and non-waste streams;
2. better inform the industry of new market opportunities and their potential viability and feasibility in the Australian context.

A further aim was to synthesise findings and make recommendations for Australian mushroom growers considering participation in food product innovation.

Methodology

This desk-top study involved an extensive, methodical review of the World Wide Web (www), grey literature and scientific publications, to identify existing "commercially ready" edible food product innovations containing fungi (specifically *Agaricus bisporus* mushrooms). Through this approach, relevant commercial, production, intellectual property and business considerations were also identified.

A mixed-methods approach underpinned six separate activities to achieve the objectives of this project. Methodologies ranged from desk-top research, critical appraisal and synthesis, feasibility and viability analyses, design thinking principles and importantly stakeholder engagement. To this end, an appropriate level of industry engagement supported this review across all proposed project activities, with input from an **Australian Industry Engagement Group (AIEG)**.

This engagement took place through an AIEG committee, and in some cases one-on-one interviews, leveraging the established connections and trust that the AMGA has with growers. The key aim of engagement with growers was to also identify the major hurdles/barriers either experienced or perceived in exploring new product development. This informed a set of insights that could be actioned in future work.

Activities:

1. Global review of commercially available fungi-based products and manufacturers
2. Case Studies (especially focused on sub-prime *Agaricus bisporus*)
3. Engagement: AIEG & solution providers including a review of processing methods
4. Key Risks: Hurdles, risk mitigation and opportunities
5. High-level intellectual property analysis
6. Ideate: Novel concepts for the Australian Market.

The methods underpinning each activity proposed in this project are described in more detail here:-

Activity 1: Global review of currently available fungi-based commercial products

Activity 1 involved an exhaustive global search of currently available, high-value mushroom-based products that have demonstrated a market locally in Australia, or elsewhere in the world. Activity 1 represented the critical initial task to be completed, and to which all other activities (numbers 2-6) were linked and/or built upon.

Methods:

- Desktop research (www; market reports; other grey literature; relevant past Hort reports) and search scientific literature to identify product concepts.
- Identified food concepts were collated in a compendium, title: *Mushroom Product Compendium 2021.* Identified food products were grouped into broad categories such as food service; health foods/nutritional supplements; meat-free products including mushrooms; meat-free products void of mushrooms; convenience products including fresh mushrooms. (Note: category labels were renamed in the compendium).
- Product name, manufacturer (company/brand name; country of origin), where product is sold and distribution channels, packaging details and company website (where information on current retail process and ingredient information could be sourced by the end-users of the compendium).
- An AIEG committee was established, mainly to address activity 2, but also to determine what growers have already tried in relation to food innovation activities, which relates to Activity 1 more specifically. After establishing the AIEG committee, it was decided that this committee provided ample advice and recommendations towards the project, hence an IEG committee was not required.

Activity 2: Case Studies

The top 3 opportunities that emerged from Activity 1 were subjected to detailed analysis via the generation of case studies, encompassing information on nutrition, food format, market opportunity and technology**. AIEG** committee engagement was essential in the determination of viability and feasibility for all opportunities sourced, as well as the identification of the top 2-3 opportunities.

Methods:

- Desktop research (www; market reports; other grey literature; relevant past Hort reports) and search scientific literature to identify product concepts, focus includes nutritional and technological opportunities.
- Synthesis and generation of communication materials for the engagement of AIEG
- Conduct meetings with AIEG committee (virtually due to COVID-related restrictions)
- Creation of 3 detailed case studies

Activity 3: Engagement: AIEG and solution providers to review processing methods

Methods:
Conduct desktop research (www; market reports; other grey literature; relevant past Hort reports) and search scientific literature to identify product concepts. Engagement with equipment manufacturers to understand options, cost and supply arrangements. Conduct meetings with AIEG committee (face-to-face or virtually).

Activity 4: Key Risks: Hurdles, risk mitigation and opportunities

Identification of specific operational requirements, licences, supply/distribution chains, required relationships/ partnerships, and specific food regulation considerations.

Methods:
Synthesise feedback and insights from AIEG meetings and other communications; market reports; other grey literature; relevant past Hort reports and search scientific literature to identify product concepts of interest. Identify any relevant nutrient and health claims on non-Australian products identified in Activity 1 - assess transferability to the Australian regulatory environment (appraise against the Food Standards Code, FSANZ).

Activity 5: High level Intellectual property analysis

This analysis will identify any potential blockers or opportunities for Australian businesses to exploit any of the products identified in Activity 2.

Methods:
Conduct searches on WIPO and IP Australia databases.

Activity 6: Ideate: Novel Concepts for the Australian Market

One concept will be designed and refined for each of the 3 largest product categories identified in the product search (retail – convenient snacks; health; food service). Consideration to key issues and leverage points for mushroom innovation (summarised in Appendix A) was given during concept creation.

Methods:
Conduct a structured ideation session with 3 participants who demonstrate an interest in mushroom-based food products and with some background knowledge of the mushroom industry to ensure concepts will have greater relevance to mushroom growers. The presentation slides used to guide the ideation session are in Appendix F.

Outputs

Written report:

Findings from all activities conducted in this project are summarised in the present written report. The completed report and compendium will be uploaded to the AMGA website and on the AMGA Digital Document Library for members to access via the online portal. All levy payers and stakeholders will be invited to a webinar to present the report. This will enable levy payers to access their levy funded report easily – providing transparency for levy funded projects. The Webinar will take place post-final report – in 2022, and will be run by AHR, who run webinars for the mushroom industry.

Publications:

A non-confidential version of the report will be published in the industry's communication publication, the Australian Mushrooms Journal. In September, an article titled "Scoping Global Innovations" was published in the Australian Mushrooms Journal (Issue 3, 2021) covering the proposed project and its aims and potential benefits to the industry (see full article in Appendix B).

Specific outputs for each activity conducted in this project are summarised here:

Activity 1:

New knowledge on currently available fungi-based commercial products in Australia and around the world emerged through the compilation of a mushroom product compendium (attached to this report as a separate document).

The compendium consisted of 180 plus products, across 13 food categories, containing the following information: product description, product and manufacturer name/brand, country of origin, and company url which offers the compendium end-users access to current information on manufacturer contact details, retail price, and product positioning.

The products identified were segmented into relevant categories i.e. Meat alternatives; Convenience meals (Ready to heat/ Ready to eat / Ready to Prepare); Soups/Stocks; Cooking sauces; Spreads; Condiments/Flavour enhancers; Snacks; Fresh and Preserved Mushrooms; Beverages; Dietary Supplements; Personal care.

An analysis of the representative sample of products in the compendium offered an indication of the prevalence of mushrooms currently available in different food product categories, as well as an indication of which product types use the most mushrooms by volume and the major food companies involved in mushroom product innovation.

A draft version of the compendium was also presented at the AIEG meeting and feedback was sought on its relevance to industry.

Selected Highlights from the compendium include:

- Mushrooms were most frequently found in the **'Meat Alternative'** category which consists of food products that are designed to look like their real meat counterparts e.g. sausages, mince, rissoles, muscle meat.
- Mushrooms were also commonly found in innovations that fit under the **'Ready to Heat'** category (e.g. microwaveable meals) or **'Ready to prepare'** category (e.g. foods that require a few additional ingredients and cooking prior to consumption (e.g. pasta meals and grain based meals).
- **Supplements** and **beverages** made from mushroom powder or extracts also featured highly in the review.

INSIGHT: Based on marketing and product positioning, *convenience* and *health* appear to be key drivers of food innovations using mushrooms (see Figure 1).

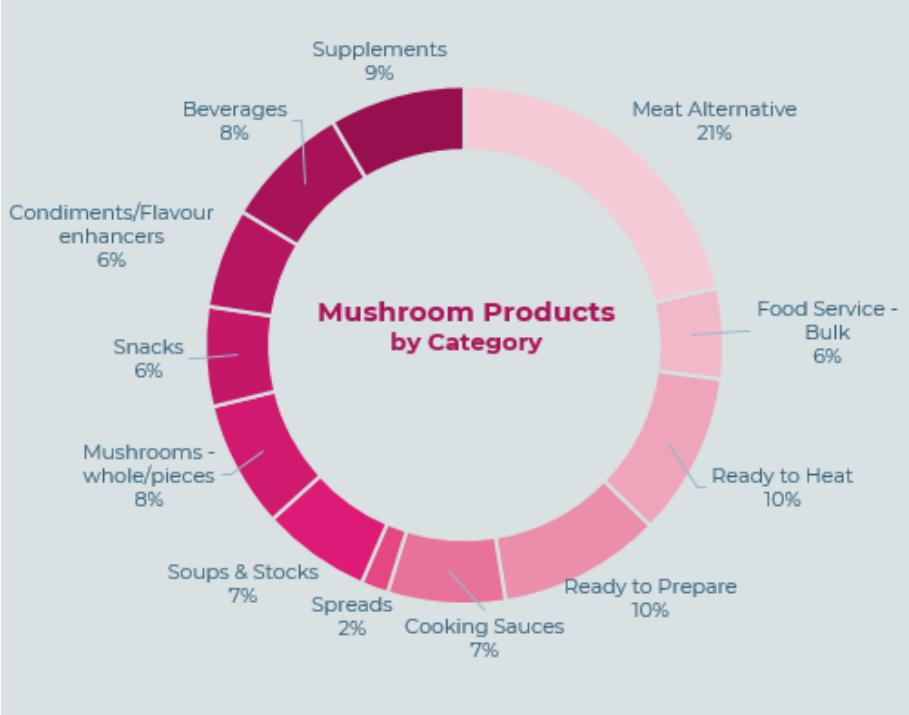


Figure 1. Mushroom products by category

- Formulations of 'meat alternative' products utilise the greatest quantity of mushrooms by weight, followed by snacks (such as crisps, jerky).
- Plant based meat alternatives is an emerging sector in Australia. In 2018-19, Food Frontiers estimated $150m in retail sales supported by 265 jobs in Australia. However, by 2030, modelling suggests retail sales could reach $3 billion and employ over 6000 Australians.

INSIGHT: Directing innovations to the meat alternative category may represent a sound investment decision (see Figure 2).

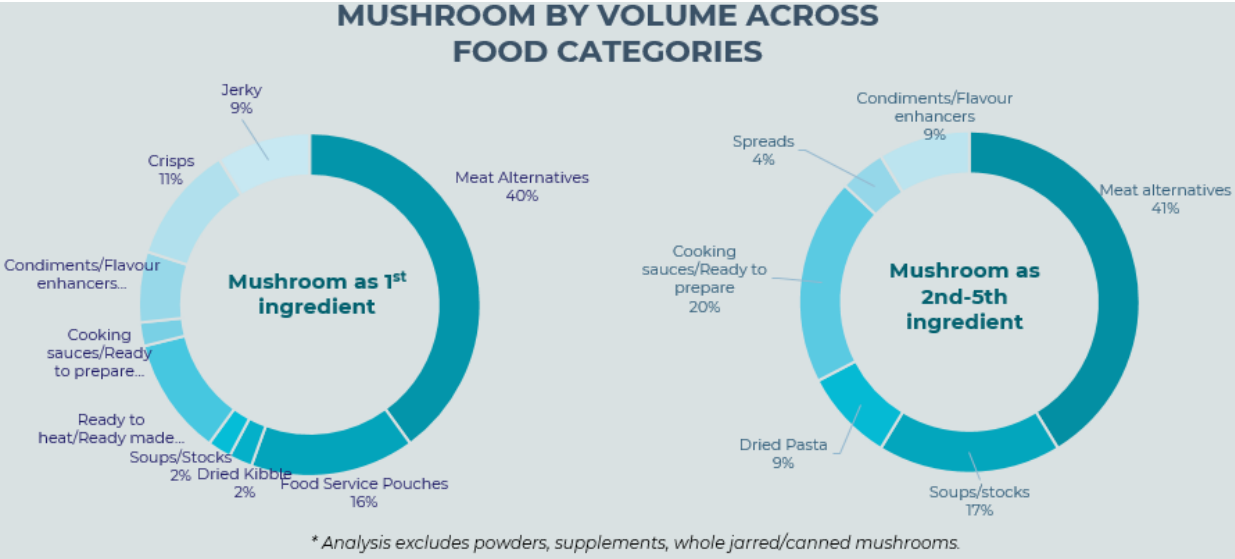


Figure 2. Utilisation of mushrooms by volume across food categories

- A number of companies are actively engaged in product development based on their different offerings, although it should be noted that these are not necessarily the highest revenue producers.

INSIGHT: Fable Foods (AU), Moving Mountains, Scelta, Monterey, Food Nation & Monaghan are **leading players in the mushroom food product innovation space. Lyfe Cykel (AU) and Four Sigmatic are leading players innovating products from powdered mushrooms, including *Agaricus bisporus* (Figure 3.).**

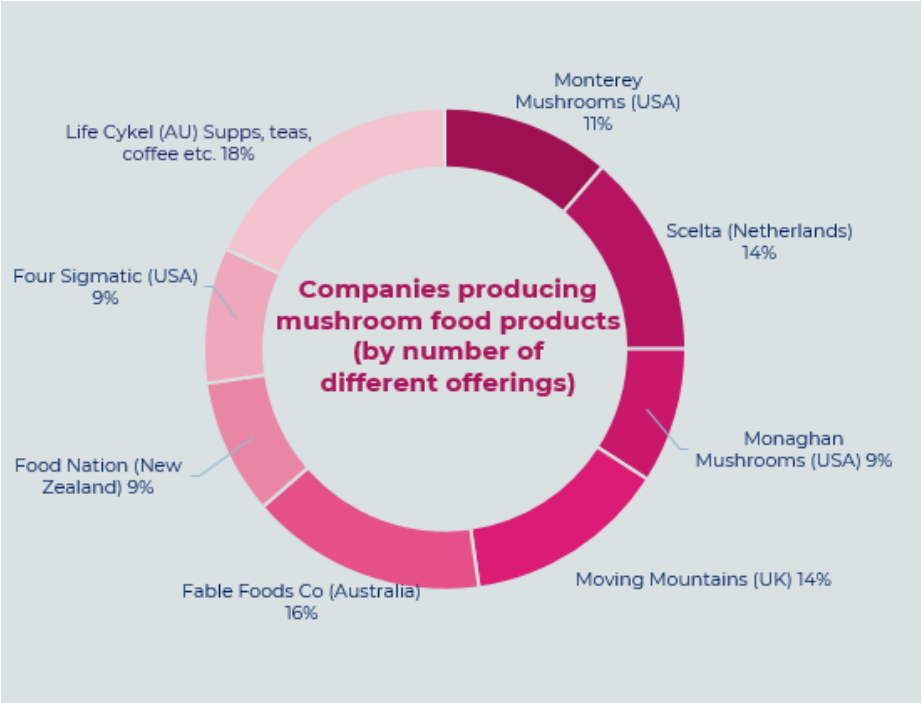


Figure 3. Major companies involved in mushroom product innovations

Observation and Recommendation

Industry feedback was positive on the compendium outputs:

"this is great. On a farm you forget what else is out there. Blue sky thinking. I'm open to anything you want to present in the future" **AIEG member**

"I agree - there is a lot of industry people who want to see this" **AIEG member**

The compendium represents a key piece of information for members, which should be monitored and updated at least on an annual basis.

Activity 2:

An industry assessment of all commercial opportunities identified for high value mushroom-based products (including waste and non-waste mushroom inputs). Based on the compendium, three representative case studies of potential opportunities for mushroom growers were identified. These case studies were designed to probe **what might be of interest to mushroom growers**, and like the compendium, they were presented at the AEIG meetings. Valuable industry insights were gained for each representative case study, helping to steer the future direction of the project (see Meeting Minutes in Appendix C). An overview of case studies can be seen in Figure 4, while detailed case studies can be found in Appendix D. The case studies were framed around the following opportunities;

Case Study 1

Selling sub-prime mushrooms to entrepreneurs engaged in creating value in the meat alternative food space, as one way that new products can be generated. Industry as a whole and individual businesses may want to consider investing money and partnering to develop and launch their own products. One example is Fable Food Co.

Case Study 2

A range of companies across the globe are being funded to set-up **fermentation processes to produce large quantities of mycelium for human consumption**. High protein whole-cut "meat-like" products can be made within 24 hours for the rapidly growing vegan and flexitarian consumer population.

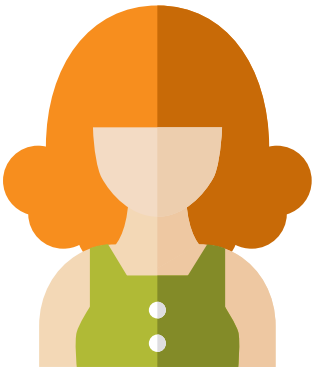
Case Study 3

In 2019, Hort Innovation invested in a proof-of-concept trial for a **powdered mushroom product**. The results were positive from a food quality and safety perspective, as well as a nutritional position and a technological and processing viewpoint. The opportunity for the Australian mushroom industry remains relevant today.

Figure 4. Overview of case studies presented to AIEG

Exemplar quotes from individual AIEG members are provided below, as are the group's collective decision regarding further exploration of the presented opportunity;

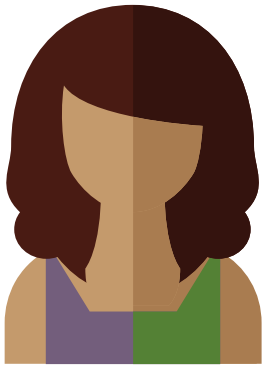
Case Study 1 Industry Feedback



- *"every farm for itself …there is no collaboration and [it is] hard to bring the industry in on partnering with companies like Fable."*
- *" AMGA doesn't get involved commercially …. every mushroom farm has spoken to Fable but can't get to the price. Also why use mushrooms? A meat alternative is soy….and it's cheap. If we could find a way to sell more mushrooms through alternative products in summer, I would be keen to hear more on this."*
- *"they are using imported mushrooms. The model isn't based on current mushroom prices…There isn't a lot of added value in this situation - there is a trend I agree, but I'd like to see where this goes. Commercial reality we haven't seen just yet."*

AIEG members recommended aborting further exploration of this opportunity.

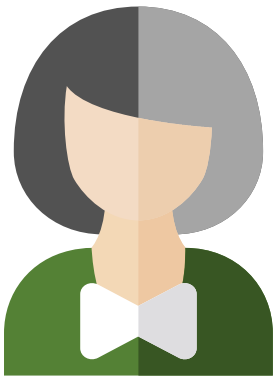
Case Study 2 Industry Feedback



- *"great idea – thumbs up – really exciting space"*
- *"exciting but I don't believe the mushroom growers will want to fund it – it will make mushroom farms redundant".*
- *"huge new market – it's not mushrooms growing though. New technology. I'd be surprised if this company is making any money on this yet – I don't think any of us have the funds. It would be good to see the figures. Meat alternatives is a massive growth area – add to reducing the carbon footprint etc …what's the capital cost? I'd like to learn more. I give this a green light".*
- *"what does this have to do with me being a mushroom farmer? I don't see the connection for us as selling fresh mushrooms - 10 years ago we were hounded to grow exotic mushrooms – it hasn't affected our sales at all. So I don't see this being a threat -Mycellium in packaging, that's interesting! but that's all".*

✓ **AIEG members recommended further exploration of opportunity.**

Case Study 3 Industry Feedback



- *"this is exciting. This is a practical outcome. Australian Mushroom powder almost makes it exportable -Vitamin D as well – this has some merit. The industry should have somewhere to sell their products when there is an oversupply….and their waste products"*
- *"it comes down to the economies of scale you need. Yes we all have mushrooms cheaper in summer but volume is the issue. It can have opportunity."*
- *"6% of a kilo left to then justify drying them than just selling them fresh. I love this space but getting peat off the stems, double cutting [is a barrier]".*
- *"[cannibalisation of the fresh market] is no longer an issue".*

✓ **AIEG members recommended further exploration of opportunity.**

New Case Study- The FUNGUSCHAIN Project

During the engagement meetings, the AIEG identified another opportunity that they would like to understand in more detail. This opportunity was the European Union's FUNGUSCHAIN project. The AIEG felt that this opportunity was particularly well suited to the Australian commercial landscape because the local industry experiences similar challenges in relation to producing large volumes of mushroom waste, driving a collective desire for opportunities that maximise waste bio-resources.

A case study for FUNGUSCHAIN was produced and can be found in Appendix E.

Fungus chain

✓ **AIEG members recommended further exploration of opportunity.**

Finally, the project team presented two additional concepts relating to packaging and new business models for the mushroom industry (as per Figure 5). Feedback was sought on these concepts to help determine whether these opportunities were worth exploring further in the project. No feedback or interest on these concepts was received, hence further evaluation of the opportunities was not conducted.

Figure 5. Additional opportunity concepts presented at the AIEG meeting.

Activities 3-5:

Outputs of activities 3-5 for each of the industry-selected case studies are reported in this section.

This section provides an informed narrative for each of the case studies of interest (Activity 2) as assessed through the lens' of business viability, technical feasibility, and other considerations such as intellectual property and food regulations. In reading this section, it is important to consider the following; (i) the objective was to present opportunities via desktop research that warrant further investigation as a potential worthwhile business opportunity for Australian mushroom growers, and (ii) the suitability of the opportunities presented will depend on the nature and risk profile of the individual mushroom growing business. This report does not constitute investment advice.

Mycelium Opportunities

- There are many companies that are seeking to exploit the meat alternative market opportunity by producing meat analogues from soy and pea protein. Mycelia offers a different food platform that Australian mushroom growers have expressed interest in due to its obvious connection with commercial mushroom growing. Two US-based companies are key companies in this area that have raised investment funds; ATLAST Food Co. (LLC) and Meati (LLC). Further investigation in this report will focus on the ATLAST Food Co.

- The ATLAST Food Co. (LLC) uses Solid State Fermentation (SSF) to grow mycelium into any desired shape. This farming process is often referred to as “aerial mycelium”. Unlike other plant-based meats, which are extruded and highly processed, the ATLAST process forms a whole structure that requires minimal further processing and uses negligible water. Noteworthy, and discussed further in this section, is the fact that mycelium is grown in beds of similar dimensions to current mushroom growing beds.

- Meati (LLC) uses submerged fermentation (SmF) indoors in stainless steel tanks. Water, sugar and selected nutrients are added to promote growth, and the mycelium is harvested in batches in a similar way to cheese production.

Which production method is best – SSF or SmF?

The documented advantages of the use of SSF over submerged fermentation is its simplicity, low energy requirements, and higher volumetric productivity[1]. On the other hand, environmental conditions in a solid environment can potentially be more difficult to regulate. Currently, both SSF and SmF techniques offer commercially viable options to grow mycelium. One method may present clear commercial advantages over the other, which may also be dependent on the desired characteristics (e.g. texture, profile) of the final product desired.

[1] Fungal Solid state fermentation – An overview, GowthamanM.et al, Applied Mycology and biotechnology, 1:305-352.

The Atlast Food Co.[2]

- The Atlast Food Co. business model supplies mycelium slabs primarily business to business (B2B) as a food ingredient and was launched as a separate company from myco-materials pioneer, Ecovative Design[3]. Atlast Food Co. has recently taken its first steps into retail grocery stores through the MyEats™ brand, the company's consumer foods initiative.

- Atlast Food Co.'s first retail food offering is MyBacon. The company claims that the MyBacon product can mimic the texture of actual bacon much better than what is possible by isolating soy or pea protein and combining it with oils, the approach used by the leading plant-based burgers. The company claims that the MyBacon product is a patented food ingredient, although likely they are referring to a patent that describes the method(s) of growing mycelium discussed later in this section. MyBacon also has at least two registered trademarks in the USA (#90135656) in meats and processed food product category, and in the UK (#UK00003681382) in class 29.

- The Atlast Food Co. has a focus on food product development, regulatory approval and scale-up as its core competitive advantage. It is noteworthy that this focus is popular by incumbent food companies seeking to gain traction in the global meat alternative market[4].

- The Atlast Food Co. has a documented investment of USD 100 M in total capital raised to date compared to USD 700 M for Impossible Foods, one of the best-known meat alternative companies.

- The latest investment update occurred in April 2021 and was a USD 40M Series A round to develop and supply whole cut plant-based meat to partners around the globe, including directly to consumers through its own brand MyEats. Viking Global Investors led the round with participation from 40 North, AiiM Partners, Senator Investment Group, Stray Dog Capital, Footprint Coalition Ventures (Robert Downey Jr's sustainable investment vehicle), and others. Also joining funding were the leaders and founders of food and CPG companies, including Applegate, Stonyfield, and Whole Foods. This funding will support the further development and scaling of the technology and team.

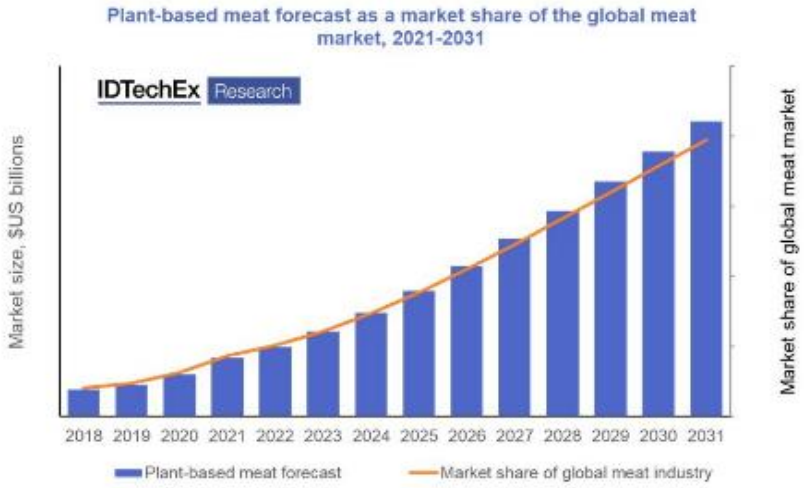
The Food Product and Target Market

[2] https://youtu.be/zmDENxTPn8Q?t=350 – At talk by Atlast CEO Eben Bayer

[3] Ecovative continues to focus on developing its mycelium into different materials like alternatives for styrofoam, packaging, skincare, apparel leather and engineered wood. The Atlast Food Co. is focused on food product development.

[4] Maker Of Mushroom-Sourced Bacon Raises $40 Million To Reach Grocers At Scale (forbes.com)

- Bacon might seem like a curious first product choice, however the company understands the popularity of bacon within its target geography of the US – USD 6.2 billion at U.S. grocers in 2021, up 21% in just 2 years according to NielsenIQ. Meatless bacon totaled just USD 37 million of that. IDTechEx Research forecasts plant-based meat to increasingly claim a larger portion of the global meat market.



- Price: Sold at $5.99 per 6oz (~170 g) package in the US, MyBacon is on par with other premium pork bacon but is not yet affordable for all consumers. As the MyEats brand grows, the company expects the price point to fall.

- Consumer feedback: “It tasted great, smelled great, even the smokiness of the cook was great. It doesn’t taste better than regular bacon, but then again, that’s not the idea. I think very few bacon-lovers would say the taste of bacon *can* be improved. When I fried up MyBacon for the first time, it did exactly what I’d hoped it would. The crunch, crisp, and savory flavor of bacon was there and no harm done to our planet, or my health.”

- According to AtlastFood Co CEO Eben Bayer, American’s love of bacon is stopping many consumers from going meat-free. “People’s love of bacon is one of the main reasons why they don’t adhere to a plant-based diet,” says Bayer. While the company has a clear drive towards sustainability, MyEats must also be competitive in cost and health. Pork bacon is very high in fat and low in other nutritional qualities. MyBacon offers a competitive alternative since both pork and MyBacon have about 30 calories a slice, however MyBacon has roughly half the fat[5].

Further Manufacturing Process Details (including intellectual property)

- The process has been designed to fit into existing white button mushroom farms with beds 30 meters long and 3 to 6 meters wide. This results in 30-meter-long slabs of mycelium meat that then get sliced into pork belly-like sections that can go into a high-speed meat slicer. Protein is the end-product, and it is grown to specifications for nutrition, texture, and flavour. It is then sliced and seasoned to the desired “meaty” results.

[5] More Bacon, Less Guilt - This Startup Is Taking On The American Classic (forbes.com)

Atlast's Mycelium (Image source: Atlast accessed at www.atlastfood.co/method)

- The mycelium fibers grow together in a tissue that resembles the fiber-like network of muscle tissues in animals (therefore mimicking its texture as well). From spore to slab, the entire process only takes 10-13 days, following these three steps: -

  Seed: Seed edible oyster mushrooms into trays filled with a nutrient rich medium to grow mycelium.

  Grow: The trays are placed into vertical farms that simulate the same conditions that mycelium grows underground (hence the term 'aerial mycelium').

  Harvest: In 10-13 days, the mycelium is harvested and ready to use as a raw ingredient for meatless meat.

- The Atlast Food Co. has a granted Australian patent *AU2007333545B2- Method for producing grown materials and products made thereby*, and this is part of a larger patent family that affords protection in various geographies including USA, China, Japan, Europe, and Israel. Most patent applications are expected to expire in 2027. It is presumed that additional intellectual property related to the mycelia growing process has been retained as a trade secret and not disclosed in any patent applications.

- The SSF process presents a potential "green processes" approach for mass producing mycelium, and has been reported to have lower cost of production when compared to SmF in the following ways; utilization of tray fermenters (or rolling drum) fermenters instead of highly sophisticated submerged reactors, minimal requirement for highly trained experts, enzymes formed are in concentrated form and recovery is easy, and liquid effluent generation is almost negligible in comparison[6].

- Cultivating heterogeneous substrates requires operating procedures to maintain optimal growth conditions. Air flow monitoring is key because it impacts temperature, oxygen supply and moisture. To maintain sufficient moisture content for the growth of filamentous fungus, waterlogged air is used and may require further addition of water. In most cases, SSF does not require a completely sterile environment as the initial sterilisation of the fermentation substrate associated with the rapid colonization of the substrate by the fungus microorganism limits the development of the autochthonous flora[7]. Generally, SSF is not a difficult

[6] Solid-State Fermentation - an overview | ScienceDirect Topics

[7] Solid-state fermentation technology and innovation for the production of agricultural and animal feed bioproducts | SpringerLink

process to run, and specialist training is not required. The Atlast Food Co. employ a facilities manager and machine operators, for example.

- The Atlast Food Co. has developed a proprietary AirMycelium® biofabrication system that includes custom-built mycelium solid-state incubation devices, as well as data analysis hardware and software. The devices control the environmental conditions for how mycelium grows and can be tailored to possess different structural properties. The mycelium product is shelf stable and no food safety or biosecurity issues were identified in the literature.

Key Insights & Considerations for Australian mushroom growers

- One of the biggest challenges in disrupting animal consumption using meat alternatives is the difficulty in production of whole cuts of meat. Ground, unstructured meats like burgers and sausages are simple to make meat-free. To be competitive in future retail sales, the opportunity may be to produce whole cuts of alternative meat. The AtlastFood Co. will attempt to disrupt the premium US steak market by utilising mycelium to scaffold beef steak. To illustrate this point, in 2021, the US market for meat substitutes contracted, while sales of regular beef, lamb and pork increased. This market contraction can be explained by the fact that many ultra-processed meat alternative products perform poorly on taste and texture, and consumers who are willing to try meat alternatives, switch back to regular meat when taste and texture expectations are not met.

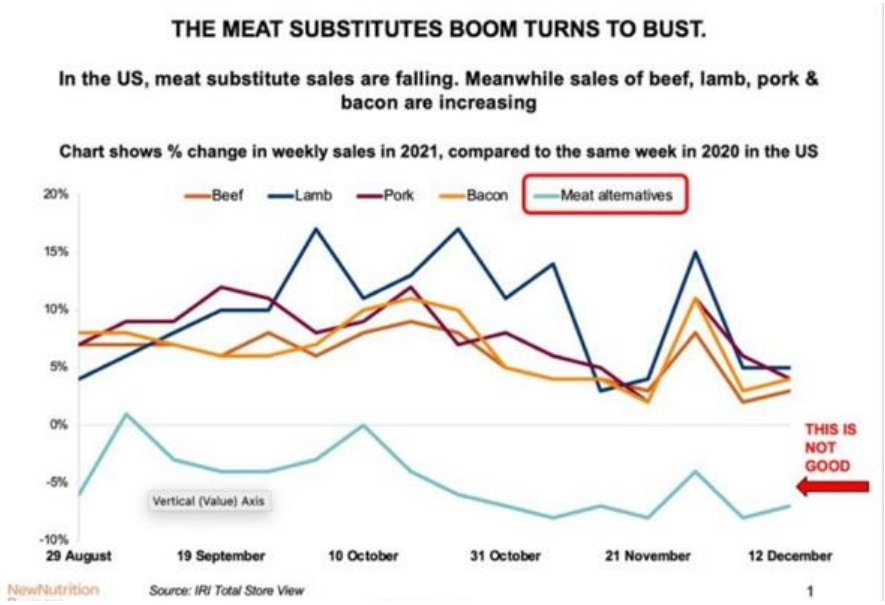


Figure 6. The meat substitutes market trends in 2021[8].

- A commitment to invest and develop quality meat alternative food products should identify and target the most attractive markets in terms of both consumer type and geography. In 2018, Euromonitor identified the US as the largest single market for meat alternatives.

[8] Adapted from a Linkedin post by Julian Mellentin, CEO of New Nutrition Business.

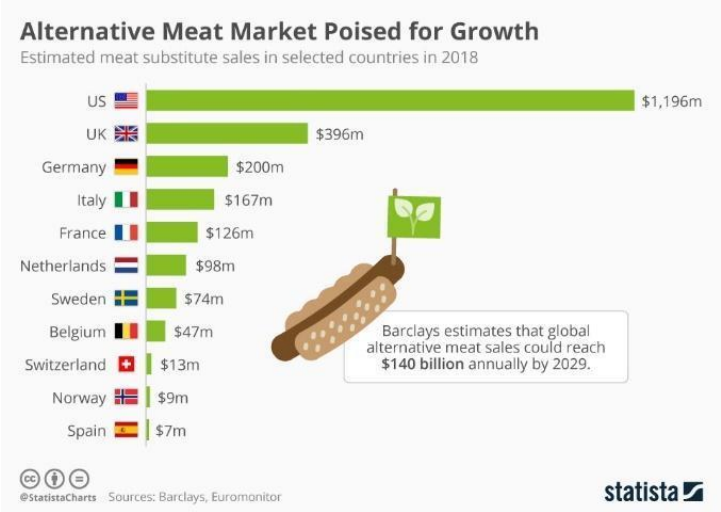


Figure 7. Meat alternative market size and growth projection by 2029[9]

- The fundamental drivers of demand for meat alternatives remains strong so investment in this area is likely to be supported by long-term global market growth. The COVID-19 pandemic has also shown a spotlight on even more of the downsides of the traditional meat industry due to interruptions in the food supply chain.
- The experiences of Australian mushroom growers and existing capital equipment should prepare them well to explore the opportunities of utilizing mycelium to produce meat alternative food products. However, it is anticipated that new purpose-built food grade equipment will be required to fully exploit the opportunity.
- Although the market for meat alternatives is growing rapidly globally, there is currently a small range of product offerings, and some of these don't perform well on price, taste and texture. These will not survive. Product innovation is key, and those companies that are able to develop quality meat alternative products best positioned for growth.
- On Jan 11, 2022, the Atlast Food Co announced their successful trial with Whitecrest Mushrooms Ltd. to produce MyBacon® strips at commercial scale. This demonstrates both the need for partnership and the expertise of mushroom growers to scale mycelium-based food products.
- There may exist an opportunity for low cost, mass mycelium production to be converted directly into mushroom powder. This could potentially reduce processing stages and increase yield. Mycelium from a variety of mushrooms is currently used to manufacture commercially available mushroom mycelium powder by the **Host Defense** company as a dietary supplement. Host Defense® Mushrooms™ are a US-based company founded by mycologist Paul Stamets and specialize in mushroom mycelium-based supplements to support natural immunity and whole-body wellness.

[9] https://www.statista.com/chart/18394/meat-substitute-sales-in-selected-countries/

Mushroom Fruit Powders

- The concept of powdering sub-prime *Agaricus bisporus* provides a flexible food format that could be used to produce a range of interesting business to consumer (B2C) and business to business (B2B) food product opportunities.

- Converting mushrooms to a powdered product allows the possibility of use as a supplement, adding the ingredient to a range of pre-made liquid drinks (coffee/tea, protein/sports supplement) and this could include thickened fluid beverages for the management of dysphagia (medical nutrition therapy); or solid foods (composite flours used in bakery products such as biscuits, as well as pastas/noodles). The range of possible product opportunities are limited only to the imagination of food innovators.

- Focusing on the nutritional or human health benefits of the *Agaricus bisporus* mushroom provides a basis to explore possible food product ideas that will meet known human food product needs. For example, UV-treated mushrooms that are powdered represent a natural, minimally processed food vehicle for the delivery of vitamin D.

- Powdered mushroom is featured largely in the Mushroom Product Compendium (Appendix A). There is a strong market opportunity for immunity-enhancing supplements (outside of dietary supplements) with projections for the market to reach almost 30 Billion USD by 2028. Mushroom powder is already gaining a reputation in the immunity supplement segment mainly on account of its nutritional components that may play a role in immune modulating, anti-inflammatory and antioxidant effects[10].

Overview of the benefits of *Agaricus bisporus* powder

- The nutritional composition of *Agaricus bisporus* has been determined previously and has been shown to be rich in antioxidants, contain virtually zero fat, are low in kilojoules, and can potentially provide 100% of the daily recommended intake of vitamin D when exposed to sunlight or a UV lamp. Some reports claim[11] that *Agaricus bisporus* esters may play a role in mechanisms associated with reducing risk of breast and prostate cancer, although further human clinical trials are required. Furthermore, bioactive components such as glucans and flavonoids present in *Agaricus bisporus* have been shown to positively benefit our immune system.[12]

MBio & Monaghan Mushroom bet on *Agaricus bisporus* powder as a Novel Food Ingredient

- On 24/01/2020, a valid application on the safety of vitamin D2 mushroom powder (*Agaricus bisporus*) as a novel food, which was submitted by MBio/Monaghan Mushrooms, was made available to EFSA by the European Commission through the Commission e-submission portal (NF 2019/1237) and the scientific evaluation procedure was initiated.

[10] A. Bhushan,et al, The Medicinal Mushroom *Agaricus bisporus*: Review of Phytopharmacology and Potential Role in the Treatment of Various Diseases, J Nat & Sci of Med, 2018 1(1), p4-9.

[11] S.C.Jeong et. al., Macrophage immunomodulating and antitumor activities of polysaccharides isolated from Agaricus bisporus white button mushrooms, J Med Food, 2012, Jan 15(1), p58-65

[12] F.R. Smiderle, et. al., Agaricus bisporus and Agaricus brasiliensis (1→6)-d-glucans show immunostimulatory activity on human THP-1 derived macrophages, Carb Polymers, 2013, 94(1), p91-99.

- During its meeting on 24/02/2021, the Panel, having evaluated the data, adopted a positive scientific opinion on the safety of vitamin D2 mushroom powder (*Agaricus bisporus*) as a Novel Food pursuant to Regulation (EU) 2015/2283.
- Full application: https://efsa.onlinelibrary.wiley.com/doi/10.2903/j.efsa.2021.6516.

Abstract: The EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA) was asked to deliver a scientific opinion on vitamin D_2 mushroom powder as a novel food (NF). The NF is an ingredient produced from *Agaricus bisporus* mushroom powder that has been exposed to ultraviolet (UV) irradiation to induce the conversion of provitamin D_2 (ergosterol) to vitamin D_2 (ergocalciferol). The NF contains concentrations of vitamin D provided by vitamin D_2 in the ranges of 580–595 µg/g. The information provided on the manufacturing process, composition and specifications of the NF does not raise safety concerns. The applicant intends to add the NF in a variety of foods and beverages, including food for special medical purposes and food supplements. The Panel concludes that the NF, used as an ingredient, is safe for the general population at the proposed condition of use in foods and beverages and that the NF used as a food supplement, is safe for individuals above 1 year. According to the applicant, this vitamin D_2 whole mushroom powder is a 100% food grade powder obtained from the dried whole fruiting body of *Agaricus bisporus*. The mushroom powder includes the whole white closed cup mushrooms which contain stalk component or unusually shaped mushrooms that have been sliced, dried, milled and UV irradiated.

Analogous foods that have found success in optimising powdering methods

Positioned initially as a 'wheat flour substitute', green banana and the coffee cherry are successful commercial examples of a "waste product" from the production of a perishable fruit or vegetable crop.

Banana Flour: Green Banana flour is the nutrient packed, light and 100% natural gluten free wheat flour alternative that is produced by companies such as Natural Evolution, MGM, and Lotus. The Natural Evolution company (https://www.naturalevolutionfoods.com.au/) uses green Cavendish bananas grown on the Atherton Tablelands in tropical Far North Queensland, Australia. The Natural Evolution company positions its products to meet a human nutrition and health need, claiming that green banana powder is the highest source of resistant starch, which has been scientifically proven to provide positive effects on gut health. The powder is also used in Product innovations that include pre-mixed bakery products and an antioxidant rich banana ointment.

Coffee Cherry Flour- Coffee cherry flour is produced using a patented process to upcycle waste coffee cherry pulp created annually from the production of green coffee beans, into a functional food product. The Coffee cherry company (https://coffeecherryco.com/) cites food Innovation, understanding flavour notes, nutritional composition and the effects on human health and manufacturing sustainability as the key elements of its success.

Coffee Cherry Flour has been positioned primarily as a B2B opportunity with the ingredient being utilized in the following commercial products developed by various other companies including;

Powder Production Methods & Costs

- Manufacturing fruit or vegetable powders requires the use of mostly commercially available equipment components according to the general functional scheme of; decontamination, material entry/supply, washing, slurry, size reduction stage(s), moisture reduction, drying.

- It is evident from investigation into the commercial efforts by MBio/Monaghan Mushrooms, as well as those by companies producing powders from green bananas and coffee cherry, that both the equipment and the processing details are identified and held as proprietary (confidential) information.

- Any commercial efforts to manufacture *Agaricus bisporus* powders would necessarily require experimentation to design and optimise processing equipment and procedures. During this experimentation, trade secrets and registrable intellectual property (patents) are likely to be produced and should be considered potentially valuable intangible intellectual property by the investor.

- Natural Evolution Foods identifies the following types of intellectual property in the case of the green banana powder product;

  (1) Natural Evolution describes their process to produce a shelf stable, dry powder product as being developed in-house and protected by international patent application (PCT2019/051083 Method and Device for Drying Plant Material, PCT2017/050256). Inventor: Robert Ogilvie Watkins Assignee: Evolution Industries IP Pty Ltd.
  (2) Additional patents identified include Method and Device for peeling green bananas, Banana Harvester, Method of Processing Plant Material, and a Liner for Packing and Transporting Fruit.
  (3) All other machine process flow, machine design and capabilities, or other processing specifications are considered to be proprietary and are tightly held as trade secrets.
  (4) Various trademarks have been registered for the product itself and the process of manufacture.

- It has been estimated that the production yield or conversion rate of whole *Agaricus bisporus* mushrooms to produce 1kg of powder is approximately 15-17:1 using a non-optimised set-up at Natural Evolution Foods.

- The cost of equipment to begin producing *Agaricus bisporus* powder is difficult to estimate since the required stages in production are currently unknown and would need confirmation. As a guide, a standard powdering line set-up at Natural Evolution is estimated through private conversation to be in the range of 1.3-1.8m AUD. Such a facility would have a footprint of up to 20m long by 5-8m wide and would have full automated control through a PLC and be operational using a mobile device. This estimation would also include full installation and commissioning.

- According to Hort Innovation MU17005 published in 2019, the estimated costs to contract (toll) manufacture powder were $4.50/kg of powder produced, with a retail cost of $18.75/kg.

- MBio/Monaghan Mushrooms submission to the European Food Safety Authority (EFSA) regarding the production of *Agaricus bisporus* powder as a Novel Food, all processing details were deemed proprietary and confidential, and as such, were disclosed only to the extent required by the assessing authority under terms of confidentiality.

Key Insights & Considerations for Australian mushroom growers

- Explore partnership options with an incumbent powder manufacturer, such as Natural Evolution Foods. This company has previously expressed a desire in developing partnerships with businesses that have an interest to supply raw products for conversion into powders; and to potentially participate in a negotiated level of new business ownership as a means of exploiting the commercial opportunity. Natural Evolution have experience in producing, marketing and selling functional powders.

- Natural Evolution propose a "Collaborative supplier equity business" model to produce functional powders for food, pharmaceutical and nutraceutical businesses. The model is based on the conversion of agricultural out-of-spec or oversupply and waste streams into consistent high grade functional ingredients and stand-alone products.

- A collaborative supplier equity business describes fruit suppliers investing cash in return for supply agreements for feedstock and equity in the drying business. A lease-licensing arrangement would also allow a production facility to be leased with balloon payments to conclude and an ongoing license fee, based on the quantity of powders manufactured.

- Explore sole or co-investment with other mushroom farmers to purchase equipment. The experience of food powdering equipment manufacturers could potentially be utilized to design and purchase a base level manufacturing capability. Once acquired, experiment and investment will be required to optimize and learn about the challenges in producing high yield of *Agaricus bisporus* powders. Further work, including the establishment of distribution channels for product sales or other partnership arrangements would be required to sell the powders.

- Australian Government Granting schemes could be explored to fund capital investment such as the Federal Governments Modern Manufacturing Initiative (MMI). The Federal Government's $1.3bn MMI is step one in a 10-year plan to transform and diversify Australia's economy. The MMI aims to correct this and to keep our manufacturing IP and capability here in Australia. Food and beverage is a priority sector. More information can be found at the following link; https://www.industry.gov.au/data-and-publications/food-and-beverage-national-manufacturing-priority-road-map. Additional Federal Government tax incentives could be utilised to support an investment into optimising Aga*ricus bisporus* powders such as R&D tax incentives. More

information can be found at the following link; https://www.ato.gov.au/Business/Research-and-development-tax-incentive/

- The following Hort Innovation projects have been identified as references for use in further exploration of the *Agaricus bisporus* powder opportunity; **MU20003** - Educating the Food Industry of the Nutritional Benefits of Mushrooms aims to discover potential markets for mushroom powders (vitamin D enriched, beta-glucan powders); **MU20001** - Mushrooms and their Potential Health Benefits of Lowering Blood Cholesterol.

The FUNGUSCHAIN Project

Background

- European Union countries generate a considerable range and quantity of agricultural by-products which are often discarded as waste or used for low-value applications, and this is also the case for their mushroom industry.

- The FUNGUSCHAIN project was occurred from 2018 to April 2021 with an overarching objective to disrupt and transform mushroom growing and its associated waste management by establishing a bio-based, circular economy. FUNGUSCHAIN was a joint undertaking by government, corporate and research sectors, and was supported by European Horizon 2020 program grant of 5.7M Euros (~9.0 M AUD).

- The European Horizon 2020 program is a financial instrument aimed at breaking down barriers to innovation and making it easier for public and private sectors to work together in European economies. To this end, the European Horizon funding helped establish a consortium of 16 partners from 10 different European countries, including research institutes and 12 different corporate companies. The consortium was coordinated by BioDetection Systems B.V.

- The FUNGUSCHAIN project ended on April 14, 2021 with an online conference that presented project findings. According to private communications with Bart van der Burg (Business Development Manager, Bio-detection Systems), there is currently no expectation that the FUNGUSCHAIN project will continue to be funded.

Key Players

- **BioDetection Systems** b.v. (BDS) is a Dutch biotechnology company providing bio-based screening technologies for safety, quality and bioactivity assessment. These services are able to be contracted via BDS laboratories or performed under license. BDS is knowledgeable in the sensitive detection of key organic pollutants such as dioxin(-like) compounds, PCBs, PAHs and other persistent organic pollutants (POPs). Lead by Professor Abraham Brouwer, a recognized expert in these fields, BDS has evolved into a knowledge intensive company in the field of safety and hazard assessments as well biological functionality screenings

- **Monaghan Mushrooms** was a key consortium partner, who were tasked with providing mushroom waste streams and practical advice on mushroom farming operations and practice. Founded in Ireland in the early 1980's by school teacher Ronnie Wilson, Monaghan have grown to be one of the world's largest mushroom producers serving some of the largest international retailers. Monaghan mushrooms currently has farms, packhouses, substrate sites and offices across Ireland, the UK, the Netherlands, Germany, Belgium and Canada, employing over 3000 staff.

- A key goal of Ronnie was that to realise the true potential of mushrooms, Monaghan needed to focus on research and innovation. Today, Monaghan is run by Ronnie's son, Paul Wilson, who is furthering his father's

innovation vision. Monaghan mushrooms are active participants in the meat alternative food product space, producing meat free burgers, mince, and sausages under separate brands. As discussed elsewhere, Monaghan are also presently actively developing a powdered mushroom product as a food ingredient.

Aims and objectives of FUNGUSCHAIN

The FUNGUSCHAIN project's main aim was to enable cost-effective extraction of diverse high-value components from mushroom agro-waste at industrial levels for the subsequent creation of new bio-based products.

Specific project objectives were to:

1. Demonstrate an integrated, cascading process that achieved more than 40% valorisation of mushroom cultivation residues into high-value bio-based products.
2. Validate and demonstrate the successful extraction of biomolecules into high value products on an industrial/commercial scale.
3. Enhance the competitiveness of participating enterprises and increase the consumer acceptance of the developed products, with particular focus on local entrepreneurship and the development of rural areas in Europe.

- According to a summary report, FUNGUSCHAIN met its overarching project aim by demonstrating that 76-95% of fungal waste could be valorised into high value products, while the remaining residues could be converted into biogas or compost. To achieve this, an effective, safe, and environmentally friendly integrated cascade process approach using scalable methods was developed that effectively deconstructed fungal waste into its constituent compounds.

- This approach has reportedly become the blueprint for the design and construction of the Monaghan Mushroom's biorefinery located adjacent to a new biotechnology-based innovation center. The objective of the center is to lead in the development of future innovative and profitable products, as well as economic development of rural areas. Functional foods and innovative products like preservatives for 100% organic cosmetics, biodegradable mulching sheets, as developed in FUNGUSCHAIN are examples.

FUNGUSCHAIN processes and technologies

The cascading process approach at the core of the FUNGUSCHAIN project involved four steps; microwave assisted extraction, pressurised hot-water extraction, saccharification fermentation and anaerobic digestion (see Figure 8).

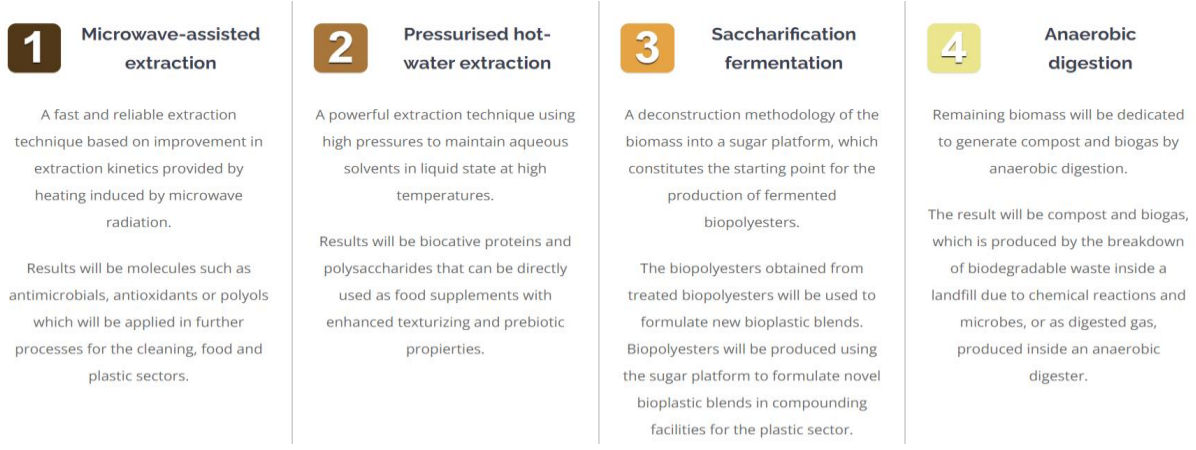


Figure 8. Steps in the Funguschain cascade and their outputs (source: www.funguschain.eu)

- A search of the literature identified polysaccharides β-D- glucans and ergosterol obtainment (90% of sterol fraction) Is attractive due to its various bioactive properties[13]. Moreover, ergosterol can be converted by irradiation into vitamin D2 for sale as a dietary supplement and food additive. Traditional liquid extraction techniques are often time consuming and require large quantities of potentially hazardous solvents[14]. Microwave-assisted extraction pressurized solvent extraction (PSE) and ultrasound-assisted extraction (UAE) techniques have all proven to provide distinct advantages in time efficient extraction at high yields. Commercial microwave equipment is commercially available, however equipment and methods are often tailored over time to suit the intended objective.

- In Australia, existing biofoundry equipment and specialist expertise can be found at the CSIRO BioFoundry[15], based at the Ecosciences Precinct at Dutton Park, Queensland. Some of the associated insights for Mushroom Grower in Australia seeking to explore this option further includes; 1) Access to equipment is a first step, but specialist knowledge is required to interpret and guide the project, 2) regulatory issues are often associated with innovation in this area- these must be addressed early and addressed as part of any project, and 3) payback will undoubtedly involve collective investment and collaboration to achieve desired results.

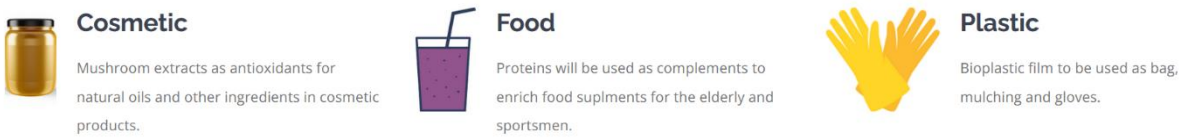
FUNGUSCHAIN outputs and outcomes

- The FUNGUSCHAIN project final conference "Biorefining and cascading approach for mushroom cultivation residues" was held online on April 14, 2021. A round-table "Market opportunities for FUNGUSCHAIN products" was conducted as part of this event.

Specific progress to each of the above-mentioned project objectives is summarised here: -

Objective 1: The original aim was to extract all valuable active molecules in a sequential cascading process for the isolation of target biomolecules, notably (i) antioxidants, (ii) antimicrobials, (iii) lipids, (iv) proteins and (v) polysaccharides, from mushroom waste in order to valorise all side stream components and maximise their value.

However, an initial version of the cascade was impeded by economic factors, and to a lesser extent some negative environmental impacts (mainly excessive energy consumption). Hence, a modified version was scaled up which proved to be viable at an industrial level. The upstream cascading steps resulted in high value protein enriched mushroom powders and flavour extracts, while downstream cascading intermediates were utilised in food and cosmetics products, as well as specialised plastics (such as biodegradable mulch and protective films with circular agricultural applications). Collectively, 76% to 95% valorisation of mushroom agro-waste was demonstrated, depending on the specific configuration of the biorefinery. In addition, residues could be used for biogas production and composting.



Objective 2: End-users validated the extracted biomolecules by introducing them into selected products within their own commercial portfolio to demonstrate enhanced functionality and improvements compared to

[13] S.Heleno et al., Optimization of microwave-assisted extraction of ergosterol (unpublished report)

[14] F.R.Smiderle et al., Evaluation of microwave-assisted and pressurized liquid extractions to obtain β-d-glucans from mushrooms, Carb.Polymers, 2017, Vol.156, p165-174.

[15] https://www.csiro.au/en/work-with-us/use-our-labs-facilities/biofoundry

current non-bio-based counterparts. The end-products were mainly focused on additives for food, protein-enhanced powders, functional foods, industrial film and cosmetics products. The cascading extraction processes developed during the project enabled the production of the selected high added value additives and end-product prototype development for the initial exploitation by project partners. A technical and economic viability study for the necessary investment in building and setting up pilot-plants and modifications of current industrial lines were carried out. Participating partners were agile and proactive in their approach to challenges and this led to the development of a range of innovative product lines, all contributing to meeting this objective. Monaghan Mushrooms made a significant investment to build an operational commercially viable biorefinery, allowing the integrated production of multiple high value bio-based ingredients and final food products.

Objective 3: FUNGUSCHAIN demonstrated the successful reintroduction of agricultural residues into a circular economy by using novel methods to identify valuable ingredients and environmentally friendly extraction procedures that are easily scalable and deployed by SMEs. Alongside this, FUNGUSCHAIN also aimed to incentive farmers and SMEs in rural areas to participate in the new circular economy and promote innovation and development, with the aims (i) to improve citizen's health; (ii) to boost the productivity of agriculture revenues and further industrial processes; (iii) to enhance environmental sustainability and safety to ensure acceptance of novel bio-based products.

Overall, demonstration and promotion of how the project met the three specific aims listed above was a key strategy to influence partner participation. Specifically FUNGUSCHAIN administrators promoted how they achieved (i) production of different types of bioplastics, some that are biodegradable and recyclable, with different applications in a circular economy; (ii) improved environmental impact, by avoiding chemical extraction and reducing energy needs; and (iii) the design and application of a novel rapid human cell-based safety assessment tool for complex bio-based undefined compound mixtures, showing no safety issues of cascade fractions and products tested.

Further, they demonstrated profitability of products without waste streams; innovative product options of which cascade residues can be used for biogas and compost production; and full circularity. To promote local entrepreneurship and further development of the rural area in the northern part of Ireland, Monaghan Mushrooms has also invested in the establishment of BioConnect Innovation Centre[16]- A Food Innovation Centre that brings corporates (Manor Farm, Lakeland Dairies, Bio-marine and other food industry partners) from across the region to problem solve, network and brainstorm new food product concepts.

Key Insights & Considerations for Australian Mushroom Growers

- Biorefineries are comprised of expensive equipment and process expertise. This area of science offers the potential of unlocking additional value from the fruiting body. Larger players in the Australian mushroom industry or those that grow a variety of horticultural produce may consider a capital purchase that could be spread throughout the business. Otherwise, partnership within the mushroom industry or across different non-competitive products could be explored. Note that expertise is required to operate equipment and interpret results. Government co-funding grants are available that are aimed at supporting Australian businesses to purchase new equipment in the Food and beverage industry[17].
- Alternatively, biorefineries currently exist within Australia. An investigation into the various equipment and expertise options may identify “hire” opportunities. The costs associated with hiring biorefinery plant and services may also be reduced by Government grants that support R&D, and/or by cost sharing through partnership with other growers or food companies.
- The FUNGUSCHAIN project was a unique collaboration that enabled commercial players to explore new foods and food ingredients, for their own commercial needs. The project clearly involved the combination of

[16] https://www.bioconnectireland.com/bioconnect-project

[17] https://business.gov.au/grants-and-programs/modern-manufacturing-initiative-manufacturing-integration

fundamental research, practical biotechnological experiments and scale-up, and ongoing commercial and business assessment of the evolving results and market opportunities.

- Monaghan mushrooms was the only commercial mushroom grower in the FUNGUSCHAIN consortia. Other commercial organisations were focused on utilising learnings and ingredients for their own markets in detergents and personal care, bioplastics, rubbers, cosmetics, and other composite materials. Each commercial player will assess the success of the outcomes according to the impact they may have for their business. Monaghan mushrooms appears clearly focused on understanding and building knowledge in how the basic chemical and nutrient building blocks of mushrooms can be efficiently extracted for further commercial value. This approach potentially places Monaghan mushrooms in a unique position to protect and licence its knowledge to others or exploit it for their own purposes. It appears that Monaghan mushrooms at present is focused on using this information to explore novel food products.

Food Regulation considerations for mushroom product innovations

To successfully launch new products in the marketplace and promote them to consumers, especially food products made from ingredients with potential benefits for human health, marketing and branding become critical components which must be conducted within a strict regulatory environment. Specifically, any food companies wishing to make a health claim must comply with "Standard 1.2.7 - Nutrition, Health and Related Claims", regulated by Food Standards Australia New Zealand.[18] This standard regulates claims appearing on food labels and in advertisements, in the form of *nutrition content claims* and *health claims.* These claims are voluntary statements made by food companies and may refer to the nutritional content of the food (nutrition content claims) or they may refer to a relationship between food, or a property of food, and a health effect (health claims). Health claims are further categorised as "general level health claims" (GLHC) or "high level health claims" (HLHC). GLHCs refer to a component or nutrient in a food and how it may affect health. For example, 'Fibre helps to keep you regular' (Dietitians Australia, 2022)[19]. These types of claims cannot be used in association with serious diseases, such as heart disease, or indicators of disease, such as cholesterol. HLHCs refer to a component or nutrient in a food and how it may affect a serious disease or biomarker (indicator) of a serious disease. An example of this type of claim is: 'This food is low in sodium (salt). A diet low in sodium may help reduce blood pressure'. Several nutrient claims and GLHC could be used with confidence to assist in marketing mushroom products, however, HLHC are less likely, especially in relation to cancer because the current level/quality of scientific evidence cannot substantiate such a claim at this point in time.

However, in Australia, when considering the launch of a mushroom-based product that has no obvious and recent history of consumption (for example a mushroom powder that is derived from off cuts which may contain SMS residue) as a human food, firstly a determination must be made on whether this type of unique mushroom powder formulation is considered a 'novel' food or food ingredient, as defined within the FSANZ Food Standards Code, notably *Standard 1.5.1 – Novel foods* (Appendix 1). The code refers to novel foods and novel food ingredients as being non-traditional foods (those which do not have a history of human consumption in Australia or New Zealand) that require assessment by FSANZ to establish their safety before they are added to the food supply. Refer to the extensive questionnaire FSANZ use to make a determination on whether a food or food ingredient is novel (https://www.foodstandards.gov.au/industry/novel/). A novel food cannot be sold as food or used as a food ingredient unless it is listed in the Standard. Anyone wanting to sell a novel food or a novel food ingredient must

[18] Food Standards Australia New Zealand (2016) https://www.foodstandards.gov.au/code/Pages/default.aspx

[19] Dietitians Australia (2022) Health Claims. https://dietitiansaustralia.org.au/smart-eating-for-you/smart-eating-fast-facts/food-labels/what-are-health-claims-and-what-do-they-mean/

apply to FSANZ to request that the Standard be amended to include the food or ingredient in the list. Novel food applications are subject to a pre-market safety assessment. If the food passes this assessment, it is added to the list in the Standard (see Appendix 2) and the manufacturer can go ahead and sell it, as long as it complies with any specified conditions. It is the opinion of the authors of this report that a simple mushroom powder without SMS residue (akin to broccoli powder made from 100% broccoli) may not be novel by the Standard's definition, however mushroom powder derived from mushrooms with SMS and peat moss, may in fact be deemed "novel" and hence be required to have a pre-market safety assessment and approval by FSANZ. After all, Australians (and likely all humans) do not have a history of consuming peat moss and other components found in SMS.

Activity 6: Ideate Novel Concepts for the Australian Market

Activity 6 intended to leverage the results of the compendium, as well as learnings from our case studies, into some early concepts for consideration by the Australian mushroom growers interested in participating in the food innovation space.

Concepts fall under three trending categories that are of current interest to consumers:

- Retail
- Health Food
- Food service

It should be noted that whilst there may be many different interesting concepts that food product innovators might be interested to develop, the execution of these concepts into sustainable businesses relies on a diverse mix of skills and experience, an entrepreneurial mindset with a high tolerance for risk, sufficient funding and business planning.

Largely, these concepts are intended to inspire mushroom growers about the potential application of *Agaricus bisporus* in food innovations across a range of food/product categories.

Value-Added Mushroom Food Product Concept – **CONVENIENT SNACK**

Vegan Mushroom Jerky / Vitamin D-Rich Mushroom Jerky

Product description

This product is a mushroom-based jerky, similar in appearance and texture to popular beef jerky.

To produce, sliced mushrooms are marinated/flavoured, then air or heat dried to produce meat-free jerky strips. Recipe formulation may be based on *Agaricus bisporus* mushrooms (whole and/or stems), vegetable oil, sugar (or maltodextrin), water, and seasonings such as onion, garlic, herbs, spices. A focus on using less salt than traditional jerky, other plant-based jerky and snacks in general would make it appealing to health-concious consumers.

As an alternative, utilisation of UV-treated mushrooms may increase the vitamin D content of the end product, as would incorporation of mushroom powder. This offering could be positioned as *high(er) vitamin D meat-free jerky*, depending on formulations, appealing to a wider range of consumers concerned about Vitamin D deficiency.

Competitors and Product Positioning

- Competition includes traditional meat-based jerky, plant-based jerky and convenient snacks in general.
- May be positioned as a healthier, vegan/vegetarian snack choice, with the optionality to provide more vitamin D than traditional beef jerky and other plant-based jerky counterparts (if UV-treated mushrooms are used).

Current Commercial Availability

- Meat-free jerky made of mushroom, soy, seitan, tempeh, and other vegetables such as tomatoes, are commercially available.
- A small number of companies offer 100% mushroom-based jerky (Pan's, Georgio, and Eat the Change); the majority are soy-based.
- No meatfree products incorporating UV-treated mushrooms were identified in commercially-ready products.

Advantages over conventional jerky

- Higher nutritional quality if salt is reduced in the formulation (reducing total sodium content).
- It can potentially offer more fibre including beta glucans, polyphenols that act as antioxidants, and Vitamin D if UV-treated mushrooms/powder are utilised.

Advantages over other meatfree jerky

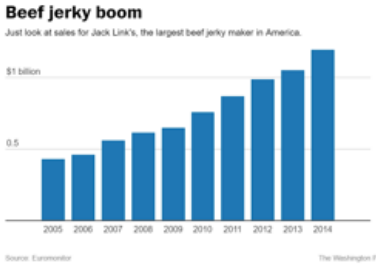
- Non allergenic (void of soy ingredients and other allergens).
- Potential for higher levels of vitamin D.

This innovation may be of interest to:

- Snack food manufacturers, jerky companies and plant-food innovators. Note, PepsiCo and Beyond Meat announced a partnership in January 2022 to produce a meat-free jerky product (although not mushroom based), highlighting the interest in this space.
- Pet Food manufacturers who are interested in reducing meat content but maintaining nutritional value to create mushroom+meat dog treats.

Opportunity

1. Jerky is the top-trending meat-based snack in Western societies including the US and Australia, and the market was worth 1.8 billion USD in 2020.



2. The meatfree jerky trend is projected to rise globally in the next decade, leveraging existing consumer trends of convenient snacking, the health-concious consumer, vegan/vegetarian/plant based diets.

3. Mushrooms have been shown to successfully replace meat (in part or entirely) in jerky formulations. On account of mushrooms' umami flavour, formulations lend themselves to reduced levels of salt compared to traditional jerky. The resultant reduced sodium content may enable nutrient claims on food labels and in turn, help to support marketing campaigns that increase sales.

Considerations for this opportunity

- Formulate a jerky recipe that (i) utilises UV treated mushrooms and/or mushroom powder to increase provision of vitamin D and (ii) exploits the natural savoury/umami mushroom flavours to reduce requirement for salt, and increase the nutritional quality offered by naturally-occuring mushroom food components.
- Devise a business plan that focuses on:
  - a) securing mushroom supply (whole and/or stems)
  - b) investigating the level of capital investment required
  - c) investing in a commercial grade dehydrator
  - d) setting up food preparation premises approved by the Food Authority
  - e) exploring the opportunities for toll manufacturing (partnerships)
  - f) labelling nutritional contents according to FSANZ Food Standards Code, and enabling successful marketing of any permissible nutrient/health claims

Value-Added Mushroom Food Product Concept – HEALTH PRODUCT

Vitamin D-Rich, Coffee-Flavoured Thickened Beverage

Product description

Base Ingredient: Mushroom Powder

Mushrooms (whole/stems) are decontaminated/cleaned, reduced in size, dried and blended to form a powder. If UV-treated *Agoricus bisporus* mushrooms are utilised, the concentration of vitamin D in end-products would be enhanced compared to non-treated mushrooms, although the latter would still be a valuable, naturally occurring source of the vitamin. Applications for mushroom powder are broad and diverse, including:

- A composite flour to produce biscuits, cakes/cookie/pancake/muffin mixes, pasta, noodles
- Powdered dietary supplements e.g. high protein supplements for medical therapy (e.g. malnutrition management) and sports use (e.g. performance enhancement)
- Dietary fibre supplements (similar to Benefibre) for promotion of good gut health and bowel regularity
- Powdered base to create elixirs
- Powdered flavour enhancer for use in cooking, or as a condiment
- Powdered beverage base including a coffee/mushroom blend or a cocoa/mushroom blend (bitter/umami compatible)

Unique mushroom powder application

This product concept is a thickened beverage designed for people experiencing difficulties with swallowing liquids (also known as dysphagia), which can easily pass into the lungs (aspiration).

Swallowing difficulties are more common in older people, and are also prevalent in people with some diseases or injuries that affect their normal swallowing function. People with dementia and Alzheimer's Disease (on the rise in Australia) often experience swallowing difficulties too. By drinking thickened fluids (from slightly thick to extremely thick consistency) instead of normal fluids such as water (classified as thin), the risk of aspiration is reduced. These groups, as well as one in four Australian adults, are typically vitamin D deficient, with 7% having a moderate or severe deficiency.

Prevalence of Swallowing Difficulties

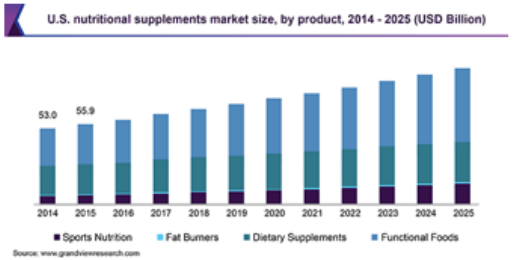
	Condition	Prevalence (%)
1	Adults aged 65 and older	≥ 13%
2	Institutionalized elderly patients	≥ 51%
3	Stroke	40 – 70%
4	Neurodegenerative Disease	60 – 80%
5	Head & Neck cancer patients undergoing radiotherapy	60 – 75%

Drivers

1. Aging population with concomitant growing prevalence of swallowing difficulties, as well as Vitamin D deficiency.
2. Medical nutrition supplements aim to be vegan, gluten free, low allergenic BUT high in vitamins, fibre and antioxidant components such as polyphenols.
3. Gut health is important – powder could act as pre-biotic to promote beneficial changes to gut microbiota through delivery of dietary fibre, resistant starch and beta glucans

Opportunity and Product Positioning

- Dietary supplements are popular, designed for personal use or as a medical nutrition therapy, such as the thickened beverage concept presented here.
- Immune enhancing supplements are also of growing interest to consumers especially in light of the COVID-19 pandemic. For example, the global immunity supplements market in 2020 was **USD 5.2 Billion and projected to reach USD 29.40 Billion by 2027 globally.**



- Mushroom powder contains functional bioactives that may have a role in immunity and are of particular interest to supplement manufacturers during COVID times.
- No medical nutrition supplements incorporate mushroom powder, presenting a novel application for the introduction of naturally occurring bioactive components, including fibre, beta glucans, vitamin D, other vitamins, minerals and antioxidants.
- Addition of mushroom powder enables the retention of gluten-free, low allergenic, vegan claims (depending on other ingredients in formulation). This is desirable for a supplement of this nature which is intended to reach a wide consumer sector.
- The umami flavour of the powder is compatible with coffee flavour (decaffeinated for this application). Although there are some coffee flavoured thickened beverages on the market, none are high in vitamin D and few in fibre, unless added separately to the beverage at point of consumption.

Competitors

- Resource® ThickenUp® Hydration; Flavour Creations' Ready-to-Drink; Precise Thick'N Ready.
- None include mushroom powder.

Point of difference
Using mushroom powder to increase nutritional value, notably vitamin D, fibre and antioxidant components.

Powdered mushroom may be of interest to:

Food manufacturers, dietary supplement companies, condiments e.g. MasterFoods, coffee manufacturers and boutique producers. The Pet Food industry may be interested in formulations that increase fibre content of dog foods or a niche pet food fibre supplement

Value-Added Mushroom Food Product Concept – **FOOD SERVICE**

Preserved Mushrooms in Biodegradable and Resealable Polybags

Product description

This concept is the development of resealable bags for the long term storage of fresh mushrooms (cut or whole). addressing the issues associated with seasonal variations in both production and domestic *Agaricus bisporus* consumption which lead to market over-supply and product spoilage.

Due to high respiratory rate, high water content, and lack of a cuticular structure (outmost protective layer),mushrooms rapidly lose quality and have a short shelf life. Sub-prime quality mushrooms often show evidence of microbial attack, enzymatic browning, shrinkage, and decreased firmness.

The freshness bags would be purpose-designed to control humidity within the bag and be stored in standard refrigerator conditions. Previous studies have shown a humidity of around 96% inside the packaging to be optimal.

Post Harvesting Processing Steps

- Cooling the mushrooms post harvest provides the optimum treatment
- Vacuum cooling preferred due to shortened cooling time and increased effectiveness of quality
- Higher capital costs may be outweighed by reduced long-term energy costs.
- Overall, cut or uncut mushrooms post cooling to be bagged in purpose designed long term storage bags (Fig 1).

Current Commercial Availability

- Scelta is the major producer of preserved mushrooms.Mushrooms are blanched and placed into polybags to extend shelf life (7 weeks in buckets, 1-4 years in polybags). Scelta use preserved mushrooms to make concentrate and powder and their Scelta Taste Accelerator (flavour enhancer).

www.sceltamushrooms.com/preserved-mushrooms/

Bag materials options:

Traditionally, polyethylene polymers are used to mass produce soft flexible bags. This would be cheap and readily available.

Bio polymers provide another materials option (layered) which could be tailored in a laminated structure. PLA and PGA are examples.

Paper/cardboard provides another option however, layers of polymer will need to be laminated on the inside to provide the desired gas transmission properties.

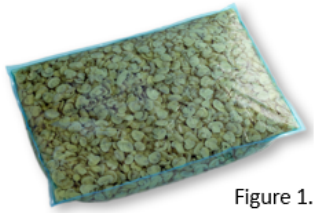


Figure 1.

Humidity Control:

Humidity is essential to control and can be achieved via: a) specialised valve located on the bag that regulates the flow of water vapour between internal bag and the external environment.
b) Humidity control bag inserts. These would be specially designed to produce the desired level of humidity. Commercial versions of this concept is shown in Fig 2.

Figure 2.

Opportunity

1. Select and design flexible bag materials based on a wide range of commercially available materials. Good environmental stewardship would focus on paper or bio-based materials.
2. Plastic Convertor and paper companies have the relevent expertise to advise on bag options to
3. Determine if a physical humidity controller or a sachet placed within the bag is the desired option.
4. Trials with fresh mushrooms and the materials and bag design set up will be required to determine the optimum performance.
5. This concept could be have use by mushroom growers or be aimed at supplying the food service industry with a solution to preserve bulk quantities of whole or cut mushrooms in refrigerated storage for long periods of time.
6. Easy to stack bags – save on storage space in facilities.
7. Scelta's experience is that shelf-life is extended to 12 months utilising polybags
8. Several large volume mushroom growers are likely to already have useful equipment to post-harvest treat mushrooms and assist in bagging.

Other Considerations

- There are a large range of poly bags that are commercially available for trials. Other materials, such as paper are increasingly being used as a materials of choice to address a consumer concern with the used of plastic.
- There is a large amount of scientific literature that can be utilised to design the desired internal bag conditions to maximise shelf life.
- Trials are relatively simple to plan and execute.
- Bag designs can be patented and protected. The bags could be sold to other industries or licenced for manufacture elsewhere, depending upon the nature of IP protection chosen.

Outcomes

"MU20004 – Macon: A scoping study to review fungi based global innovations to inform product development opportunities" aligns with a key strategy in the Mushroom Strategic Investment Plan (SIP 2017-21): "diversification through the identification and establishment of new markets." Through alignment with this strategy, outcomes of this proposed project have the potential to contribute towards the attainment of the SIP's key target of domestic consumption of 4 kilograms per person per year of mushrooms by 2021.

Key outcomes:
The Australian mushroom industry, including stakeholders from all parts of the value chain, will gain knowledge from this review about the viability and feasibility of new food-based opportunities utilising mushrooms (including waste by-products). This knowledge has the potential to more reliably inform their future business and investment decisions. The review's findings will uncover the market potential for a variety of mushroom products for three audience segments seeking health-promoting foods and natural products, including consumers (retail), food service and healthcare providers

Through the learnings from the project activities and summarised in this report, Australian mushroom growers who wish to explore value-add opportunities also received specific guidance to help with their decisions regarding participation in food innovation, including these recommendations:

1) Conduct innovation in the right way by engaging a multidisciplinary team that provides the necessary expertise and experience; involve funders who understand their own risk appetite, and who know how to mitigate project risk; and ensure a well-defined innovation process is followed.
2) Share commercial and financial risk through careful fostering of partnerships (public and private)
3) A key pillar of any future industry-focused or organisational decision-making should be based on comprehensive and up-to date information, hence it is strongly recommended that the mushroom-based food product compendium is held in a central repository that is accessible to industry for use and that it is updated regularly.

Hort innovation Australia will benefit by having at their disposal, current information necessary to educate and support levy payers about potential new revenue streams, thereby potentially strengthening the local industry through gains in profit margins over time.

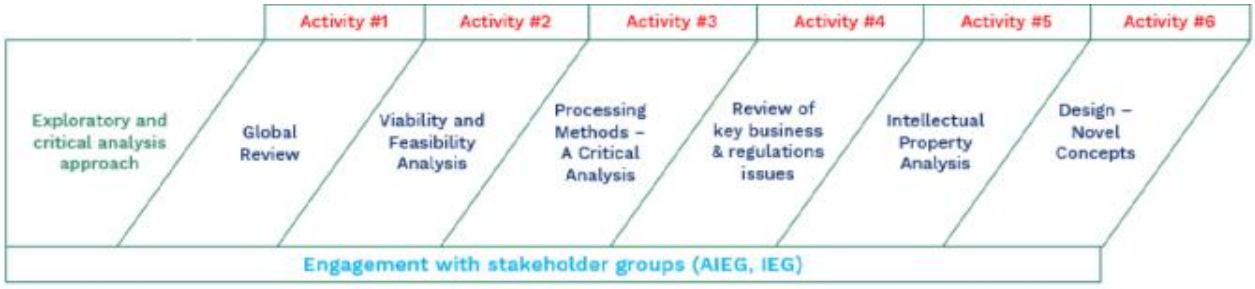
Monitoring and evaluation

As MU20004 is a 6-month project, which was primarily delivered as a desktop review, it was agreed that Hort Innovation would accept Key Evaluation Questions (KEQs) to monitor and evaluate the projects effectiveness, efficiency, appropriateness, relevance and impact towards the goals of the Mushroom Industry's SIP.

The project objective was to go beyond just a desktop review of mushroom containing commercially available food products available in Australia and globally, to identify 2-3 opportunities for mushroom product innovation, and the relevant commercial, production, intellectual property and business considerations associated.

The project framework diagram in below outlines the 6 activities undertaken by this project to identify, analyse and recommend leverage points for mushroom innovation moving forward, to potentially discover new markets for Australian grown *Agaricus Bisporus*.

Project Framework



Key Evaluation Questions

Five Key Evaluation Questions (KEQs) were identified to evaluate the projects effectiveness, efficiency, relevance and, alignment with the goals of the SIP (see Table 1).

Table 1. Key Evaluation Questions

Domain	Key Evaluation Questions
Effectiveness	**To what extent has the project achieved its expected outcomes?** The project has: ● Identified over 180 mushroom-containing products, across 13 food categories. ● Created a compendium of products, with products segmented into relevant categories. The compendium will be made available to industry. ● Analysed a representative sample of products to provide an indication of the prevalence of mushrooms currently available in different food categories, as well as identifying which product types use the most mushrooms by volume and highlighting which are the major food companies involved in mushroom product innovation.
Relevance	**How relevant was the project to the needs of the intended audience?** ● The industry and Hort Innovation have a thorough understanding of mushroom-containing product innovation globally, and a compendium of products to reference. ● The project identified industry relevant product innovation opportunities by way of case studies for further investigation and analysis ● The industry has an understanding of the relevant hurdles, risk mitigation and opportunities associated ● For each case study of innovation, specific insights and considerations relevant to mushroom growers was provided

	● Final recommendations offered guidance on 3 key factors essential for participation by mushroom growers in the food innovations space
Process appropriateness	**How well has the intended audience been engaged in the project?** ● An AIEG committee consisting of key mushroom growers, AMGA project managers and Hort Innovation was formed to guide the direction of the project. ● Previous and current Hort Innovation projects were considered in guiding the project direction and forming recommendations for continuance
	To what extent were engagement processes successful to the target audience/s of the project? ● AIEG were presented with the analysis of the compendium, which identified emerging trends and opportunities. ● Based on the results, three representative case studies were presented as potential case studies. ● AIEG recommended aborting one opportunity and recommended three for further exploration (Funguschain Project was a new case study). ● Engagement with company owners and organisational staff to help answer questions for case studies.
Efficiency	**What efforts did the project make for efficiency?** ● A shared Google Drive was created to efficiently share information ● The compendium was created and made available to the AMGA project managers for further input ● Synthesis and generation of communication materials for the AIEG committee ● Group and one-on-one discussions with the AIEG committee, as well as other relevant domain experts, to efficiently identify their perceptions towards new product development and use these insights to guide the future direction of the project, thereby ensuring the project's relevancy to industry

Recommendations

Findings from the activities conducted in this project were synthesised into three major recommendations for mushroom growers considering mushroom-based food innovation participation:

1. Embrace Innovation to develop a long-term competitive advantage

Innovation lures humanity by the dreamy potential of creating solutions that may provide gains to individuals and businesses that have never previously been experienced (better, faster, cheaper etc). Innovation may also produce a solution to a problem that has never previously been able to be overcome; or innovation may unlock a key competitive advantage to its owner. To innovate also involves an investment of resources (financial and human) in areas that are often unfamiliar and outcomes are not guaranteed. This often leads industries and business leaders to avoid innovation due to this perceived risk. However, research and anecdotal evidence across all industries suggest that there is potentially a greater risk of not innovating. **The key therefore is to ensure that innovation is conducted in the right way.** As a guide for Australian mushroom growers to ensure that innovation projects have the right ingredients for success, the following critical factors[20] should be considered a) projects are driven by a unique multidisciplinary team that provide the necessary expertise and experience, b) funders understand their own risk appetite, and also how to mitigate project risk, and c) projects use a well-defined innovation process that incorporates flexibility when needed.

2. Partner to win

The plant-based dietary movement will intensify in the years to come due to undeniable environmental and health patterns. This provides an excellent platform for the Australian mushroom industry to capitalise by developing new food products for this expanding global market. **Mushroom growers can explore beyond growing the raw mushroom ingredient into value-add activities by sharing commercial and financial risk through careful fostering of partnerships.** Promotion and development of staff within mushroom companies as intrapreneurs is another method to bridge the knowledge gap between the mushroom industry and launching new product enterprises. Funding projects via Government programs and other investors, partnerships with innovation service providers, equipment owners, engineers and process experts, and other food companies will create an ecosystem that can make new mushroom innovations a commercial reality.

3. Data is your friend

This report contains a comprehensive mushroom-based food product compendium, several case studies about companies who are currently investing in efforts to produce novel food products, and even some novel food concepts to offer inspiration about the possibilities. A key pillar of any future industry-focused or organisational decision-making should be based on comprehensive and up-to date information. This report demonstrates how dynamic the opportunities can be when pursued by organisations within and outside the global mushroom industry. **It is strongly recommended that the mushroom-based food product compendium is held in a central repository that is accessible to industry for use and that it is updated regularly.**

[20] https://hbr.org/2011/07/innovations-9-critical-success

References

The references listed here are cited in the **INTRODUCTION** section of this report.

All other sections of this report incorporate foot notes to help guide the reader to relevant citations.

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Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

Acknowledgements

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Kyle Kessler – Project Lead Xinova Mushroom Project

Marion Lawson – Mushroom Expert

Michael Fox – CEO Fable Foods

Russell Rankin – CEO Food Innovation Partners

Geoff Martin – Chair Australian Mushroom Growers Association (2019 documented conversations incorporated in this body of work)

Appendices

Appendix A: – Key issues and leverage points for mushroom concept ideation (Activity 6)

Several important issues for food product innovations incorporating *Agaricus bisporus* were identified in the activities conducted for this project. These issues are summarised below, and offer some insights into leverage points to mitigate potential hurdles and technological barriers for innovators, scientists, processors and other stakeholders. Importantly, an eye to these leverage points was consistently maintained during the idea generation for novel food product concepts conducted in Activity 6: -

Issue 1: *Agaricus bisporus* is Australia's most consumed mushroom but it is only represented in a small range of products
Leverage point: Innovation of new foods incorporating *Agaricus bisporus* to extend the product range beyond only fresh mushrooms and simultaneously take advantage of global consumer trends of health and wellbeing, "snackification", and reduction in consumption of animal-sourced protein.

According to the Australian Guide to Healthy Eating (AGHE, 2013), mushrooms are classified as a vegetable, and thereby are considered to confer similar health benefits to plant foods in general, yet mushrooms are not found in a broad range of products on supermarket shelves. The Mushroom Compendium indicated that *Agaricus bisporus* mushrooms are the most common variety currently sold fresh in Australian supermarkets, including the button mushroom, larger field mushrooms, Portabello and Swiss brown. Most typically, these mushrooms are presented loosely for consumers themselves to portion out in quantities they desire to purchase. More recently, bags of sliced *Agaricus bisporus* mushrooms and pre-packaged exotic varieties such as Shitake, oyster and Enoki mushrooms, are also being stocked on shelves, although they tend to come in smaller quantities and attract premium prices (see Figure X). The soup category, namely canned or pouched soups, is where mushroom ingredients are also predominantly incorporated.

Figure. Sample of current mushroom offerings in Australian supermarkets

The under-representation of mushrooms in value-added food products available to Australian consumers identifies an opportunity for food innovation and product line expansion. An obvious space for mushroom positioning is the snack food category which is large and expected to continue to grow, especially with consumers tending towards smaller and more frequent eating occasions.
Other prospects for innovation lie in the cereal food category to produce a cereal grain-mushroom end-product that offers a complete range of nutrients, which would otherwise be limited in the individual mushroom or cereal grain (Brennan, 2018). For example, the proportion of essential amino acids of most mushrooms is comparable to that of egg, and is specifically rich in lysine, which is limited in most cereals. On the other hand, mushrooms lack the essential sulphur amino acids, such as methionine and cysteine,

which are abundant in cereals. Cereal products and mushrooms when consumed independently may therefore be limited in these nutrients (relative to animal-based foods), however by combining cereal grains with mushrooms, an adequate level of essential amino acids may be delivered to meet human requirements.

Issue 2: Fresh Mushrooms, including *Agaricus bisporus*, are susceptible to spoilage (6-8 day shelf life), which may limit opportunities for innovation and expansion of the fresh product range.
Leverage point: Novel processing technologies to keep fresh mushroom foods microbiologically safe and extend shelf life. Other food processing technologies that can value add and create new ready-to-eat and snacking products desirable to Australian consumers will be useful.

In domestic kitchens, mushrooms have been traditionally used as a base ingredient for soups, liquid stocks and pates, although their short shelf-life and propensity for spoilage has always been a major issue. Canning, brining (champignons) and drying are conventional methods employed to prolong the quality and microbiological safety of mushrooms, however, with each technique there are limitations including changes to flavour, colour and texture. Commercially, mushroom producers are faced with the same problems of spoilage, on a greater scale, warranting significant expenditure on preservation measures such as refrigerated storage/transportation from farm gate to retailer, in addition to costs associated with product losses. Interestingly in the past, the problem was somewhat mitigated through horizontal integration by major mushroom soup producers (such as Campbell's Soup Company) who grew their mushrooms on the sites of their canning facilities, for example the current-day *Costa's Mushroom* site at Mernda, Victoria.
Today, the preservation of mushroom quality and microbiological safety remains paramount, especially in a strict food regulatory environment. To this end, the emergence of high pressure processing (HPP) and similar cold pasteurization technologies provides new opportunities for the production of high quality and safe mushroom products with a long shelf life, all year round. Note, whole mushrooms cannot be HPP-treated due to encapsulated air within the mushroom, although products using mushroom ingredients, such as soups etc., may be suitable. The product, **Avo Fresh** (see Figure 8), is a great success story for the use of HPP processing to increase consumers' year-round access to a usually season-dependent, highly perishable food. Avo Fresh is Australia's first cold pressed/HPP treated avocado range, which promises consumers "beautiful ripe avocado, ready to use every day straight from the fridge".

Advantages of HPP include:-

- In-pack, 'impact' pasteurisation, ready-to-eat (RTE) products
- ~100 day shelf life
- Reduced salt, preservative free
- Authentic natural flavour
- Nutrient preservation

Figure 8. Avo Fresh

Underpinning this solution are current drivers of '*Innovation in Food Preservation*' applicable to the mushroom industry:

- Secure a safe & stable food supply that minimises waste
- Premium convenience foods that are fresh-like & more nutritious
- Economic growth in the food sector
- Flexibility & choice to the food industry; facilitates innovation

Issue 3: Stipes are often contaminated with casing material which has led to a perceived need to clean or "double-cut" the stipes prior to any further food processing into final products. This has led to increased labour costs
Leverage point: Novel processing technologies to minimise labour or even to eliminate the requirement to remove casing material from stipes will be of interest.

The contamination of mushroom off cuts with casing material, as seen in the Figure below, poses a potential barrier to food innovation utilising mushroom waste (namely stipes). Although the casing material is comprised of non-toxic components (such as peat and calcium carbonate), there are no studies to confirm their microbiological safety and suitability for human consumption. Observations of the stipes coated in remnants of casing material, suggest that they would be gritty and unappealing to eat, though this is not formally confirmed in any feeding trials. Furthermore, refrigeration is paramount if they are to be used in commercial applications on account of degradation at ambient conditions, which results in an unpleasant smell and yellowish/green liquid.

In countries where harvesting labour is cheap it is possible to cut the stem twice by hand, thereby producing a reasonably 'clean' stipe, free of contamination, however this is not cost-effective in Australia where labour costs are high. There are suggestions that some solutions may already be underway; a company in Melbourne who has produced a mushroom sauce from stems, report that they are able to cope with the casing soil contamination (confidential/private communications). This requires further exploration. Overall, according to Dr Geoff Martin, an Australian mushroom expert, the most important technological questions are:-

- Is it possible to remove the casing soil contaminants from the stems by an ultra-sonic washing process or some other novel method?
- How much casing material could be safely consumed, if any?

Appendix B: Australian Mushroom Magazine Article

SCOPING GLOBAL INNOVATIONS

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Google "innovative mushroom products" and the answers are indeed many, with products ranging from mushroom-infused coffees and hot chocolates, umami seasonings, mushrooms chips and snacks, through to skincare and packaging. The humble mushroom, it seems, can do just about anything.

While there is undoubtedly a wide range of non-food innovations on the market, most products are food-related, looking to leverage consumer demand for healthy products. A new six-month, levy-funded project is underway to review fungi based global innovations to inform product development opportunities for the Australian industry.

Managed by the Australian Mushroom Growers' Association, the project work is being undertaken by Dr Anita Stefoska-Needham, a PhD-qualified Advanced Accredited Practising Dietitian, lecturer, researcher and inventor, with a particular interest in food innovations.

Dr Stefoska-Needham explained that the project's main aim is to conduct a global scan of commercially ready products using mushrooms from both waste and non-waste streams.

"What we want to do is to scope these innovations and then use the findings to inform the industry of new market opportunities, explaining the potential viability and feasibility in the Australian context."

Dr Stefoska-Needham said the key was to examine everything from an industry perspective.

"My approach is what they can't see, they can't consider. I intend to deliver a project to the industry that unlocks the door to the potential opportunities."

To be successful, she explained, will require robust engagement with stakeholders.

"Within the project, we are bringing together an industry group to present ideas and get them involved to see what they think may be of interest."

The AMGA is helping drive the engagement process, building a diverse representation, both from within Australia and internationally, to interact with the project management team. The first meeting of the stakeholder group is scheduled for September 2021.

Dr Stefoska-Needham said the project would examine opportunities in areas such as vegan and meat alternatives, healthcare, foodservice and retail.

"There are several categories of products that are of consumer interest at the moment. Things like the plant-based diet movement, the vegan movement and the push for meat alternatives are all areas driven by consumer trends and represent growing markets."

"And if you look across the other areas such as healthcare, foodservice and retail, they all represent the potential to target the health-conscious consumer."

"The approach will be to try and capture innovations as widely as possible, but looking specifically in those areas that are trending with consumers."

"It will be about showing growers the opportunities that exist and in ways that test their appetite for risk."

It is that element of risk that is the missing part of the puzzle, she said.

"From a growers perspective, some early adopters are likely to have a higher appetite for risk. These growers may well take something and invest and demonstrate to industry the benefits in diversifying their business operations in a particular direction."

Dr Stefoska-Needham said the industry is understandably focused on fresh mushrooms, but the project would look at other ways of adding value to the business.

Mushroom crisps are a deliciously different snack alternative. Image courtesy: South Mill Champs (US) - southmill.com

"This project will hopefully help guide and inform good business decisions."

"The overarching aim is to identify commercially ready innovation and to then have an informed discussion around what is found, taking into account potential barriers or hurdles for the Australian industry. This industry engagement and discussion will help us validate what we find, as for various reasons industry may say that something does not work in the Australian context."

Dr Stefoska-Needham said she was currently scoping the innovation pool and listing a wide range of products.

"I am trying not to leave any stone unturned, and there are some fascinating things that are coming through."

The search is taking into account not only existing companies and products but also examining the scientific literature to test early-stage concepts, particularly in the health area.

One such example of an early-stage concept is New Zealand-led research looking to develop a sorghum-based biscuit using mushroom powder to gain the benefits from the sorghum whole grain and the additional nutrients from mushrooms, such as dietary fibre from beta-glucans and phenolic compounds that act as antioxidants in the body.

Dr Stefoska-Needham said the example highlights the approach of looking at the emerging innovations in science, particularly in peer-reviewed publications.

"I am very hopeful we will capture a nice range of concepts to inspire and challenge industry participants."

"To help understand the technology in more depth, I will be presenting three of the concepts in more detail to industry participants. While the innovation will be explained, the case study analysis will look at the costs of investment, the benefits and the potential hurdles to enable further consideration and discussion by the stakeholder group."

She outlined a vital aspect of the project was communication.

Drink in all that mushroom goodness. Image courtesy: South Mill Champs (US) - southmill.com

"The project will deliver a comprehensive collection of products and technologies, but it also needs to be communicated effectively to encourage action."

"With a project like this, it is often the smaller, more innovative companies that have the appetite for higher risk, but it is also about trying to nudge the behaviour of the bigger companies to inspire some action and add business value beyond just fresh mushrooms."

Dr Stefoska-Needham said innovation was not about coming up with wacky or unusual ideas.

"It is often something that is mainstream that can deliver real success, particularly with companies that have a sustainable business model and a product that is selling well and is profitable."

"By sharing information grounded in solid and rigorous market research, Australian industry participants will be much better positioned to make sound decisions about how any innovation can fit with future business strategies."

She explained that while the focus was Agaricus mushrooms, it is simply not represented in an extensive range of products.

"In the area of food innovation, if we are going to incorporate Agaricus product, we need to look at ways to encourage their use and leverage into new food products. And while this takes advantage of global consumer trends for health, it may be that any push in this area requires additional consideration of issues such as freshness and spoilage."

"In the search process, I am already keeping an eye out for novel processing technologies, such as high-pressure processing, that deliver on those issues, particularly from a microbiological perspective."

"We will also look at those products that do contain other types of mushrooms and look at what the barriers are to using *Agaricus*."

Dr Stefoska-Needham said the case study materials would be presented directly to the industry, with information also disseminated through the Journal and an industry webinar. Further information on the timing of these resources will be made available through the Industry Update e-newsletter.

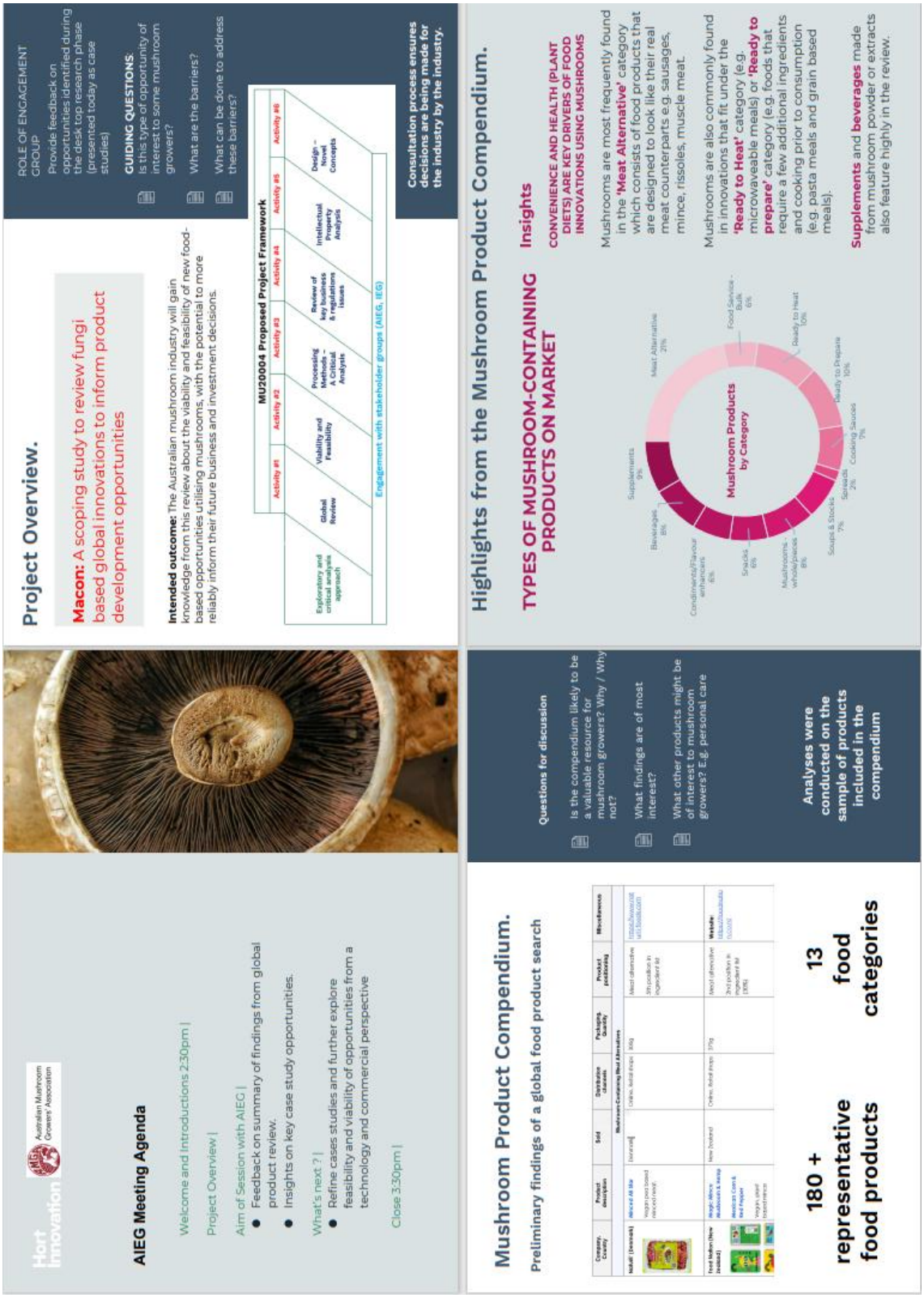
Hort Innovation | MUSHROOM FUND

This project has been funded by Hort Innovation using the mushroom research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Appendix C – AIEG Meeting Presentation Slides and Minutes

MU20004 AIEG Presentation Slide Deck

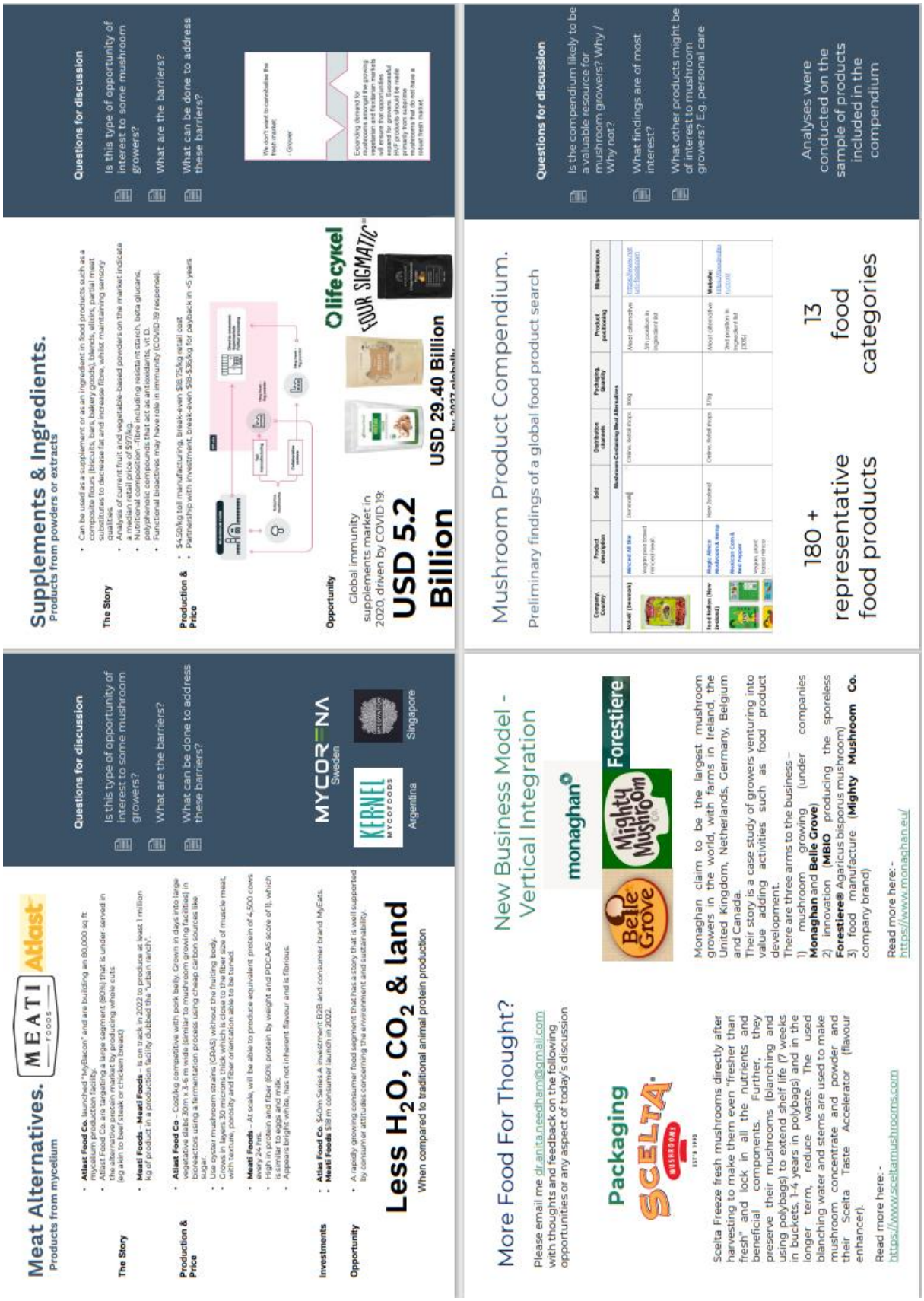
Slides 1-4



Slides 5-8


Highlights from the Mushroom Product Compendium.
MUSHROOM BY VOLUME ACROSS FOOD CATEGORIES
Mushroom as 1st ingredient
Mushroom as 2nd-5th ingredient
Insights
Formulations of 'meat alternative' products utilise the greatest amount of mushrooms by weight, followed by snacks (such as crisps, jerky).
Directing innovations to these categories may represent a sound investment decision.
Highlights from the Mushroom Product Compendium.
MAJOR COMPANIES
Companies producing mushroom food products (by number of different offerings)
Insights
A number of companies are actively engaged in product development based on their different offerings i.e. not necessarily the highest revenue producers.
Fable Foods (AU), Moving Mountains, Scelta, Monterey, Food Nation & Monaghan are key players in the mushroom food product innovation space.
Lyfe Cykel (AU) and Four Sigmatic are important companies innovating products from powdered mushrooms, including Agaricus bisporus.
What might be of interest to mushroom growers?
Case Study 1 Fable Food Co.
Case Study 2
Case Study 3
Meat Alternatives: Products from Fresh Mushrooms
Meat Alternatives: Products from Mushroom Mycelium
Supplements & Ingredients: Products from Mushroom Powders
Meat Alternatives.
Products from mushrooms
The Story
Production & Price
Investments & Partnerships
Opportunity
1000 T
2022 production volume
Questions for discussion
Is this type of opportunity of interest to some mushroom growers?
What are the barriers?
What can be done to address these barriers?
Formulations can use dried or fresh stems

Slides 9-12


Meat Alternatives.
Products from mycelium
MEATI FOODS
Atlast
The Story
Production & Price
Investments
Opportunity
Less H_2O, CO_2 & land
When compared to traditional animal protein production
Questions for discussion
Is this type of opportunity of interest to some mushroom growers?
What are the barriers?
What can be done to address these barriers?
MYCORENA
Sweden
KERNEL
MYCOFOODS
Argentina
Singapore
Supplements & Ingredients.
Products from powders or extracts
The Story
Production & Price
Opportunity
Global immunity supplements market in 2020, driven by COVID 19:
USD 5.2 Billion
USD 29.40 Billion
life cykel
FOUR SIGMATIC
Questions for discussion
Is this type of opportunity of interest to some mushroom growers?
What are the barriers?
What can be done to address these barriers?
Mushroom Product Compendium.
Preliminary findings of a global food product search
180 + representative food products
13 food categories
Questions for discussion
Is the compendium likely to be a valuable resource for mushroom growers? Why / Why not?
What findings are of most interest?
What other products might be of interest to mushroom growers? Eg. personal care
Analyses were conducted on the sample of products included in the compendium
More Food For Thought?
Please email me dr.anita.needham@gmail.com with thoughts and feedback on the following opportunities or any aspect of today's discussion
Packaging
SCELTA
MUSHROOMS
Scelta Freeze fresh mushrooms directly after harvesting to make them even "fresher than fresh" and lock in all the nutrients and beneficial components. Further, they preserve their mushrooms (blanching and using polybags) to extend shelf life (7 weeks in buckets, 1-4 years in polybags) and in the longer term, reduce waste. The used blanching water and stems are used to make mushroom concentrate and powder and their Scelta Taste Accelerator (flavour enhancer).
Read more here: -
https://www.sceltamushrooms.com
New Business Model - Vertical Integration
monaghan
Belle Grove
Forestiere
Mighty Mushroom
Monaghan claim to be the largest mushroom growers in the world, with farms in Ireland, the United Kingdom, Netherlands, Germany, Belgium and Canada.
Their story is a case study of growers venturing into value adding activities such as food product development.
There are three arms to the business -
1) mushroom growing (under companies Monaghan and Belle Grove)
2) innovation (MBIO producing the sporeless Forestiere® Agaricus bisporus mushroom)
3) food manufacture (Mighty Mushroom Co. company brand)
Read more here: -
https://www.monaghan.eu/

MU20004 MINUTES AIEG

Date: 16 September 2021 – 2.30 AEST
28 September 2021 – 12.30 AEST

These minutes captured 2 x AIEG meetings

Invited to Attend:

- Georgia Beattie
- Nick Femia – 2nd meeting
- Matthew Fensom- GM White Prince
- Phil Higgins – 2nd meeting
- Marion Lawson
- Dr Anita Stefoska-Needham
- Leah Bramich
- Kathryn Young
- Martine Poulain

Background:

A desktop review, including viability and feasibility analysis of potential opportunities for the Australian context, will be conducted utilising an appropriate level of industry engagement, both in Australia and overseas.

The Australian Industry Engagement Group (AIEG) comprising key mushroom growers who will invited to provide input on potential opportunities for the Australian Mushroom growers' market. Hence, this project aims to:

(i) identify "commercially ready" fungi-based global innovations and product development for Australia, from both waste and non-waste streams;

(ii) better inform the industry of new market opportunities and their potential viability and feasibility in the Australian context.

Welcome and Introductions
Aim of Session with AIEG:

- Feedback on preliminary findings of a global product review.
- Insights on key case study opportunities.
- Australian Industry Engagement Group (AIEG) comprising key mushroom growers who will provide input relating to their appetite for engagement/participation/further exploration in and of opportunities presented through the case studies
- Suggestions for key members of the IEG?

What's next?

- Refine cases studies and further explore feasibility and viability of 2-3 opportunities from a technology and commercial perspective

ENGAGEMENT MEETING - PART A: COMPENDIUM

Overview of project:

ASN provided an overview of the project

ASN defined the brief - project team tasked with conducting a global scan of commercially ready mushroom innovations, in order to inform industry of potential opportunities.

Intent of AIEG meeting:

ASN clarified meeting intent - to share key findings from the global scab and seek AIEG members' feedback on opportunities identified during the desk top research phase (presented in the meeting as case studies).

Early stage findings from the compendium:

A draft product compendium has been assembled and includes 180 food products across 13 different food product categories.

Although the project brief was to compile a compendium, ASN sought to obtain more meaningful data from the compilation (beyond a catalogue of products). Some results from this analysis include:-

- 21% of the products analysed in the compendium fell in the meat alternative category – which consists of food products that are designed to look like their real meat counterparts e.g. sausages, mince, and so on,
- 20% fell into either the **'Ready to Heat'** category (e.g. microwaveable meals) or **'Ready to prepare'** category that require a few additional ingredients and cooking prior to consumption also feature highly,
- **And powders used in Supplements** and **beverages** feature highly also.
- It seems that convenience, health, plant based foods are key consumer drivers and this aligns with global mega trends too.
- A deeper dive into food products containing mushrooms, found that mushrooms are used in the greatest volumes in formulations of **'meat alternative'** products, followed by snacks (such as crisps, jerky). This finding may be useful to direct innovations to these categories as a good starting point.
- A metric of innovation in food product manufacturing is the number of different product offerings. To this end, the compendium identified key companies who are active in the

food product innovation space. This is not reflective of revenue or other metrics of company success. (Food products - **Fable Foods (AU), Moving Mountains, Scelta, Monterey, Food Nation & Monaghan. Powdered products - Lyfe Cykel (AU)** and **Four Sigmatic).**

ENGAGEMENT MEETING - PART B: CASE STUDIES
What we found and what we are asking of the group:

- Convenience, health, and plant based products are key consumer drivers of mushroom-containing food product innovations
- Next step for project team in working towards answering the brief is to ask industry (AIEG members) this question: **What might be of interest to mushroom growers?**

T**o assist the members of the AIEG in discussions relating to the case studies presented, the following GUIDING QUESTIONS** were proposed by ASN:

- Is this type of opportunity of interest to some mushroom growers?
- What are the barriers?
- What can be done to address these barriers?

Case Study 1
Deeper dive into food products
1 – meat alternative products first
Valuable insights:

- Sub-prime mushrooms in the alternative space
- Products from fresh mushrooms
- They aren't novel or different but the new data validates what you expected and what you already know.
- is this an opportunity of interest?
- What are the barriers, and how to we address the barriers?

Fable:
They are in their 2nd year- partner with Grill'd, Guzman, and in November in America
They are projected to use 3 times the number of mushrooms stems for the next 10 years (from 300T in 2021 to 1000T in 2022 and beyond).
How does this make the growers feel about this type of partnership? What is the appetite to engage or partner with companies/food product innovators such as Fable?
They are backed by significant venture capital funds – they do use dried stems, but they

can work with fresh or dried mushroom.

To date it's been cost prohibitive to use fresh Aussie stems

ASN asked the group "would the industry launch these types of products and would growers provide stems to Fable or similar companies?"

Nick F – Whatever you sell them there is someone out there who will undercut.

Phil. H responded –Stems are a waste product for Parwan – the issue is the labour with the double cut and the washing process. His view is that mushrooms become an ingredient and would we enter that space – if mushroom sales grew so much because of this then it is value.

you have funds available where do you invest them? Might be easier to open a market stall-open a restaurant - selling mushrooms stems are just an ingredient. Fable will want a very low price – what's the return to us?

If using stems in China, their govt subsidise this – if it was in Australia it could work

what is the cost of double cutting, cleaning and transport and get a margin on sale price – it would need to be $2.50-$3.00 a kilo

ASN – instead of mushroom stems going to waste, could any growers be interested in moving their stems? What is the appetite with industry to support the development of innovation to support smaller companies to do that?

Phil – it becomes a commercial item so it comes down to individual businesses unless AMGA says we want to develop this market – once the commercial area is crossed, difficult to manage

Georgia B –they are using imported mushrooms – the model isn't based on current mushroom prices. There isn't a lot of added value in this situation - there is a trend I agree, but I'd like to see where this goes. Commercial reality we haven't seen just yet

Marion – Marion confirmed that she did this research work to develop mushroom stems to make mushroom burgers many years ago. It was a patent, but it has lapsed. They were using Indonesia as labour, which was cheaper – but she found it couldn't be done in Australia, as labour is too expensive. There is no system for cleaning mushroom stalks (peat moss) so it is labour intensive – so it is a 2 cut process and you can't compete with meat with the cost - it didn't work then and nothing has happened yet for agaricus - for the other areas of fungi there is scope.

ASN – this is what Fable said re price and making it competitive by using Australian stems

Based on comments, she wanted to clarify who the early adopters might be to get into this through partnerships? could the mushroom industry be a supplier here?

Georgia: "every farm for itself" there is no collaboration – hard to bring the industry in on that

Matthew – His view is that the AMGA doesn't get involved commercially. He said cutting of stalks doesn't work – every mushroom farm has spoken to Fable but can't get to the price. Alternatives from poorer grade mushrooms. Why use mushrooms? meat alternative is soy….and cheap– was is it that drives the meat alternative products? He said if we could find a way to sell more mushrooms through alternative products in

Summer, he would be keen to hear more on this. They produce the same amount of mushrooms all year round, but consumption is slow in summer. if we could find an alternative in Summer - then we would all be happy.

Leah – Leah mentioned the Fungus chain project in Europe - a lot of R & D took place for that project. and it would be worth consulting with the fungus chain project for innovations in that space. They show how to wash and dry stalks.

Marion –not familiar with that project –

From the perspectives of the industry members present in the meeting, interest in further developing Case study 1 was not strong.

Case Study 2

The second case study from the findings from the compendium were products made from mycelium

Strong consumer attitudes, sustainability and the environment

2 companies:

Meati Foods and Atlast – 4500 cows worth pf protein produced every 24 hours - done from mycellium

ASN: Anita said there was a capacity to grow mushrooms for this type of product

Georgia: great idea – thumbs up – really exciting space –food and packaging

Marion: exciting area – Marion had been involved in it. They didn't use agaricus mycelium, but rather chicken of the woods, lions mane – there is now the technology to do that much less cost to produce - more industrial manufacturing

Matthew – exciting but I don't believe the mushroom growers will want to fund it – it will make mushroom farms redundant.

Georgia: I disagree-it is coming and we are in a good place to take advantage and we can be on the front foot

Phil H: Huge new market – it's not mushrooms growing though. New technology. I'd be surprised if this company is making any money on this yet – I don't think any of us have the funds. It would be good to see the figures. Meat alternatives is a massive growth area – add to reducing the carbon footprint etc …what's the capital cost? Id like to learn more – I give this a green light

Nick F: what does this have to do with me being a mushroom farmer. I don't see the connection for us as selling fresh mushrooms - 10 years ago we were hounded to grow exotic mushrooms – it hasn't affected our sales at all. so I don't see this being a threat - Mycellium in packaging, that's interesting! but that's all

Leah: We need to look at the mycelium based products as they are a threat to industry. we need to see this coming

ASN –we have to go beyond "what's out there"' – Mycellium is being used to mimic real meat - has the same texture/fibre – so in the meat alternative category, this is where mycellium comes in. Should we be gaining knowledge in this space?

From the perspectives of the industry members present in the meeting, interest in further developing Case study 2 was evident.

Case study 3

Immunity supplements markets/Mushroom powders

Driven by the findings

featured largely

There is a market opportunity

Global immunity sector projected to hit $30b over the next 6 years

On the back of Covid 19 - Mushroom powders are gaining the reputation for immunity effects

Anita drew upon the Xinova report- mushroom powder was of value then

Costs from Xinova report:

Value MP $95 kilo

produce was $19

partnership was $18-$36

payback projected in 5-year period

ASN: This was a successful trial in Xinova - levels of BC and D and fibre were impressive, so I've gone back to understand why this hasn't moved in Australia –there was an identified partner that could manufacturer the powder

Nick: this is exciting - this is a practical outcome – Australian Mushroom powder almost makes it exportable -Vitamin D as well – this has some merit. The industry should have somewhere to sell their products when there is an oversupply….and their waste products

Phil H: You have to take into account that a mushroom is 90% water – you need 10 kilos to make 1 kilo. You just need to do the numbers - a business case

Anita: when you look at the price $97 retail – wholesale is $50 a kilo - fresh mushrooms you do better than that – you could use waste product – but you use energy and labour. Do you see value in updating this as a case study/an opportunity.

Georgia: I have done research - have you taken into account water content in mushrooms? price - per kilo and dry that down and there is 6% of a kilo left to then justify drying them than just selling them fresh. I love this space but!

ASN – what about waste?

Georgia – getting peat off the stems, double cutting - same as case 1

ASN – what about the normal mushrooms and seconds

Matthew- it comes down to the economies of scale you need. Yes we all have mushrooms cheaper in summer but volume is the issue. It can have opportunity.

Marion- comes down to fruiting body versus mycelium

ASN – theme that growers were concerned about cannibalising the fresh market in the Xinova project

Georgia – no longer an issue

Leah: HIA is funding a project to explore lowering cholesterol (CSIRO) – so the stalks which are a waste product. Is there an opp pending the results, for us to get ahead of the game and explore this further here in Australia. This is Fungus Chain also.

ASN – FSANZ encompasses the Food Standards Code in Australia – medical health supplements requires the TGA to be involved – dietary supplementation

Marion – had suppliers In China – products they said were Reishi etc, but it wasn't great-heavy metal content was high so there is a need for testing product that comes into the country

From the perspectives of the industry members present in the meeting, interest in further developing Case study 3 was evident.

Conclusions

A final slide was presented to encourage discussions related to:-

(i) PACKAGING

Interesting area to explore.

Customers want to buy packaged products for food safety.

Shelf life is a big thing for industry – how much? Need to see the figures.

(ii) BUSINESS MODELS - vertical integration.

(iii) COMPENDIUM FEEDBACK

Anita sought feedback on the value of the compendium – is this a valuable resource?

Georgia – this is great. On a farm you forget what else is out there - Blue Sky thinking

I' m open to anything you want to present in the future

Matthew –I agree - there is a lot of industry people who want to see this.

AEIG members were invited to email ASN with any opinions / feedback on these issues.

~END~

Appendix D – Case Studies Presented to AIEG

Case Study 1.

Meat Alternatives.

Products from mushrooms

The Story

- 3 co-founders (a mycologist, mushroom farmer and an entrepreneur), based in Queensland.
- Product development in Malaysia, now in its second year of production of producing shitake-based (stems) foods from product conception to product on shelf.
- Currently offer burgers, pulled pork products, meal kits, ready to heat meals.
- First sold in AU, now also sold in Singapore, UK & US (Nov 2021)
- Inspired by Impossible Burger and Beyond Burger start-ups in USA
- Key drivers are 1) taste 2) meaty texture 3) affordability
- Values based company – seeks to reverse 110kg meat vs 3 kg mushroom consumption pattern of Australians.

Production & Price

2021 mushroom utilization 300 T per annum.
2022 mushroom utilization 1000 T per annum target
Must be cheaper than meat. Currently @ $25-40/ kg product dependant

Investments & Partnerships

- Marley Spoon and Dinnerly
- Grill'd (136)
- Soul Burger
- Guzman y Gomez
- Heston Blumenthal brand ambassador
- Sold into Coles (470), Woolworths (600), Harris Farm Markets.
- Sold into 200 independent restaurants and cafes

Opportunity

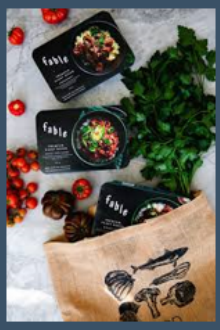
- Australia is the worlds 2nd largest vegan market (behind UK)
- $215m by end 2021 (Euromonitor International)
- In August 2021, raised $6.5m (Blackbird Ventures, AgFunder, and others)
- Food service push, including discussions with Govt departments
- Particularly interested in using AB stems

1000 T
2022 production volume

"We have a definite desire to use agaricus bisporus stem from Australia, however the price is too high and we need to avoid compost residue" **Michael Fox - CEO**

Questions for discussion

- Is this type of opportunity of interest to some mushroom growers?
- What are the barriers?
- What can be done to address these barriers?



Formulations can use dried or fresh stems

Case Study 2.

Meat Alternatives.

Products from mycelium

MEATI FOODS

Atlast

The Story

- **Atlast Food Co.** launched "MyBacon" and are building an 80,000 sq ft mycelium production facility.
- Atlast Food Co. are targeting a large segment (80%) that is under-served in the alternative protein market by producing whole cuts (eg akin to beef steak or chicken breast)
- **Meati Foods – Meati Foods** – Is on track in 2022 to produce at least 1 million kg of product in a production facility dubbed the "urban ranch".

Production & Price

- **Atlast Food Co** – Cost/kg competitive with pork belly. Grown in days into large vegetative slabs 30m x 3-6 m wide (similar to mushroom growing facilities) in bioreactors using a fermentation process using cheap carbon sources like sugar.
- Use oyster mushroom strains (GRAS) without the fruiting body.
- Grows in layers 30 microns thick which is close to the fiber size of muscle meat, with texture, porosity and fiber orientation able to be tuned.
- **Meati Foods** – At scale, will be able to produce equivalent protein of 4,500 cows every 24 hrs.
- High in protein and fiber (60% protein by weight and PDCAAS score of 1), which is similar to eggs and milk.
- Appears bright white, has not inherent flavour and is fibrious.

Investments

- **Atlas Food Co**. $40m Series A investment B2B and consumer brand MyEats.
- **Meati Foods** $18 m consumer launch in 2022.

Opportunity

- A rapidly growing consumer food segment that has a story that is well supported by consumer attitudes concerning the environment and sustainability.

Less H_2O, CO_2 & land

When compared to traditional animal protein production

Questions for discussion

- Is this type of opportunity of interest to some mushroom growers?
- What are the barriers?
- What can be done to address these barriers?

MYCORENA
Sweden

KERNEL MYCOFOODS
Argentina

MYCOVATION
Singapore

Case Study 3.

Supplements & Ingredients.

Products from powders or extracts

The Story

- Can be used as a supplement or as an ingredient in food products such as a composite flours (biscuits, bars, bakery goods), blends, elixirs, partial meat substitutes to decrease fat and increase fibre, whilst maintaining sensory qualities.
- Analysis of current fruit and vegetable-based powders on the market indicate a median retail price of $97/kg.
- Nutritional composition –fibre including resistant starch, beta glucans, polyphenolic compounds that act as antioxidants, vit D.
- Functional bioactives may have role in immunity (COVID-19 response).

Production & Price

- $4.50/kg toll manufacturing, break-even $18.75/kg retail cost
- Partnership with investment, break-even $18-$36/kg for payback in <5 years

Opportunity

Global immunity supplements market in 2020, driven by COVID 19:

USD 5.2 Billion

life cykel

FOUR SIGMATIC®

USD 29.40 Billion

by 2027 globally

Questions for discussion

- Is this type of opportunity of interest to some mushroom growers?
- What are the barriers?
- What can be done to address these barriers?

We don't want to cannibalise the fresh market.

- Grower

Expanding demand for mushrooms amongst the growing vegetarian and flexitarian markets will ensure that opportunities expand for growers. Successful HVF products should be made primarily from subprime mushrooms that do not have a robust fresh market.

Appendix E – Fungus Chain Case Study

The FUNGUSCHAIN Project*

Valorisation of mushroom waste using cost-effective extraction technologies

BioDetection Systems

Estimated total funding 8.14 m EUR (12.9 m AUD) collaborative project between public and corporate

What is FUNGUSCHAIN?

Counties in the European Union generate a considerable amount of agricultural by-products which are often discarded as waste or used for low-value applications. This is also seen in European mushroom farming practices.

The FUNGUSCHAIN project was established to disrupt and transform mushroom growing and its associated waste management by establishing a bio-based, circular economy. The main aim was to enable cost effective extraction of diverse high-value components from mushroom agro-waste at industrial levels for the subsequent creation of new bio-based products.

Specific objectives were to:
1.Demonstrate an integrated, series of cascading processes that achieved more than 40% valorisation of mushroom cultivation residues into high-value bio-based products.
2.Validate and demonstrate the successful extraction of biomolecules into high value products commercially.
3.Prove consumer acceptance of products developed and enhance the competitiveness of participating businesses, with a particular focus on local entrepreneurship and advancement in rural areas in Europe.

METHOD A cascading process approach, following 4 steps of microwave-assisted extraction, pressurised hot-water extraction, saccharification fermentation and anaerobic digestion to extract high value bio-based additives. Lipids are converted into bio-plasticisers and polysaccharides into biopolymers. The remaining side streams are composted and/or used for biogas synthesis.

Additives were incorporated into high added value products: protein supplements for the elderly, eco-friendly house cleaning products, novel bio-based thermoplastic masterbatches, bio-plasticisers and industrial film products.

Interesting observations: Monaghan Mushrooms invested in the creation of an operational commercially attractive biorefinery & innovation centre, providing both the equipment and knowledge for sustained and varied mushroom-based product innovation. Monaghan mushrooms are investing in innovation, and the translations of science to new product development as their core future competitive advantage.

* Grant: BB1_VCR_D5-2015 "Valorisation and side streams from the agro-food industry"

Opportunity

1. Poor management of agricultural waste streams.
2. Environmental concerns e.g. expiration of non-renewable resources.
3. Opportunities to create value to waste streams and increase profits.
4. Movements towards creation of circular economies globally.

Considerations for the Australian Mushroom Industry

1. What are the current infrastructure and skills capabilities in Australia to exploit a similar model to FUNGUSCHAIN?
2. What are the market opportunities for bio-based products?
3. What possible partnerships could be pursued?

Appendix F – Ideation Session Presentation Slides

Slide 1

Hort Innovation

Australian Mushroom Growers' Association

Macon: A scoping study to review fungi based global innovations to inform product development opportunities

Activity 6 – Product concept ideation session

3:30pm AEDT 19 Jan 2021 |

Welcome |

Activity Overview and Aims/Desired Outcomes |

Review of Methodology |

Ideation Session |

What's next ? |

Close 3:30pm |

Slide 2

Product concept ideation

Intended outcome: To leverage the results of the compendium, as well as learnings from our case studies, into some **early concepts** for consideration by the Australian mushroom growers interested in participating in the food innovation space.

Concepts will fall under three trending categories that are of current interest to consumers:

- Health foods
- Food Service
- Snackification

It should be noted that whilst there may be many different interesting concepts that food product innovators might be interested to develop, the **execution of these concepts into sustainable businesses relies on a diverse mix of skills and experience, an entrepreneurial mindset with a high tolerance for risk and sufficient funding and business planning.**

Results of Activity 6 aim to

inspire

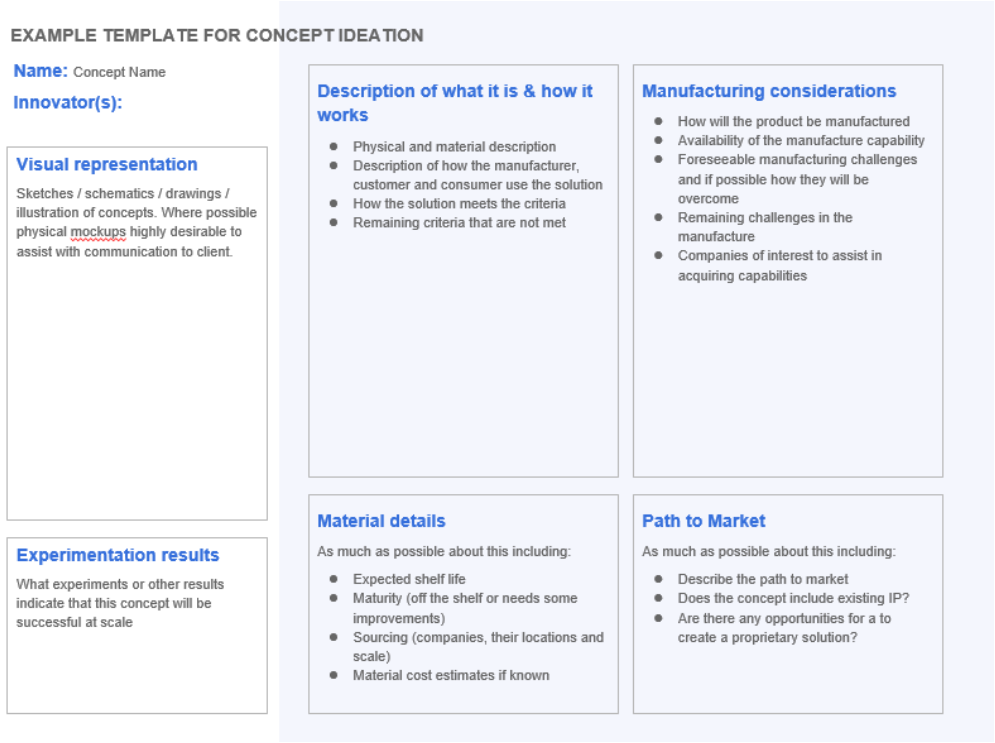
Australian mushroom growers who are interested in mushroom food product innovation.

ADVANTAGE OF OUR IDEATION APPROACH: Conducting an ideation session with participants who have experience with the mushroom industry ensures concepts have greater relevancy to industry members.

Slide 3


Hort Innovation
Australian Mushroom Growers' Association
Ideation Session:
For consideration with each concept:-
Opportunity / market / target group
Advantages over existing counterparts
Current challenges
See overpage for additional guiding questions

Slide 4


EXAMPLE TEMPLATE FOR CONCEPT IDEATION
Name: Concept Name
Innovator(s):
Visual representation
Sketches / schematics / drawings / illustration of concepts. Where possible physical mockups highly desirable to assist with communication to client.
Experimentation results
What experiments or other results indicate that this concept will be successful at scale
Description of what it is & how it works
Physical and material description
Description of how the manufacturer, customer and consumer use the solution
How the solution meets the criteria
Remaining criteria that are not met
Manufacturing considerations
How will the product be manufactured
Availability of the manufacture capability
Foreseeable manufacturing challenges and if possible how they will be overcome
Remaining challenges in the manufacture
Companies of interest to assist in acquiring capabilities
Material details
As much as possible about this including:
Expected shelf life
Maturity (off the shelf or needs some improvements)
Sourcing (companies, their locations and scale)
Material cost estimates if known
Path to Market
As much as possible about this including:
Describe the path to market
Does the concept include existing IP?
Are there any opportunities for a to create a proprietary solution?