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We look forward to continuing to work with all members of the mushroom supply chain, delivering information the industry wants, the way the industry wants it.

(MU21003: Mushroom industry communications program) is a Hort Innovation mushroom fund project.
It is funded through the mushroom levy and contributions from the Australian government. Applied Horticultural Research (AHR) is the key research provider for this project.

Highlights

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Figure 1. Mushroom phorid on a mushroom cap

PHORID ECOLOGY AND MANAGEMENT

by **Dr Jenny Ekman**

Flies in mushroom crops are a persistent, annoying, and occasionally, very damaging issue that all growers will face at some time.

Most research has focussed on sciarids (*Lycoriella* spp.), often the most common species present. The maggots feed on organic matter in compost and readily adapt to captivity, making research relatively easy.

Mushroom phorid flies may be a minor problem on most Australian farms, but in many countries – including Spain, Turkey, India, the UK and the US – they are a major pest. Yield losses of 10 to 40% have been widely reported[1]. Some Australian farms are now also reporting persistent populations of these flies.

Unlike sciarids, phorid maggots feed directly on the *Agaricus* mycelia, potentially affecting both yield and quality.

Apart from direct crop damage, phorids are pathogen vectors, particularly dry bubble disease (*Lecanicillium fungicola* var. *fungicola*). This fungal parasite produces masses of conidia covered with sticky mucilage that readily sticks to tiny fly feet[2]. Brown blotch bacteria and mites can also be spread by flies moving around the grow room.

High populations of phorids (or any fly species) are also a significant nuisance in growing rooms. Getting and keeping good staff is difficult enough without asking them to pick mushrooms in a cloud of annoying flies.

Then there are the issues with the neighbours. In a recent MushroomLink podcast, Geoff Price from Giorgi Mushroom Co. Penn State commented on this issue in the US.

"The whole community here is up in arms about the phorids, it's become a big problem."

1 Navarro MJ, Escudero-Colomar LA, Carrasco J, Gea FJ. 2021. Mushroom phorid flies – A review. Agronomy: 11:1958. https://doi.org/10.3390/agronomy 11101958

2 Gea FJ et al. 2021. Control of fungal diseases in mushroom crops while dealing with fungicide resistance: A review. Microorganisms, 9:585.

Figure 2. Phorid flies on mushrooms infected with dry bubble. From Navarro et al., 2021.

"There are a lot of mushroom farms here, but also a lot of expensive housing. In summer, when people are outside, they can get really clobbered".

New research has been investigating phorid biology, ecology, and the best ways to manage these annoying pests.

LIFE CYCLE

The phorid *Megaselia halterata* has been considered a significant mushroom pest since 1953, when population explosions occurred in British mushroom farms. While there are other *Megaselia* species which can also cause problems, particularly *M. nigra*, *M. halterata* is an *Agaricus* and *Pleurotus* specialist not found on other fungal hosts.

Female *M. halterata* are strongly attracted to growing *Agaricus* mycelia. The more mycelia present, the stronger their response. They are therefore more attracted to Phase III compost than compost which has been recently spawned[3].

Each female can lay at least 50 eggs during her lifecycle. These are deposited close to growing mycelia, so primarily in the top layer of Phase III compost. Eggs are also laid in casing if it has been colonised by the mycelium; flies do not lay into freshly applied casing[4].

The maggots feed on *Agaricus* mycelia until they are fully mature, after which they migrate upwards into the top of the compost or casing and pupate. Males tend to emerge before females, with both sexes being ready to mate around five days after emergence.

Temperature vs time

Temperature is a key determinant of development rate for all insects, and phorids are no exception. Development slows markedly once temperatures fall below 18°C[5]. As a result, it takes twice as long for flies to complete their lifecycle at 15°C compared to 18°C (Figure 4).

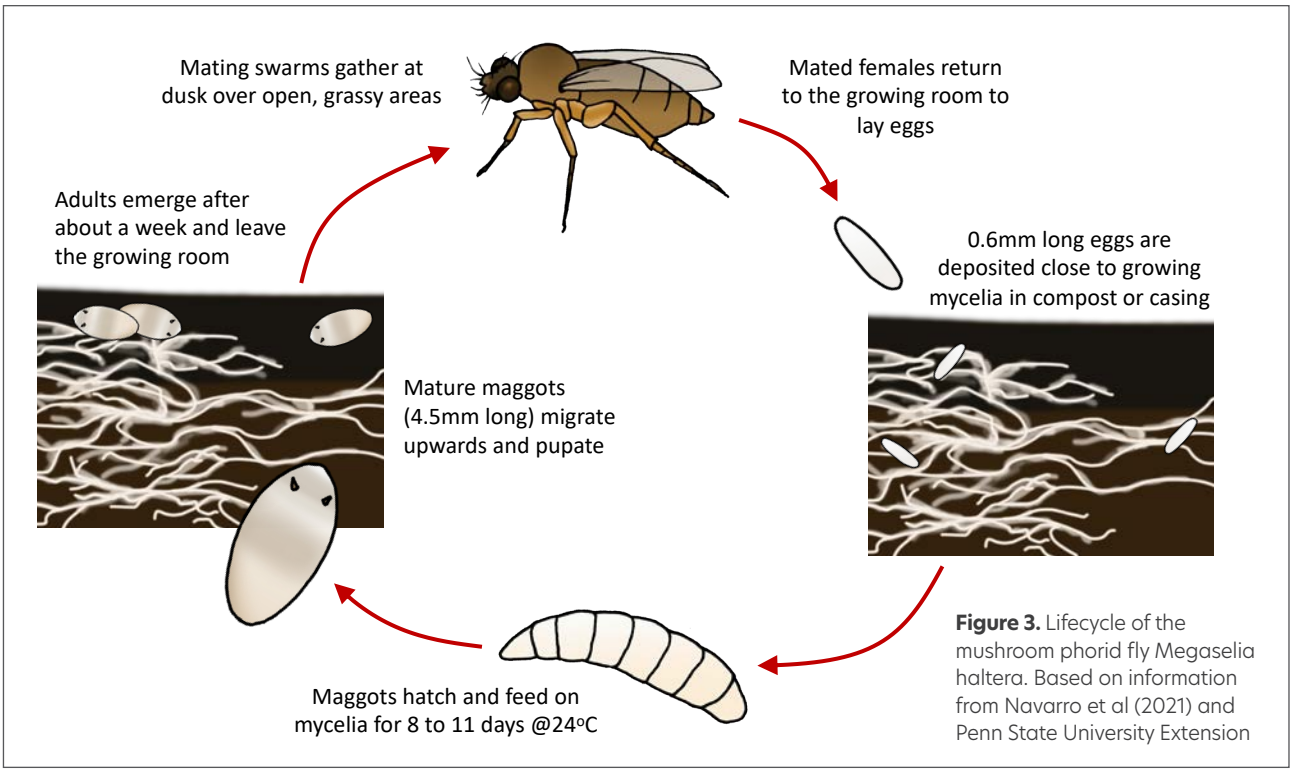


Figure 3. Lifecycle of the mushroom phorid fly Megaselia haltera. Based on information from Navarro et al (2021) and Penn State University Extension

3 Tibbles LL et al. 2005. Evaluation of the behavioural response of the flies Megaselia halterata and Lycoriella castanescens to different mushroom cultivation materials. Entomol. Exp. Applic. 116:73-81.

4 Scheepmaker JWA, Geels FP, Smits PH, Van Griensven LJLD. 1997. Location of immature stages of the mushroom insect pest Megaselia halterata in mushroom growing medium. Entomol. Exp. Applic. 83

5 Barzegar S et al., 2016. Temperature dependant development modelling of the phorid fly Megaselia halterata (Wood)(Diptera: Phoridae). Neotrop Entomol. 45:507-516.

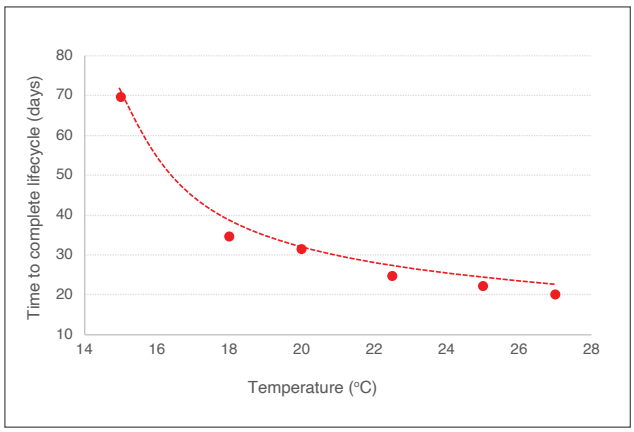


Figure 4. The development rate of phorids from egg to adult fly increases as temperatures rise, so populations can grow rapidly at temperatures 20°C or more. Derived from Barzegar et al., 2016.

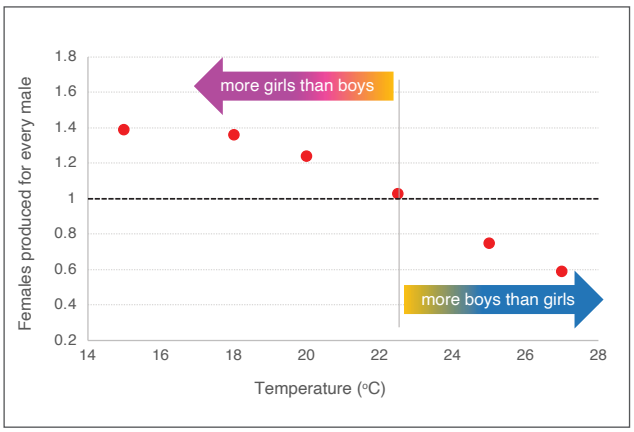


Figure 5. Temperature also affects the male to female sex ratio of phorids, with temperatures below 22°C increasing the number of female flies. Derived from Barzegar et al., 2016.

However, low temperatures also mean that adult flies live longer. For example, a female phorid will live for 4-5 days at 21°C, but 8-9 days at 15°C[6]. This increases her opportunity to mate and lay eggs.

Interestingly, temperature also has a big impact on the male to female ratio[4]. At low temperatures more females are produced than males. However, once the temperature goes over 22°C the situation is reversed, with more males than females (Figure 5).

Humidity is also important. Research indicates increasing RH from around 45% to 80% allows phorids to live at least 50% longer, with females being more responsive than males[5].

The cool (15 to 21°C), humid (>80%) conditions inside most mushroom grow rooms are therefore ideal for phorids. However, despite constant year-round conditions inside growing rooms, large seasonal fluctuations in populations occur. For example, in Pennsylvania fly populations double during spring, grow during summer, peak in autumn then dramatically decline during winter[7].

This is because the flies mate outside. Once the males emerge from their pupae, they leave the grow rooms and form groups outside, waiting for the females. A life-cycle study by Mazin et al[8] revealed that courtship and mating occur over grassy areas, with most activity from late afternoon until dusk. At these times great swarms ('leks') would form, with clouds of insects circulating rapidly close to the ground. Mating occurs mid-air, with around 30% of captured flies 'in-copula'.

Phorids were rarely found around spent mushroom compost or wooded, windbreak areas, further confirming that they only go outside to mate, then return to the grow rooms to lay eggs (Figure 6). Fresh compost, and piles of cooked-out spent compost, are not sources of infestation as they do not contain active *Agaricus* mycelium, so are therefore unattractive to the flies.

Agaricus mycelium can feed a lot of maggots; a single kilo of Phase III compost has been shown to support the development of 4,000 flies. Theoretically, this could translate into an apocalyptic 160,000 flies/m^2 inside a grow room, something nobody wants to experience!

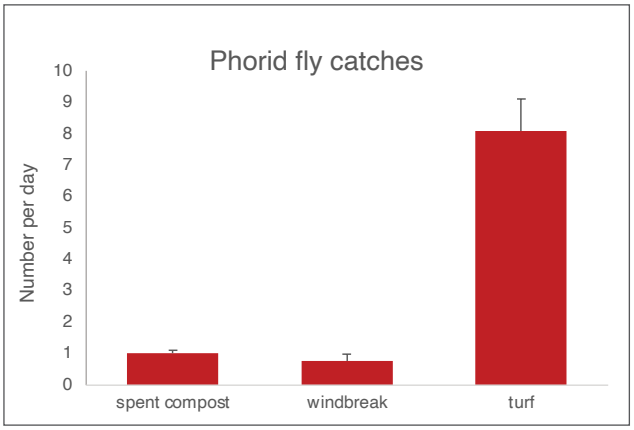


Figure 6. Number of phorids caught using yellow sticky traps placed at different locations around mushroom farms. Derived from Mazin et al., 2019.

6 Shikano I et al., 2021. Biology of mushroom phorid flies, Megaselia halterata (Diptera: Phoridae): Effects of temperature, humidity, crowding and compost stage. Environ. Entomol. 50:149-153.

7 Keil, CB., 2002. Mushroom integrated pest management. The Pennsylvania State University, PA.

8 Mazin M et al., 2018. Activity and distribution of the mushroom phorid fly, Megaselia halterata, in and around commercial mushroom farms. Entomol. Exp. Applicata. 167:389-395.

MANAGING PHORIDS

Chemical fly swats

The list of chemicals once registered in Europe to control phorids was long, including orghanophosphates, methoprene, benzoylurea, pyrethroids and carbamates. They were generally mixed into either the pasteurised compost or casing.

However, most can no longer be applied due to potential uptake of these chemicals into the mushrooms. Phorids first became a problem in Pennsylvania in 2012, when the US EPA cancelled the registration of diazinon insecticide for use on mushroom farms.

By the mid 1980s, *M. halterata* had become resistant to a wide range of insecticides[9]. Moreover, results were variable for several products, while others had toxic effects on the *Agaricus* mycelia[1].

There are several products registered for control of phorids on Australian mushroom farms. Most have fipronil as the active ingredient, while one has cyromazine. They are applied by mixing with peat during preparation of casing. There are no insecticides listed by APVMA which can be applied post-casing (N.B. Always use insecticides according to the label directions and confirm it is registered in your jurisdiction).

Biological fly swats

Biological products may or may not provide an alternative. For example, trials in Turkey[10] found that two neem-based products were as effective as chlorpyrifos at controlling phorid maggots in compost. However, the products were applied as a drench after casing, raising the possibility of transfer into the mushrooms. Although a natural plant extract, neem is not currently registered in Australia for use on edible crops, so approval of this use pattern seems unlikely.

Targeting the adult flies and avoiding contact with the mushroom substrate is a less problematic approach.

Pesticide screening by Penn State Researcher Dr Mike Wolfin showed that adult phorid flies were highly susceptible to a biopesticide composed of botanical oils (EcoVia EC by Rockwell Labs). The researchers applied the biopesticide to areas likely to be contacted by the flies, such as air vents and attic areas. It was also applied to electrostatic screens placed at key entry and exit points.

Dr Wolfin comments: "By November 2020 we were seeing almost complete elimination of phorids on our test farms. On the test farm where we implemented all the controls, we didn't find any flies."[11]

Another proposed control strategy lies with the white muscardine fungus *Beauveria bassiana*. This entomopathogenic fungus has a wide host range and can certainly kill insects.

A commercial formulation of *B. bassiana* (BotaniGard ES) has a label extension in the US allowing use in mushroom houses against phorid and sciarid flies (NB. this product is not currently registered with APVMA). Although Penn State researchers[12] found that exposure to the product led to 100% mortality of adult flies, it

Figure 7. Installing an electrostatic screen treated with biopesticide in a mushroom house, and dead phorids inside the screen. *- Photos: M Wolfin.*

9 Cantelo WW. 1985. Control of Megaselia halterata, a phorid fly pest of commercial mushroom production, by insecticidal treatment of the compost or casing material. J. Entomol. Sci. 20:50-54.

10 Erler F. et al. 2008. Control of the mushroom phorid fly Megaselia halterata (Wood) with plant extracts. Pest Mgmnt. Sci. 65:144-149.

11 https://www.psu.edu/news/impact/story/penn-state-entomologists-devise-system-control-mushroom-phorid-flies/. Published online January 2021 by J Mulhollem.

12 Andreadis SS., et al. 2021. Efficacy of BotaniGard® against the mushroom phorid fly Megaselia halterata. Biocontrol Sci. Tech. 31:1098-1106.

Figure 8. The white muscardine fungus Beauveria bassiana is deadly against a wide range of insects, including this caterpillar. *- Photo by G Jacob.*

Figure 9. Adult phorid fly. From Navarro et al., 2021.

took an average of eight days for flies to die. While a significant result, it was concluded that this was unlikely to meaningfully reduce phorid populations on mushroom farms.

Insect-attacking nematodes are another possible biological control agent. Various nematode species, include *Bradynema* spp. and *Howardula* spp. parasitise flies, and there are reports of infection rates reaching 60 to 75% during autumn when phorid populations are highest[13]. Unfortunately, while these nematode species can reduce egg laying, they do not kill their host. Rearing and releasing infected flies is therefore unlikely to provide a practical control measure[14].

There are also several *Steinernema* spp. nematodes that attack phorids. There have been positive reports of their effects when watered into the casing layer, not only on emergence of phorids but also on quality and yield of mushrooms [15]. Commercial formulations of factory grown nematodes are available in Europe and can be easily applied. Unfortunately, as with many biological products, effectiveness can be highly variable[1].

Avoiding the issue

Prevention is better than cure, so blocking access to growing mycelium is sure to be part of the answer. In the US, most farms load Phase II compost then conduct the spawn run inside the growing rooms. Once Phase III is complete, the rooms are opened to permit casing. Opening the room at this stage provides a powerful attractant to the invading phorids. One of the proposed control strategies is to avoid scheduling such critical activities at times when phorids are active. Phorids are inactive at night and cannot fly at temperatures below 15.5°C. Infestation of Phase III compost is therefore unlikely between sunset and early morning, and later in cooler areas.

Australian farms generally load Phase III compost, casing it as the room is filled. This presents a smaller window of opportunity to phorids, which may be one reason we have less problem with these pests.

Pennsylvania's cold winter breaks the phorid lifecycle, and this may also hold true in southern areas of Australia. It also seems possible that the hot, dry summer in parts of Australia could have a negative impact on the ability of phorids to lek and mate.

To conclude, a whole range of tools are available to help manage phorids. However, prevention is better than cure, so regular scouting and monitoring is the first step to managing these tiny pests.

13 Hussey, NM. 1964. Observations on the association between Bradynema sp. (Nematoda : Allantonematodidae) and the mushroom infesting fly Megaselia halterata (Diptera:Phoridae). In "Proc. 12th Int. Conf. Entomol." London, UK:pp. 71-83.

14 Richardson PN, Chanter DO. 1981. Aspects of the laboratory production of mushroom phorid flies (Megaselia halterata) parasitised by the nematode Howardula husseyi. Ann. Appl. Biol. 99:1-9.

15 Grewel PS, Richardson PN, Collins G, Edmondson RN. 1992. Comparative effects of Steinernema feltiae (Nematoda: Steinernematidae) and insecticides on yield and cropping of the mushroom Agaricus bisporus. Ann. Appl. Biol. 121:511-520.

EXPLORING THE POTENTIAL OF SPENT MUSHROOM SUBSTRATE FOR **SUSTAINABLE AGRICULTURE**

To maintain consumer appeal and a competitive edge, business must strive for that magical triple bottom line of social, economic and environmental sustainability. Striking that balance is an ongoing challenge due to a fickle global economy and increasingly unpredictable weather patterns.

Despite enjoying more controlled and controllable conditions than most horticultural industries, the mushroom industry is still at the mercy of some external factors. For example, the Australian mushroom industry relies heavily on wheaten straw as a key ingredient in the production of mushroom growing substrate. However, the effects of drought, climate change, changed farming practices, and increased competition from the feedstock industry have reduced the availability of wheaten straw to mushroom farmers, driving up prices.

Increasing the value proposition of SMS for the end user, particularly grain growers, is one approach to help offset the increasing costs of wheat straw.

The project

In a R&D levy-funded project, a team of experts has been developing models for the upgrading of spent mushroom substrate (SMS), which would work toward a circular economy that is not only sustainable but improves a grower's economic bottom line.

This project, led by agricultural scientist Dr Kevin Wilkinson, soil scientist Dr Cassandra Schefe, and

Key points

- The Australian mushroom industry relies heavily on wheaten straw, which has become less available and therefore expensive.
- Increasing the value proposition of SMS for the end user will help generate more income from this waste product.
- A levy-funded project is underway with a focus on improving SMS value proposition for end-users, particularly grain growers.
- One of the significant challenges in developing a circular economy for SMS is the geographical disconnect between grain cropping and mushroom farms.
- Strengthening linkages between the mushroom industry and grain growers could have a significant impact on the sustainability of agriculture in Australia if these challenges can be overcome.

agronomist Mr David Hawkey, seeks to equip Australian mushroom growers with an improved understanding of the options available for recycling SMS.

The team has already completed several key steps in the project, including a review of past research, to establish the value proposition of SMS as a value-added product, and mapped potential end-users of SMS – the agricultural producers. Another critical part of the project is the physico-chemical characterisation of SMS to confirm whether boosted SMS is any good as a soil amendment/fertiliser.

The team is in the process of conducting interviews with grain growers to understand what value they place on SMS and their willingness to use a value-added SMS fertiliser product.

Demonstration trials are a potential next step, involving mushroom growers and agricultural producers to showcase the product.

The challenges

For cropping farmers to consider receiving SMS-derived products - either instead or, or in-addition to other farm inputs - a range of issues around product quality/ integrity, transport, logistics and soil/plant benefits need to be addressed.

An analysis of the composition of SMS revealed several shortcomings for use as a fertiliser supplement by grain growers including:

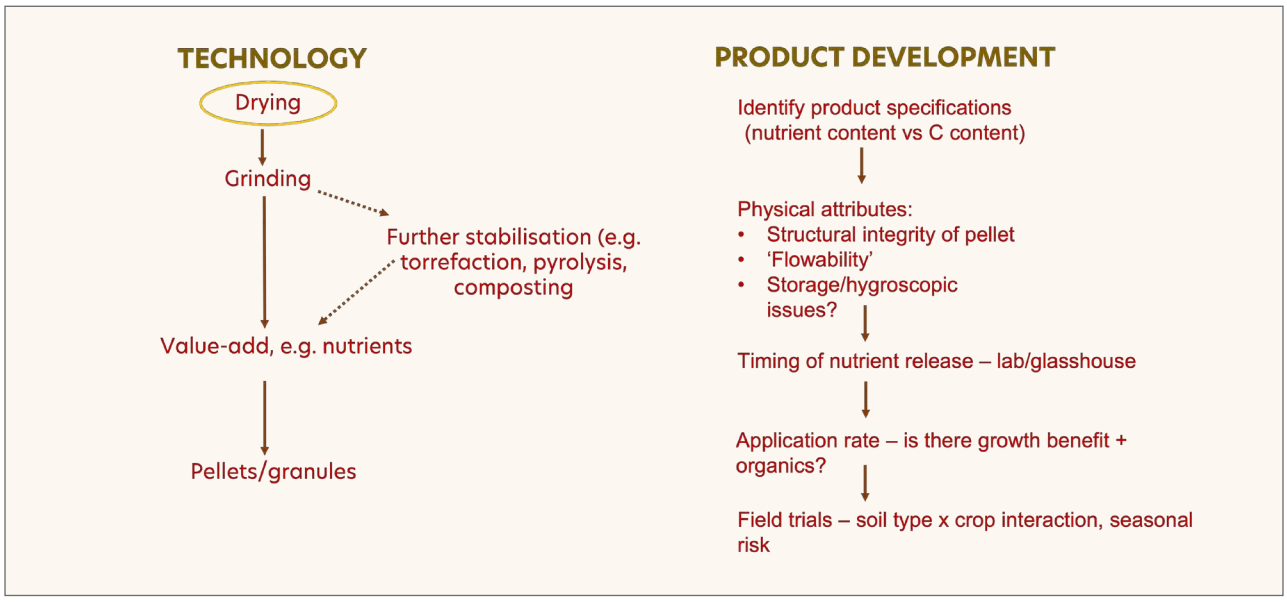
- High moisture content of 50-70%, making it heavy to transport.
- The nutrients are tightly bound by organic matter, so the release of nutrients from SMS is slow and unpredictable.

Other factors which need to be considered in using SMS include the cost of stockpiling SMS by grain growers, cost of application, whether there are any positive impacts on yield, and the timing of supply of SMS versus when it is needed in grain cropping.

Furthermore, while the mushroom industry is reliant on straw, grain growers have many other customers competing for this valuable by-product.

Noteworthy is the increasing use of organic soil amendments in cropping, and in this category, SMS is at some advantage due to it consistent composition as well as being free of contaminants (for example animal waste).

One of the significant challenges in developing a circular economy for SMS is the geographical disconnect



Steps required in SMS value adding, with drying representing a key limiting step in the development of pellets or granules. *Adapted from Wilkinson et al, 2023, webinar presentation*

between the cropping farms from which the straw is sourced, the mushroom compost manufacturers, and the mushroom growers who then generate the SMS. This means that any value-adding process may need to be either mobile or located close to the mushroom producers. And although it may be attractive for mushroom growers to provide SMS back to cropping farmers in exchange for favourable straw agreements, the SMS may be generated by several businesses, across a range of locations, complicating any *quid pro quo* arrangements.

Furthermore, while value-adding SMS through nutrient addition and pelletisation may increase the attractiveness for reuse in broadacre cropping systems, there is significant cost in creating the product.

The to and fro logistics are also complicated by a value imbalance. Transporting wheat straw to compost producers is feasible as the wheat straw has value to the mushroom producer. However, the economics of transporting SMS back to wheat farmers is not equal as the SMS does not have the same significant value to the wheat farmer. And despite empty trucks travelling to wheat farms to pick up straw, they are not the right configuration for transporting SMS. Unless the transport issue can be resolved, the present value of SMS is diminished due to the high cost of transport over large distances.

What next

While strengthening linkages between the mushroom industry and grain growers could have a significant impact on the sustainability of agriculture in Australia, project leader Dr Wilkinson is cautious.

"Given that all mushroom farmers currently have sustainable disposal methods that are either cost neutral or make a small return, it needs to be questioned what the benefit of seeking alternative uses of SMS is at present, given the logistical and economical challenges highlighted by this research," he said.

Nevertheless, given market volatility, understanding the potential of SMS in a mushroom circular economy may be an important part of future-proofing the mushroom industry.

WEBINAR
Recycling spent mushroom substrate (SMS) for fertiliser in a circular economy (MU21006)

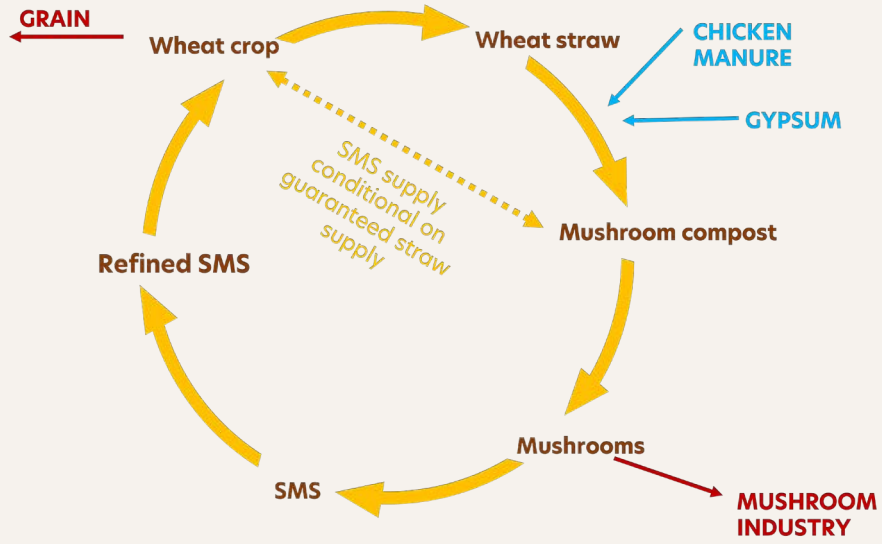
Watch the webinar here: http://bitly.ws/Ha2v

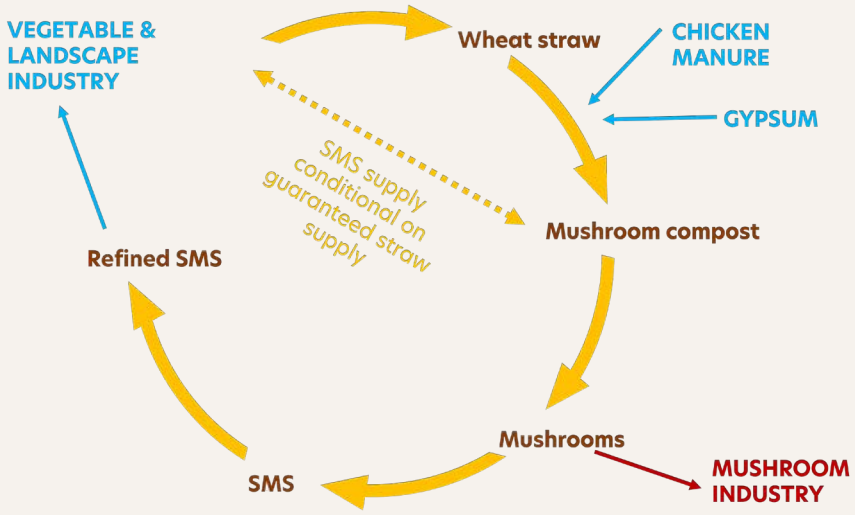
The circular economy and mushrooms

A circular economy gives incentives to reusing products, rather than disposing of them and then extracting new resources. In such an economy, all forms of waste are returned to the economy or used more efficiently.

Globally, mushroom production has increased as demand for sustainable food rises. This will be accompanied by an increase in SMS, which may exceed a trillion kg a year, representing six tonnes of SMS/km^2 global land area[1]. There are different options to use these enormous amounts of SMS, but understanding how it can be used in the most circular way, to the benefit of both the producer and the end-user, relies on modelling studies such as this one.

The research team explored two models, a closed and open loop, and the benefits and shortcomings of both. While the closed loop represents a true circular economy, which may[2] provide compost producers with some certainty on straw supply, the challenge remains in how to make this product valuable to grain growers while overcoming many logistic issues. Sending SMS to the nursery and landscape industry, as some growers already do, overcomes some of the logistic challenges, however in this open loop, the link between the mushroom industry and grain growers is broken.





A closed (top) and open loop (bottom) model for spent mushroom substrate. *Adapted from Wilkinson et al, 2023, webinar presentation*

1 https://doi.org/10.1007/s00253-018-9226-8

2 Note that the dynamics of supplying straw to growers in exchange for a value-added SMS product is based on assumption and would require further investigation as part of any future techno-economic analysis.

Hort Innovation Strategic levy investment | 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

The team

Dr Kevin Wilkinson is a composting and compost utilisation specialist. Spanning over 30 years, Kevin's career has touched on many issues such as biosecurity, food safety, soil science and agronomy, as well as the economics of practice change.

Dr Cassandra Schefe has over 20 years of experience in soil carbon and organic amendment research, with a focus on identifying the key functional components in organic amendments for delivering specific soil benefits.

Mr David Hawkey has over 25 years of hands-on commercial agronomic experience, including time as a specialist agronomist in the irrigated cotton and broadacre cropping industries, and as a field research agronomist in the pasture industry.

THE FUTURE OF **MUSHROOM PACKAGING**

As consumers and regulators become increasingly concerned about sustainability, the Australian mushroom industry needs to explore alternative packaging solutions to meet the growing demand for environmentally friendly products. With fewer than 50 commercial growers, the mushroom industry has the opportunity to adopt sustainable packaging solutions across the board, positioning itself as a leader in Australian horticulture.

Mushrooms are well adapted to the cool, humid, still conditions inside growing rooms.

They are less well adapted to the harsh outside world, including the warm, dry conditions found in an average supermarket. Cut off from their parental mycelia and lacking even a proper skin, harvested mushrooms are vulnerable to physical damage, microbial contamination and moisture loss. Even the slightest bump, squish or misplaced fingernail leaves an ugly brown stain across their soft, white skin.

Packaging not only keeps mushrooms together, it helps to protect them from the environment. It also protects them from microbial and physical contamination – the potential result of grubby fingers riffling through a bulk box.

The current PET (polyethylene terephthalate) tray with a thin PVC (polyvinyl chloride) stretch wrap has many advantages. Crystal clear materials not only let customers see what they are purchasing but can improve the product appearance. The wrap has gas transmission properties that suit mushrooms, while anti-fog coating helps prevent condensation. It's been a great solution for many years, and has undoubtedly improved convenience and quality for consumers.

However, there is pressure to improve the sustainability of packaging, not just for mushrooms but all fresh produce. With increasing pushback from customers on single use plastics, the mushroom industry needs to explore more sustainable solutions.

Developing more environmentally friendly packaging can also keep the industry ahead of potential regulatory pressure. New laws could well affect "Fast Moving Consumer Goods" (FMCG) such as mushrooms in the

Key points

- Social and regulatory pressure mean that the Australian mushroom industry will need to find sustainable packaging solutions.
- The industry is currently using a packaging solution comprising a PET punnet tray and a PVC stretch wrap seal.
- A R&D levy-funded project is examining various packaging formats based on commercial viability, operational feasibility, and sustainability.
- Global and domestic scans of packaging alternatives found 56 solutions potentially suitable to the Australian mushroom industry
- Two were selected to progress to a high-level cost-benefit analysis: recycled polyethylene terephthalate (rPET) and corrugated/fluted cardboard, both overwrapped with PVC.

An example of cardboard mushroom punnets used in Spain by Ayecue: The real green food company, has been exploring sustainable punnets for a number of years (FreshPlaza 2019)

near future. The 2025 National Packaging target, administered by the Australian Packaging Covenant Organisation (APCO)[1] and member organisations (including retailers) reflects a strong commitment to sustainable packaging targets.

Pre-packaged and value-added products[3], such as sliced mushrooms, are the fastest growing segment in the domestic retail market. This sector is currently driving around 80% of current growth. If this is to continue, it is vital to keep up with consumer sustainability expectations.

A new, R&D levy-funded project has been examining various packaging formats available to the Australian mushroom industry. The aim is to evaluate their commercial viability, operational feasibility, and sustainability. The review will determine the readiness of sustainable packaging options for mushroom growers in Australia.

Global and local scans

To fully understand the state of play in sustainable packaging, the project team conducted a global and domestic scan of packaging alternatives.

The aim was to identify best practice as it relates to sustainable packaging in the fresh produce sector and investigate sustainable packaging solutions from different countries, including those viewed as leading in environmental, social and corporate governance (ESG). Countries included in the scan were Australia, the United Kingdom, the United States, the European Union, and India.

Overall, 56 solutions were identified that had a near-term potential to meet the requirements of the Australian mushroom industry.

A Project Advisory Group (PAG) of industry representatives, packaging providers and retailers were engaged in a series of four workshops to ensure the validity, accuracy, and relevance of project findings. The group consisted of eight participants from the mushroom value chain including three grower representatives, three retailers, an expert from a packaging industry association, and one mushroom industry body representative. Industry consultations were also conducted throughout the project.

The desktop review indicated that alternatives to PVC wraps are not yet commercially viable for the mushroom industry.

Thereafter, the primary focus of analysis was on sustainable punnet tray alternatives.

The suitability of punnet tray alternatives was evaluated using a multi-criteria assessment. The criteria included five core components:

1. **Cost** – packaging solutions needed to be commercially viable for the industry to ensure that it does not an create additional cost burden to either the business or the consumer.
2. **Sustainable** – the solution needed to align with the National Packaging Targets administered by the Australian Packaging Covenant Organisation (APCO) 2025.
3. **Product quality and safety** – the solution needed to meet the physical and biochemical demands of mushrooms to maintain product quality and safety requirements for consumer purchase and consumption.
4. **Supply chain suitability** – the solution meets logistics requirements including the necessary durability and robustness to withstand the entire mushroom supply chain.
5. **Consumer acceptability** – the packaging solution does not hinder consumer acceptance or demand for the product.

From the evaluation, 12 solutions were identified as high scoring on a scale of 0-10 and were presented to the Project Advisory Group for feedback and evaluation. PAG votes and further industry consultations led to two solutions deemed worthy of a high-level cost-benefit analysis.

The top two solutions considered in the cost benefit analysis were:

1. Recycled polyethylene terephthalate (rPET) and,
2. Corrugated/Fluted cardboard.

High-level cost benefit analysis

The high-level cost benefit analysis compared the commercial viability of the two prioritised punnet tray solutions with an industry reference standard, a PET punnet tray.

The analysis identified the relevant costs, benefits, and considerations of adopting alternative packaging solutions in the mushroom industry, at a high level. Based on discussions with the PAG, the analysis used consistent size and closure method for the punnet tray across each option, with factors including size and grower output, to show potential impacts of these variables.

An additional supplementary analysis is now examining the cost of adopting wrap and seal alternatives to PVC cling film in greater detail. This will include consideration of the cost of transitioning to alternative materials, such as polylactic acid (PLA) cling film.

Once complete, the project team will present a series of recommendations and next steps for consideration.

There is no doubt that comprehensively addressing climate change is hard. However, eliminating single use plastics may be even harder. Achieving the right balance between environmental sustainability (by reducing plastic) and avoiding produce waste (by using plastic) is definitely not easy. However, by exploring the various solutions available to industry, this project will allow growers to choose the best possible option for their mushrooms.

Hort Innovation Strategic levy investment | 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

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Around the world, many companies are already using cardboard punnets to package organic mushrooms.

A LIFE CYCLE ANALYSIS OF **THE MUSHROOM INDUSTRY**

It's one thing to claim sustainability, and quite another to prove it.

A new R&D levy-funded project is bringing 'life cycle thinking' to the Australian mushroom industry, which will highlight the strengths and weaknesses in mushroom sustainability across the industry. With recent media attention and a new investigation by the ACCC exposing greenwashing, it is more important than ever to understand the real impact of a business and the effectiveness of any sustainability measures.

Life Cycle Assessment (LCA) is a powerful tool that measures the environmental impact of products and services throughout their entire life cycle. From production to disposal, LCA considers various environmental factors such as climate change and water scarcity, and gives businesses sufficient and accurate information to manage and communicate their impact on the environment.

LCA is governed by international standards and is an essential tool for the mushroom industry. Business owners can measure their environmental impact, including the carbon footprint, waste generated, materials recycled, the water and energy used.

With specific data about mushroom growing practices, growers can gain a comprehensive understanding of the sustainability of their businesses and identify unsustainable hotspots in production.

This two-year project aims to develop a benchmarking tool for the environmental performance of the Australian mushroom industry. Jeff Vickers, Steve Mitchell and Vi Kie Soo from sustainability firm thinkstep-anz are leading this work. The team will measure the industry's environmental performance and develop industry-average results.

Key points

- Life Cycle Assessment (LCA) measures the environmental impact of products and services throughout their entire life cycle.
- LCA considers various environmental factors including climate change and water scarcity.
- By applying LCA tools, mushroom growers will have a comprehensive understanding of the sustainability of their businesses, identify areas of improvement, and address unsustainable practices in production.
- Business owners can communicate any sustainability claims with confidence, not assumption.

The project aims to:

- Inform the mushroom industry of its environmental performance, including strengths and gaps in data and performance.
- Allow the mushroom industry to measure or track changes in its environmental performance in the future.
- Although the project is only in its early stages, some likely weaknesses have been identified, including:
- Transport distances from major raw material suppliers
- Substrate composting and pasteurisation.
- On-site energy use, such as emissions from diesel and thermal energy sources.
- Electricity use and source (grid average or renewable energy).

So how does an LCA help?

Information gathered as part of the LCA paves the way for sustainable mushroom cultivation. With reliable data, mushroom growers can avoid the pitfalls of greenwashing and communicate with customers in a credible manner.

Vi Kie Soo, who hopes to visit mushroom farms soon, emphasises the importance of data when discussing sustainable practices.

"Basing claims on solid facts rather than making vague and unsubstantiated assertions avoids greenwashing and builds trust and credibility," she said.

"By promoting sustainable production practices and highlighting eco-credentials, the mushroom industry can appeal to environmentally conscious consumers seeking evidence of sustainable choices."

The team is collaborating with Hort Innovation and will run a pilot with a small group of mushroom growers to develop key data before rolling out a questionnaire to the wider industry by late 2023.

About thinkstep-anz

thinkstep-anz is an independent sustainability firm helping businesses from many industries succeed sustainably. They work with government, NGO and business clients in both Australia and New Zealand across food services, utilities, construction, manufacturing, agriculture, horticulture, forestry, aquaculture, retail trade, finance, transport, and tourism sectors.

Their services span sustainability strategy and technical solutions to make products and businesses more sustainable.

Learn more at thinkstep-anz.com

Project Manager **Vi Kie Soo** –

Team Lead LCA with thinkstep-anz
Keep an eye out for Vi Kie as she visits mushroom farms over the coming months.

Hort Innovation Strategic levy investment | MUSHROOM FUND

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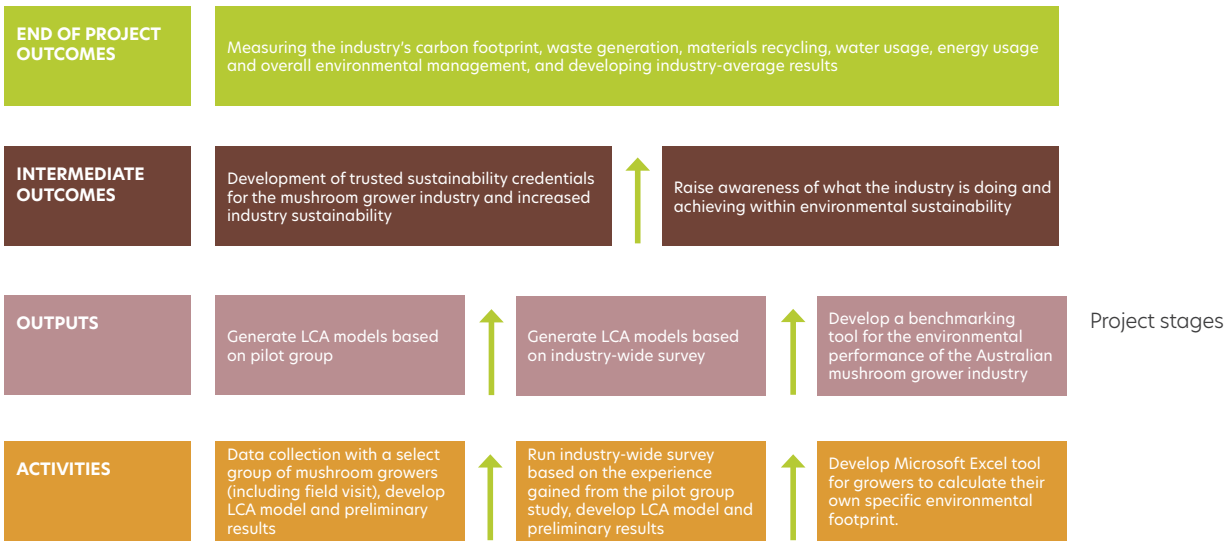


CAN YOU CLAIM VITAMIN D **ON MUSHROOMS?**

By Tim Cassettari, Accredited Dietitian, Nutrition Research Australia

Vitamin D deficiency is an increasing public health problem in Australia, with almost a quarter of Australians deficient. Mushrooms provide a unique solution to address this deficiency and would lend some 'nutrition heft' to any marketing campaign. However, before claims can be made about vitamin D, it is necessary to take a closer look at the vitamin and the specifics of the food regulations.

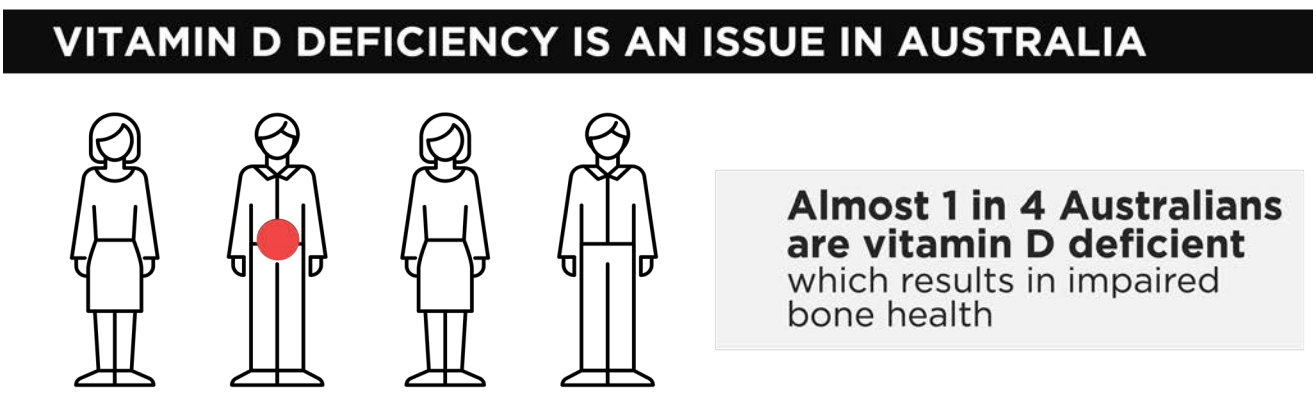
This R&D levy funded project explored Australia's food regulations and found that there is an opportunity for the mushroom industry to add a vitamin D claim.

Is your current diet meeting vitamin D needs?

Probably not. For almost all (>95%) Australians, the answer to this question is 'no' [1]. Vitamin D is present in only a small number of foods – including oily fish, eggs, fortified margarine, some fortified breakfast cereals, and dark chocolate – and generally only in small amounts. Even if every bite you take is in accordance with the Australian Dietary Guidelines – vitamin D is the one vitamin that is difficult to obtain through food and drink alone [3].

For some sun-loving people, this may not be a problem; enough skin exposure to UV and we can make the 'sunshine' vitamin ourselves. Others have turned to vitamin D supplements. However, many people get neither adequate sunlight nor take vitamin D supplements. In the 2011-12 Australian Health Survey, a nationally representative survey that included assessment of vitamin D status via blood tests, almost 1 in 4 (23%) Australians were deficient in vitamin D [4]. Deficiency rates were even higher in the more southern parts of the country - up to 49% in Victoria and the ACT in winter [4]. The risk of vitamin D deficiency can also increase for older Australians, smokers, people with more sedentary lifestyles, those born outside of Australia, and people with either very light or very dark skin [5, 6].

Why does any of this matter? Vitamin D plays a critical role in our overall health, and is essential for bone health, due to its role in calcium absorption and utilisation [7]. Additionally, vitamin D plays an important role in immunity, gene regulation, and supporting muscle function. Deficiency has also been associated



"There is no other food that has the potential to provide as much vitamin D in a single serve, or to reverse current rates of vitamin D deficiency, as mushrooms."

– Tim Cassettari, Accredited Dietitian, Nutrition Research Australia

with increased risk of autoimmune diseases, high blood pressure, and increased infectious diseases [8]. With these substantial associated health consequences, vitamin D deficiency is widely established as a significant public health problem, both in Australia and globally.

The opportunity for mushrooms

With few foods providing vitamin D, and caution over too much sunlight due to the risk of skin cancer, there are few clear solutions to this problem. Enter mushrooms, the only natural, non-animal source of vitamin D [9]. Data from 2015 showed that a 75 gram serve of common (Agaricus bisporus) mushrooms contains 15% of vitamin D needs [10]. When exposed to UV-light for as little as 10-15 minutes, their vitamin D content can increase more than 10-fold, and they can provide more than 100% of vitamin D needs [10, 11]. In a recent review, there was strong evidence that UV-exposed mushrooms not only increased vitamin D status, but that their efficacy was equivalent to that of vitamin D supplements [12].

Investigating the food regulations for vitamin D claims

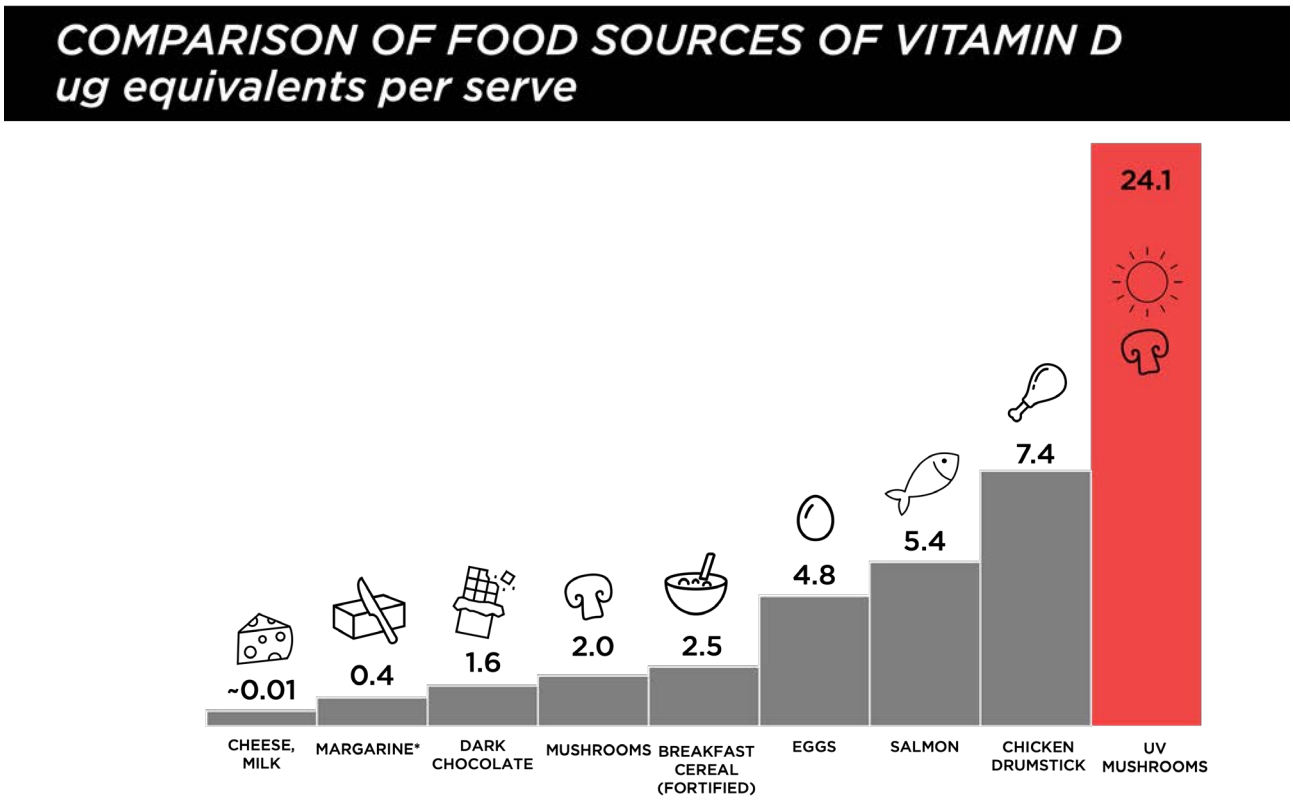
So, with all this good news, what's stopping the mushroom industry from claiming that mushrooms contain vitamin D? To help answer this, we need to look deeper at vitamin D and current food regulations.

Vitamin D comes in two forms: vitamin D3 (cholecalciferol) and vitamin D2 (ergocalciferol). In most foods, the vitamin D is in the form of vitamin D3. Mushrooms are unique as they only contain vitamin D2 (not vitamin D3):

Currently, to substantiate a vitamin D claim, a serve of food must contain a minimum 10% of the regulatory Recommended Daily Intake (RDI) listed in the Food

Vitamin D3 = cholecalciferol = animal sources of vitamin D (e.g., eggs, oily fish).

Vitamin D2 = ergocalciferol = non-animal sources of vitamin D (e.g., mushrooms).



Standards Code. The regulatory RDI for vitamin D is 10 µg cholecalciferol (vitamin D3), with no RDI provided for ergocalciferol (vitamin D2) [13]. It is therefore unclear if vitamin D claims for mushrooms would breach food regulations, as they contain 0 (zero) µg cholecalciferol.

To assess the likelihood of a vitamin D claim for mushrooms being a breach to food regulations, we (Nutrition Research Australia (NRAUS)) scoped the science and food regulations and consulted with key stakeholders. This lengthy process yielded exciting news: although there is a technical argument that a vitamin D claim on mushrooms *could* breach the Food Standards Code, this risk was considered **very low.** Furthermore, there was **no risk** of such a claim being misleading or deceptive to customers.

A recently held workshop also helped to educate and empower the industry on making such claims.

There is still more work to do to maximise vitamin D claims for mushrooms, including:

1. Developing an analytical testing program to validate the data from 2015 and to ensure that claims are always substantiated,
2. Communicating the mushroom and vitamin D story via advertisement and packaging, including an updated customer-facing website,
3. Exploring opportunities for new vitamin D health claims, such as vitamin D for heart health, and,
4. Considering industry-wide exposure of mushrooms to UV-B light, to strengthen the possible claims for vitamin D and to enable mushrooms to be a solution to a significant public health problem in Australia.

Mushrooms could provide a solution to a significant public health problem in Australia, which could have ramifications for mushrooms within Dietary Guidelines and other public health policies. The outcomes from this project are an exciting step forward in this direction.

Easy to use claims document

View the document in the AMGA Digital Document Library, via the Members only area of the AMGA website: **australianmushroomgrowers.com.au or contact the AMGA for a copy.**

Tim Cassettari is an Accredited Practising Dietitian with 10+ years experience. His experience includes developing nutrition strategies, managing consumer and healthcare professional communication campaigns, conducting systematic reviews for health claims, and developing food education programs, for many of Australia's largest food brands. Overseeing a team of 20+ nutrition researchers and communicators at Nutrition Research Australia, Tim contributes to the senior management of all NRAUS projects.

Hort Innovation Strategic levy investment | MUSHROOM FUND

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IMPROVING THE FOOD INDUSTRY MENU, **WITH MUSHROOMS.**

By Leah Bramich, AMGA

Anyone who has ever spent more than a few days in a hospital, or visited an elderly friend or relative in a care home, would most likely agree - despite the best intentions, the catering is less than inspiring. A collaboration between Nutrition Research Australia (NRAUS) and the AMGA is working hard to show the benefit of adding mushrooms to the menu, not only to improve the palatability of institutional meals, but to boost their nutritional offering as well.

One-on-one interviews highlighted the potential of mushrooms to boost menus in the institutional catering sector, with their significant nutritional and culinary benefits. The next part of the project includes menu interventions, showcasing how adding Australian mushrooms to menus can be a cost-effective way to vastly improve the nutritional profile and appeal of menus in these settings.

Initial research undertaken by Nutrition Research Australia in partnership with the Australian Mushroom Growers' Association reveals the Australian food industry has a lot more to learn about the health benefits of the mighty mushroom, with taste and culinary benefits overshadowing the vast nutritional benefits of mushrooms in the nationally accredited commercial cookery curriculum.

CEO of NRAUS, Dr. Flavia Fayet-Moore explains that mushrooms are part of the Fungi Kingdom with a unique set of nutritional properties found across different food groups, including vegetables, grains, nuts, and meats, as well as unique bioactive compounds not commonly found in animals or plants.

"Mushrooms contain three unique bioactives not commonly found in animals or plants and provide essential vitamins and minerals such as B vitamin,

selenium and are a natural non-animal source of vitamin D. With one in four Australian adults having Vitamin D deficiency, this provides a great opportunity for the institutional sector to tap into a 'Food as Medicine' approach."

"Mushrooms are not specifically recognised as a fungi group within the nationally accredited commercial cookery curriculum. There is an opportunity to provide further education about the qualities of the unique Fungi Kingdom and its ability to support many diverse dietary requirements of Australians - including the growing flexitarian, vegetarian, vegan, dairy free and gluten free needs."

The qualitative in-depth interviews with 12 Key Opinion Leaders and quantitative research conducted with

654 food industry professionals from a broad range of areas, revealed there is a common misconception with non-health industry professionals that mushrooms are a meat protein equivalent.

"Mushrooms have a unique umami and meaty taste profile, making them a great culinary replacement for meat. From a nutritional perspective, unlike meat, mushrooms contain minimal protein, but they also contain no saturated fat. With their combined umami and nutritional profile, mushrooms can help to reduce the sodium and saturated fat content of meals when replaced for meat."

The research is part of a bigger project funded by the Australian mushroom industry to educate the food industry of the unique nutritional benefits of Australian grown white and swiss brown mushrooms. These everyday mushroom varieties provide a unique combination of nutrients that can assist food service providers, in particular catering institutions, achieve their plant-forward menu goals, while reducing fat and sodium, and increasing the nutritional content of menu items - in a cost-effective way.

The educating the food industry of the nutritional benefits of Australian Mushrooms project is a Hort Innovation Mushroom Fund strategic levy investment and is led by the Australian Mushroom Growers Association (AMGA). Together with Nutrition Research Australia (NRAUS) and food industry expert Chef Adam Moore, the project aims to tackle some of the nation's biggest nutrition problems with mighty mushrooms. Engaging key players in the food industry, including Hospitals, Aged Care, Quick Service Restaurants and Food Manufacturers and identifying opportunities for Australian mushrooms to be included in menus, the program aims to improve health outcomes on a large scale.

After consolidating the relevant nutrition research and discovering the unique benefits mushrooms provide in a culinary setting, the project has developed a number of resources, designed by Chef Adam Moore and Dr. Flavia Fayet-Moore of NRAUS. The resources provide nutritional and culinary information specifically relevant for the food industry and will be used as the 'educational tool kit' as the project shifts to the engagement phase. The kit includes educational videos, a kitchen poster, fact sheets and an educational booklet, and are housed on the Australian Mushroom Growers website, https://australianmushroomgrowers.com.au/food-industry/. The resources are free to download, will be communicated to the broader food

industry, and will be utilised as the project shifts to the last and most exciting phase - engaging with high quantum of influence food industry organisations.

Leah Bramich, project lead and General Manager of the AMGA explains.

"Right now, we are in preliminary talks with the Mater Hospital in Brisbane, and an aged care facility in Coffs Harbour, to collaborate with NRAUS and Chef Adam Moore for 'mushroom menu interventions'."

"By identifying the organisation's unique nutrition challenges, and working directly with their chefs and kitchen teams to use mushrooms to solve these challenges, we are creating powerful case studies to highlight mushrooms unique culinary and nutritional benefits for the next phase, where we educate the food industry at scale, via a PR campaign and a roadshow conference program."

Exciting opportunities

Renowned chef Luke Mangan is the executive chef of the Mater Hospital, an institution already in the food service and health care spotlight due to its revolutionary in-room on-demand dining service. This presents an exciting opportunity to highlight the unique culinary and nutritional benefits of mushrooms to the wider food service industry.

Hort Innovation Strategic levy investment | MUSHROOM FUND

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FOOD SAFETY FAQS

YOUR QUESTIONS ANSWERED

A visit from the auditor has been known to strike fear into the heart of even the most organised mushroom business QA manager. This is not necessarily because records are not in order, or practices are in any way unsafe. It has more to do with uncertainty about the process itself.

People may wonder "What will the auditor ask?" "What evidence will I need to provide?" "What haven't I done?" "What do I do if I get a lot of corrective actions?". It can be like going for an exam without knowing the scope of the subject.

Clare Hamilton-Bate has had more to do with food safety certification than just about anyone in Australia. Clare has also been an advisor to the mushroom industry for over 10 years. MushroomLink recently talked to Clare about tips and traps for QA managers on mushroom farms.

ML: Your career includes three years working in fresh produce with Franklins Supermarket, 17 years as head of Freshcare and three years as technical and QA manager with a large mango grower. That means you've experienced QA as a retailer, certifier, and a grower. Which one was the hardest?

CHB: Without a doubt, it's hardest when you are on farm. That's because you've got so many competing operational priorities to get fresh product to market. Compliance systems are just one of the things you need to deal with.

ML: So, what certification options are there for mushroom farms?

CHB: The mushroom industry was one of the first fresh produce industries to adopt HACCP (hazard analysis critical control point). However, HACCP alone is no longer recognised by Australian retailers.

The base schemes currently used in Australia are Freshcare, SQF, GlobalGAP and the British Retailer Consortium (BRCGS). If you are supplying one of the major retailers, you will need to include HARPS as well, as an addition to your base standard.

Through the Hort Innovation R&D levy-funded Mushroom Food Safety Project (MU20000) we have also developed a mushroom specific code of practice called Safe Mushroom. This was developed for farms whose customers don't require them to have a third party audited program in place, but who still want to demonstrate that they are growing and packing mushrooms safely.

Safe mushroom

ML: What would you say are the key success factors for businesses implementing a food safety program?

CHB: Good business preparedness and culture is essential. This includes:

- Clear responsibility for specific tasks
- Clear accountability for those tasks being done correctly
- Clear ownership of the system – and this does not just mean the compliance officer, but the whole management team
- Committed champions of the cause – people understand not just **what** they need to do and **how**, but also the **why**
- Making sure that good food safety practices are integrated into all business operations. Operations drive the business, and food safety needs to fit within all operations. In other words, no more silos.
- Compliance officers therefore need to make sure there are opportunities to question, share and improve in all parts of the business

ML: OK, you've put all the systems in place, next step is scheduling the audit...

CHB: The most important thing is to start planning early. It's easy to put off, but before you know it the audit is next week and you're not ready.

When you get a notice that an audit is due, talk to your certification body (CB). Make sure that your business details are correct in their system. That could mean changes to personnel, additional sites, or changes in product scope and procedures.

You have put effort into creating an effective system – celebrate it, don't hide it.

If it's an unannounced audit then you absolutely must tell the CB your blackout dates. These are the dates when you're not growing or packing, or when you're simply not available. While blackouts are normally limited to 10 days, it's still worth talking to your CB if, for example, you are taking a month's leave during the audit period. And if the situation changes, always let them know.

ML: Once you know when the audit is going to happen, how should you prepare?

CHB: For starters, celebrate your system, don't hide it. You've put effort into creating an effective system and this is your chance to show it off.

If situations happen that are not compliant – like a test result over the MRL, or an internal corrective action – then document it. This demonstrates that you are culturally committed to the system, and it's all about improvement.

Mushroom growing rooms are very different environments to outdoor vegetable farms and orchards, so many elements in food safety standards are not applicable.

It's essential to do an internal audit. The internal audit shows that you've been through the requirements and thought about them. Moreover, you will now have the supporting evidence for the actual audit ready to hand.

When the auditor comes it should be business as usual. Be prepared, be compliant with the requirements, but also be confident. Be proud of the success of your process.

Although mushroom compost is not "Treated in accordance with AS4454" it has been subjected to a documented, validated procedure, with pasteurisation confirmed through testing

ML: There are a lot of general requirements which don't seem relevant to mushroom growing. What do you do about them?

CHB: It's true that there are elements of standards which are '**Not Applicable'** to mushroom farms. There aren't a lot of livestock in mushroom growing rooms! Nor are mushrooms washed after harvest, so postharvest water quality is not an issue.

There are other elements that can be '**Excluded**' with supporting evidence such as a risk assessment. An example might be demonstrating (through a risk assessment) that soy proteins added to compost do not transfer to the mushrooms, so do not present a risk of allergic reaction.

Irrigation water must contain *E. coli* <100 CFU/100ml; verify this through microbial testing.

Finally, some elements may be granted a specifically agreed **'Exemption'** at an industry wide level. An example is compost. Certification programs normally require it to be treated 'in accordance with Australian Standard 4454', and a test certificate supplied with each batch. This is clearly not feasible or applicable for mushroom compost.

ML: So how does the grower show that they should be exempt from this requirement?

CHB: The key issue is that AS4454 includes exposure to temperatures >55°C for three consecutive days, with the process repeated five times. Mushroom compost isn't produced this way and mushroom compost suppliers are unlikely to be accredited to AS4454.

However, they do have a documented, validated procedure. They are also likely to keep batch and temperature records. Effectively, this pasteurisation process makes the composting process equivalent with AS4454.

Obtaining a copy of this procedure from your compost supplier to support this industry wide position is a good idea, especially if your auditor is unfamiliar with mushroom farms.

ML: How about other inputs?

CHB: With regard to water, the key requirement is meeting microbial limits. Irrigation and wash down water must contain less than 100 *E. coli* bacteria/100ml, whereas water used for cleaning equipment that contacts mushrooms must contain less than one *E. coli* bacteria/100ml. Water can be recycled, but needs to be treated (e.g. with chlorine) to achieve these limits and verified through testing.

ML: There are clearly a lot of different and varied requirements, so what are the areas where growers are most likely to end up with a corrective action?

CHB: Chemical application records is definitely one. Every spray in every growing room needs to be documented. It's the same whether spraying 100 hectares of grapes or 50m^2 of growing room.

Water treatment records can be another. Every dose, to every tank, every day, must be recorded. It's a repetitive but essential record, as the act of recording helps to

Check the calibration of your cold room using an accurate data logger or thermometer.

ensure that water is sanitised appropriately. Of course, if you are on town water, water sanitation is unlikely to be needed.

Checking the calibration of cold rooms is important not just for food safety, but for quality in general. If the cold room calibration is out, you could be reducing storage life as well as failing to meet a certification requirement.

Finally, it is important to document **why** an element is **Not Applicable**. It might seem like stating the obvious, but the auditor won't necessarily understand this. The same goes for Exclusions and **Exemptions**. In both cases, there should be clear risk assessments and supporting documentation.

ML: Many of the procedures need to be annually reviewed, which sounds a bit tedious. Is there an efficient way to meet this requirement?

CHB: It's good business practice to do an annual review regardless of system requirements. This is where you discuss what went well or didn't, what was profitable or lost money, what was operationally efficient and how things can be improved in the future.

The meeting agenda needs to include issues relating to your food safety certification, such as;

- Changes to organisational structure, roles and responsibilities
- Changes to food safety and quality policies
- Procedures and work instructions (especially if new equipment has been purchased)
- Training needs
- Risks to the business (risk assessments)
- Review of compliance, such as corrective or preventative actions
- Customer feedback both good and bad

Keep minutes of the meeting, and your annual reviews will be complete. It's good to do this when the whole management team is sitting around the table. You can get their buy in plus it actually benefits the business. This is definitely a much better approach than rushing to gather key information the week before your next audit.

ML: Perhaps that's one of the key messages we can take from this - Food safety is part of good business management, for the whole business operation

CHB: Definitely. We all own food safety as part of a good and effective business culture.

Hort Innovation
Strategic levy investment
MUSHROOM FUND

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Beau Ryan launches the first ever Mushie Meat Tray at Canterbury-Hurlstone Park RSL Club in Sydney LO - Eleven PR

MARKETING UPDATE

MEAT TRAYS GET A MUSHROOM MAKEOVER

Meat raffles are a cultural icon in many Australian pubs and clubs but in April the traditional raffle was turned on its head.

Hort Innovation, through the mushroom marketing fund, partnered with Australian Mushrooms to launch what is believed to be the world's first Mushie Meat Tray. Complete with butcher-quality cuts of portobellos, buttons, flats and cups, alongside the usual sausages and steaks, this is the flexitarianism meets Aussie pub culture at its finest.

Former rugby league footballer, television presenter and RSL club enthusiast Beau Ryan launched the Mushie Meat Tray at the Canterbury-Hurlstone Park RSL Club in Sydney.

Patrons on the night enjoyed mushroom-inspired versions of classic Aussie dishes, including mushroom parmigiana, mushroom risotto, and mushroom burgers. Combined meat and mushroom - or mushroom only - trays (25 in total) were raffled on the night.

Hort Innovation marketing manager, Emma Day, said research had revealed that more than 70% of Australians head to their local RSL for their chance to win the meat raffle and more than a quarter of Australians would much rather win an RSL meat tray than go surfing at Bondi Beach.

The team behind the campaign are delighted with the media buzz surrounding the event.

"To date, we have secured more than 100 pieces of coverage, providing more than 60 million opportunities to reach Australians," Ms Day said.

"We received coverage on platforms and in publications such as News.com.au (Australia's leading news site), Sunrise (Australia's number one TV breakfast show) and Man of Many (Australia's largest men's lifestyle site). We also secured an interview with Australian Mushrooms grower Chris Tolson, with the North Queensland Register piece syndicated across six titles.

"On launch day, we secured an opportunity with breakfast TV show Sunrise. During the five minute live cross from the Canterbury RSL, Beau Ryan explained what the Mushie Meat Tray was, talked to our key messaging and mentioned Australian Mushrooms on multiple occasions. The clip syndicated 44 times nationally.

"To further drive our social media presence, we launched an Instagram competition to encourage different community groups to apply to win their very own Mushie Meat Trays. To enter, fans had to comment on why they thought their community group deserved to win trays to auction off. This garnered more than 700 entries."www.instagram.com/australianmushrooms/

The trays are now set to be rolled out nationwide, with Australian Mushrooms launching a toolkit to help RSL clubs create their own take on the Mushie Meat Tray, and RSL clubs in both Queensland and Victoria have answered the call.

Beau Ryan with a winner of the World's first Mushie Meat Tray - Eleven PR

FAR FLUNG Fungi

Mushroom research from around the world

Statistical modelling for precision agriculture: A case study in optimal environmental schedules for Agaricus bisporus production via variable domain functional regression

Panayi E, Peters GW, Kyriakides G. 2017. PLoS One 12:e0181921.*

**Originally published in 2017, this research paper was updated in December 2022.*

What's it about?

Sensor network technologies are not just evolving in industrial and home environments, but also increasingly used for precision agriculture. New technologies are driving sophisticated control of nutrition, irrigation, pest and disease control and harvest management in everything from massive broadacre cotton farms to high-tech glasshouses, and everything in between.

Mushroom farming is no exception. The previous MushroomLink magazine featured an article on Mycionics. This company is not only developing robotic harvesting units but also systems that provide detailed maps of CO_2 levels, humidity, temperature, moisture and airflow across sectors of individual beds.

Collecting all this big data is all very well – but how can you use it?

This is the focus of the Panayi *et al* paper – using sensor data to optimise environmental conditions within a mushroom farm. Detailed data was gathered on compost type, pH, moisture content, air temperature, oxygen and CO_2 levels, evaporation rates and growing time. Data was recorded at 30 minute intervals over 92 growing cycles in a modern, shelf system mushroom farm.

The researchers then used complex statistical modelling to understand the impact of key environmental conditions on yield, developing models that aimed to find the optimum growing conditions for mushrooms.

One of the issues faced was the variability in the total growing time for each crop. They therefore expressed growing time as a proportion of the total time, rather than in days after casing.

What was concluded?

The researchers developed a mathematical model that could predict the optimal level of each environmental variable during the growing period. This included how different factors (temperature, humidity etc) interacted with each other to produce effects on yield.

A cost function was then added to account for additional energy, labour, wear and tear of the device etc. required to change the physical environment to the new environmental condition.

The aim of the system as a whole was to allow a grower to select the combination of controllable environmental conditions most likely to optimise yield on their farm, while taking into account uncontrollable drivers such as local conditions and costs.

In the case of the farm used to develop this model, one of the key findings was a clear impact of oxygen concentration on total yield. The results showed that a lower oxygen level (approximately 20%) was beneficial on the first two-thirds of the growing process, while normal oxygen levels (21%) contributed to increased yields in the final third of the cycle.

For temperature, higher temperatures (potentially up to 21°C) were beneficial over the first half of the cycle. During the second half, warmer temperatures were only beneficial if the growing time was extended.

The mathematics presented in this paper are extremely complex. It is certainly not something that could be readily applied on farm in its current state. However, models such as this could potentially provide the engine room of environment optimisation software, allowing advanced monitoring and control of every part of the growing room.

Mushroom farming has long relied upon grower instinct, and although the advent of Smart Farming cannot replace years of experience, but it might at least allow a few more days off.

CURRENT HORT INNOVATION MUSHROOM FUND PROJECTS

Project Name	Project Code	Organisation	Project Description
Development of a biosecurity plan for Australian mushrooms	MU18006	Plant Health Australia	Development of the mushroom industry's biosecurity plan.
Developing a database of bio-markers for compost quality control to maximise mushroom production yield	MU17006	The University of Sydney (USYD)	Exploring how microbial populations within compost can be used to understand, measure and manipulate compost quality.
Optimising nitrogen transformations in mushroom production	MU17004	The University of Sydney	Optimising the rate and timing of nitrogen additions, to achieve maximum yield and nutritional value.
Mushroom industry minor use program	MU16002	Hort Innovation	Submit renewals and applications for new minor use permits for the mushroom industry, as required.
Extension and adoption for food safety, quality and risk management	MU20000	AMGA	This investment is delivering targeted information on food safety, quality and risk management to the mushroom industry through a range of proactive channels.
Regulatory support and response coordination (pesticides)	MT20007	AKC Consulting Pty Ltd	This project provides the Australian horticulture industry (including mushrooms) with key information regarding domestic and international pesticide regulation.
Mushroom industry crisis and reputation risk management	MU20006	AMGA	Maintaining a crisis and reputation risk management plan for the Australian mushroom industry.
Educating the food industry about Australian mushrooms	MU20003	AMGA	Delivering evidence-based information about Australian mushrooms to health and food service professionals in Australia.
Mushrooms and their potential health benefits of lowering blood cholesterol	MU20001	CSIRO	Generating scientific evidence on mushrooms and their ability to lower blood cholesterol.
Strategic Agrichemical Review Process (SARP) - Updates	MT21005	AGK Services	This short investment is facilitating the 2021 Strategic Agrichemical Review Process (SARP) for a number of industries including mushrooms.
Consumer behavioural data program	MT21004	Nielsen	Provides regular consumer behaviour data and insight reporting through the Harvest to Home platform (www.harvesttohome.net.au).
Mushroom industry communications program	MU21003	Applied Horticultural Research (AHR)	Deliver communications to Australian mushroom growers and other industry stakeholders on latest mushroom R&D and marketing investments, developments and outcomes.
Mushroom price elasticity of demand	MU21005	Natural Capital Economics	Delivers information on how changes in the price of mushroom and substitute/complementary products can affect the industry's market share and overall revenue.
Desktop review of pathway risks for the mushroom industry - Agaricus mushrooms and growth substrate imports	MU21002	AHR	Identifying exotic mushroom pests and diseases and investigating the potential ways that they could enter Australia.
Recycling spent mushroom substrate (SMS) for fertiliser in a circular economy	MU21006	Frontier Ag & Environment	Developing models for a spent mushroom substrate (SMS) circular economy by improving the value-proposition of SMS for the end-user (primarily grain growers).
Marsh Lawson Mushroom Research Centre of Excellence	MU21004	USYD & AHR	The running and development of the Marsh Lawson Mushroom Research Centre (MLMRC) at the University of Sydney.
Consumer usage and attitude tracking 2022/23	MT21202	Fifty-Five Five	Provides a category tracking service to allow various horticultural categories to better understand consumer usage and attitudes and the effectiveness of marketing campaigns.

CURRENT HORT INNOVATION MUSHROOM FUND PROJECTS

Project Name	Project Code	Organisation	Project Description
Pest and disease management for the Australian mushroom industry	MU21007	University of Tasmania	Research into pest and disease management options, extensively engage with growers and provide access to farm-focused extension activities.
Non-synthetic alternatives to complement pest and disease management practices in mushrooms	MU22000	Victorian Department of Jobs, Precincts and Regions	This project is improving the Australian mushroom industry's knowledge of the potential of non-synthetic bioprotectants in an integrated pest and disease management (IPDM) approach.
Mushroom education resources	MU22002	PIEFA	Developing two mushroom-focused teaching resources that will encourage secondary school students to have a greater understanding and interest in the mushroom industry.
Evaluating existing and potential ergocalciferol (vitamin D2) health claims for mushrooms	MU22004	Nutrition Research Australia	Summarising the nutrition content and health claims that can be made about vitamin D in mushrooms that meet the Food Standards Code so that mushrooms can be credibly and legally promoted as a key source of vitamin D to consumers.
Scientific basis for a mushroom food group in the Australian Dietary Guidelines	MU22001	AMGA	Reviewing and collating the scientific evidence base to support mushrooms (fungi) being classified as a separate food group within the Australian Dietary Guidelines.
PhD program to study viruses associated with Agaricus mushrooms in Australia	MU22003	Victorian Department of Jobs, Precincts and Regions	Supporting a PhD candidate studying viruses associated with Agaricus mushrooms in Australia by researching host/virus interactions to improve understanding of their impact on quality and yield.
Alternate casing substrate – providing review of research to date and an expert forum for future R&D investment	MU22009	Australian Mushroom Growers' Association	Investigating the current situation regarding peat availability and existing research into finding suitable alternatives for mushroom growing.
Industry level lifecycle analysis updated to better understand eco-credentials and minimise risks	MU22005	thinkstep	This investment is developing a benchmarking tool for mushroom growers to compare their environmental performance against industry-average benchmarks.
Mushroom supply chain best management	MU22011	Applied Horticultural Research	Delivers a supply chain best practice guide for the mushroom industry.
Review and evaluation of mushroom packaging	MU22008	KPMG	Identifying and evaluating the suitability of alternative packaging options for the Australian mushroom industry.
Mushroom international study tours – inbound and outbound	MU22010	AMGA	This project delivers a range of inbound and outbound international study tours for the mushroom industry.

Scan this QR code to read more about these projects

https://www.horticulture.com.au/growers/mushroom-fund/

Hort Innovation Strategic levy investment | 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

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