MushroomLink

AUTUMN 2024 ISSUE 8

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- Our website contains factsheets, case studies, videos, webinars and podcasts.

MushroomLink is for composters, growers, pickers, and everyone in between.

If you have a suggestion for something you would like to see, or some feedback on the project, please let us know at admin@ahr.com.au

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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Cover: *Photo supplied by FoodIQ*

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The Australian Mushroom Growers' Association and New Zealand Commercial Mushroom Growers' Federation invite you to attend the

AU & NZ MUSHROOM GROWERS CONFERENCE 2024

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AUCKLAND, NEW ZEALAND

With an additional tour option to Christchurch, to tour Meadow Mushrooms

For Sponsorship and Exhibition opportunities,
contact Leah Bramich, AMGA General Manager - 0450 504 675 or leah.bramich@amga.asn.au

Hort Innovation MUSHROOM FUND

This project has been partially 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

LEVY FUNDED PROJECT UPDATES

EDUCATING ON THE BENEFITS OF MUSHROOMS IN HEALTH CARE SETTINGS

Educating food and health professionals about the nutrition and culinary benefits of Australian mushrooms: Progress update.

By Leah Bramich

If the proof of the pudding is in the eating, then get set for some fascinating data coming soon. Now in its final year, the 3-year Hort Innovation-funded project, *MU20003: Educating the food industry,* has moved onto the 'showing' phase of its mission.

Collaborating with research partner FOODiQ (formally NRAUS) and chef Adam Moore, the AMGA has engaged two leading examples of the institutional food sector to educate food and health care professionals about the unique nutritional benefits of Australian-grown *Agaricus bisporus* mushrooms.

Major interventions are underway with Mater Hospital Brisbane and Shoreline Aged Care in Coffs Harbour to add more Australian mushrooms to the menu. The team will investigate the impact on nutritional intakes of residents and patients, as well as enjoyment of the menu.

Leah Bramich, General Manager of the AMGA, says the project is showcasing the impressive health and culinary impacts that mushrooms can have, while catering to a breadth of dietary needs and preferences.

"Plant-based eating is the biggest global trend of the last decade, with more than one third of Australians choosing to eat less meat, or no meat at all, yet research shows that the food service sector is not tapping into the opportunity. Our education campaign is highlighting to food and health care professionals that mushrooms tick all the boxes – they boost the nutrition and flavour of meals while catering to the growing demand of plant-forward dietary preferences including vegan, vegetarian, and flexitarian.

"The initial industry blueprint and research identified the institutional food sector (aged care and health care organisations) to have the largest opportunity to influence, so to work with Mater Hospital and Shoreline Aged Care is a big win. We'll be able to provide evidence of the incredible benefits mushrooms can have in a health care and residential aged care setting, and most importantly, showcase this to the wider industry and community."

MUSHROOMS ON THE MENU AT SHORELINE LUXURY AGED CARE

With partners Shoreline Luxury Retirement Living in Coffs Harbour, the team have embarked on a first-time research study focusing on enhancing vitamin D and overall nutrient intake among aged care residents.

The *Mushrooms on the Menu* study is investigating the feasibility of adding vitamin D enriched mushrooms to the menu at Shoreline residential aged care centre and the impact of this specially crafted mushroom-based menu, designed by Shoreline's executive chef and nutritionist. The team will evaluate the impact of

the menu on nutritional intakes of the aged care facility residents as well as their overall enjoyment of the menu. The vitamin D enriched mushrooms for the study are being supplied by White Prince Mushrooms.

The Shoreline Residential Aged Care (RAC) facility has been chosen as a focal point to evaluate the acceptability, demand, practicality, and implementation of the mushroom menu intervention within an aged care environment. Given the imperative to address malnutrition in RAC facilities, especially regarding vitamin D deficiency, and the growing momentum towards prioritising food-first nutrition approaches, mushrooms stand out as a remarkable ingredient to incorporate into daily menus. Recognised for their flavour-enhancing properties and content of vitamin D and other nutrients, mushrooms present a unique opportunity to enhance nutrition and patient satisfaction in aged care settings.

While the benefits of dietary intake of UV-exposed mushrooms in improving vitamin D status and enhancing flavour are acknowledged in research, there remains uncertainty regarding the feasibility of integrating UV-treated mushrooms into RAC facility menus and their impact on residents' food and nutrient intake. This study aims to bridge this research gap, offering valuable insights to the scientific community and gaining real-world evidence of the transformative potential of a mushroom-focused menu on the nutrition and overall well-being of older adults in RAC settings.

To launch the study, Chef Adam Moore hosted a live cooking demonstration for Shoreline residents in January. As part of the study, Shoreline residents will be provided with the opportunity to select a mushroom meal at main meal occasions and must select at least one mushroom meal (containing at least 75g vitamin D enriched mushrooms) each day for 28 days. Food intake will be assessed before and during the mushroom-menu intervention with nutritional analysis carried out to compare intake. Independent living residents are also being recruited to take part, with participants receiving two punnets of mushrooms each week and weekly recipe cards for meal inspiration, to prepare their own daily mushroom meal throughout the study intervention.

Participating residents are aged 65+, an age group that is more susceptible to vitamin D deficiency. Studies have shown that up to 80% of women and 70% of men living in nursing homes in Victoria, New South Wales, and Western Australia are vitamin D deficient. Vitamin D deficiency is associated with higher risk of falls in this group, with vitamin D supplementation shown to improve fall rate, meaning this study could improve the wellbeing and livelihood of many residents in aged care facilities.

The study is currently underway, and findings expected to be finalised by mid-year.

MUSHROOMS ON THE MENU AT MATER HOSPITAL BRISBANE.

The project team also partnered with The Mater Hospital Brisbane, for a comprehensive initiative aimed at elevating their services through a mushroom-

Top left, discussing mushrooms in the Shoreline kitchen; top right, delicious mushroom pastries; bottom left Shoreline residents being introduced to the program.

focused program. The initiative was born out of Mater's recognition of mushrooms as a unique, versatile, and vegan source of vitamin D, aligning seamlessly with their commitment to prioritising food first dietary solutions for health and wellness.

With one in four Australian adults being vitamin D deficient[1], the Mater saw mushrooms as a problem-solving ingredient to incorporate into the hospital menu, as they are the only natural non-animal source of vitamin D[2]. Vitamin D is crucial for immunity and bone health, and in an era when plant-based dietary preferences are on the rise, plant-forward meal options providing vitamin D are especially important in health care environments.

The mushroom menu was designed by dietitians and Chef Luke Mangan to optimise nutritional intake and the culinary experience for patients choosing plant-based meals, and continues Mater Hospital's dedication to innovative food and beverage programs.

The Mater provides a wide range of adult surgical, medical and cancer services, including intensive and coronary care, day surgery, day oncology and day respite, as well as busy medical, cancer and surgical units. It was the first hospital in Australia to implement room service and is already known as an innovative leader in hospital catering.

"The partnership is a holistic approach involving a multi-disciplinary team incorporating Mater's dietitians, chefs and customer service staff together with celebrity chef Luke Mangan, together with input from FOODiQ and AMGA to achieve a plant forward, nutritious food program," says Leah Bramich.

The initiative encompasses multifaceted efforts including educating nutrition and food service professionals, as well as supporting them in their education of patients and the community. Central to this initiative was the introduction of 'Mushrooms on the Menu' specials menu within their private hospital campus, featuring a dedicated mushroom centric plant-based meal option integrated into their existing four-week rotating Luke Mangan specials patient menu.

Three workshops were conducted to increase the culinary and nutritional knowledge of the chefs and kitchen team, customer service team, and dietitians, led by experts Dr Flavia Fayet-Moore (FoodIQ), Chef Adam Moore (Culinary Revolutions), and Leah Bramich (AMGA). These workshops were instrumental in disseminating knowledge and motivation to include mushrooms in the menu.

The team provided an educational toolkit comprising printed resources and complimentary punnets of mushrooms (provided by Brisbane based grower, Marland Mushrooms). Patient resources were developed by the Mater Hospital alongside hospital social outreach initiatives that educated staff and patients about mushrooms for a holistic approach to nutrition and culinary education – from the Mater Hospital chefs, dietitians and food service team through to the patient consumer.

Initially slated for a 3-month duration, the 'Mushrooms on the Menu' intervention garnered such positive reception from the Mater team that it was extended for an additional three months, now scheduled for completion by March 31, 2024.

THE NEW EDUCATION RESOURCES FOR FOOD AND HEALTH PROFESSIONALS

Throughout the project, a suite of informative resources has been created, specifically for food and health professionals, available on the AMGA website.

The AMGA and FOODiQ will host an educational roadshow this year to present the results of the MU20003 research study, inviting key opinion leaders, nutritionists, dietitians, and food industry professionals to attend the events and conference opportunities.

A growing database of health and food professionals has also been developed, allowing the resources and updates to be regularly shared with the wider health care and food industry as the project progresses.

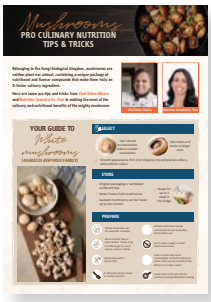
An online portal of educational and inspirational resources for food and health care professionals has been developed on the AMGA website, featuring a suite of new videos, facts sheets and an e-Book.

Health and food professionals can visit the site for nutrition and cooking information, trends, statistics, insights, tips, and tricks about Australian mushrooms. The resources include three YouTube videos and associated fact sheets.

Click each video or fact sheet to view or download from australianmushroomgrowers.com.au/food-industry/

Video 1: How to cater to plant-based dietary preferences and mushrooms as a meat substitute. This video contains a variety of surprising tips on how to cook mushrooms to retain optimum flavour and boost the nutritional content of meals, from Chef Adam Moore and Dr Flavia Fayet-Moore (Dr Flav), Nutrition Scientist.

Video 2: Pro culinary tips and tricks: Dr Flav and Chef Adam Moore discuss the different plant-based diets, and the importance of including Australian Mushrooms within each diet, due to their unique nutritional and culinary benefits.



Video 3: From farm to you: learn how mushrooms grow. Dr Flav and Chef Adam visit Australian mushroom grower, Rowan Anderson at White Prince Mushrooms, a farm located in the Hawkesbury region west of Sydney, to learn about (*Agaricus bisporus*) mushrooms' unique growing process, from compost to harvest.

IN THE MEDIA

The project has already generated significant positive media coverage. You can view recent coverage, including local newspapers and industry related publications. View the full list at https://australianmushroomgrowers.com.au/press/.

"We look forward to seeing the results of the MU20003 studies, and sharing the findings widely with food and health professionals, in turn encouraging other institutional organisation to add more mushrooms to menus," says Leah Bramich.

LEARN MORE

Food industry professionals can express interest in participating in the project by enquiring via the form on the AMGA website: https://australianmushroomgrowers.com.au/food-industry/

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

This Australian Mushrooms project is a Hort Innovation Mushroom Fund strategic levy investment and is led by the Australian Mushroom Growers Association (AMGA). Together with FOODiQ Global, 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.

READ MORE

The resources can be found here: https://australianmushroomgrowers.com.au/food-industry/

The project delivery team, from left: Leah Bramich, Shoreline executive chef Andrew Wright, chef Adam Moore, Dr Flavia Fayet-Moore, and Lucy Downey

MUSHROOM FARM HYGIENE MINI-SERIES

A new virtual mini-series in farm hygiene, to be delivered in May and June 2024, is an opportunity to review current knowledge, learn new techniques, and explore the topic of hygiene across the whole production process. By Judy Allan

The AMGA is delivering a Hort Innovation Mushroom Fund project – *Mushroom International Study Tours – Inbound and Outbound (MU22010).*

This 3-year project has been designed to deliver educational programs to a wide range of industry personnel across a broad range of industry topics, with the aim to improve knowledge of growers, compost producers and their employees, and build an industry that is resilient, efficient, and sustainable.

In 2023, the project facilitated two, 2-day in-person workshops with international mushroom production expert Eric de Groot. The workshops *Mushroom production – review and update*, had great attendance at both the South Australia and New South Wales events, however, many farm owner-operators were unable to attend in-person. Responding to feedback received from participants and the wider industry, the project has now pivoted to present bite sized (1.5hr) training virtually, with the aim of reaching and educating more farms around Australia.

ABOUT THE MUSHROOM FARM HYGIENE MINI-SERIES

Good pest and disease control begins and ends with good hygiene; however, practices and procedures can sometimes fall by the wayside – particularly when farms are short staffed or have high turnover of labour.

The mini-series program consists of four 1.5 hr sessions delivered remotely on consecutive Thursday afternoons of the 16, 23, and 30 May and 6 June. The program has been designed and delivered by Warwick Gill and Judy Allan, who will highlight resources developed through the Hort Innovation-funded *MU21007 Pest and Disease Management for the Australian mushroom Industry* project.

A follow-up remote event with an international speaker who specialises in farm hygiene audits and training is currently being developed as part of this initiative.

AMGA will host the mini-series. The recorded sessions will then be uploaded to the *Agora Pest and Disease* website.

TARGET AUDIENCE

For both experienced and less experienced key farm staff, the mini-series is an opportunity to refresh what they know and explore what they don't know about the impacts of good (or bad) farm hygiene.

Please note that this series is not targeted to new entrants with no experience on a mushroom farm. Less experienced participants can attend but will be expected to watch the new *Farm Hygiene and Integrated Pest Management Voice-Over PowerPoint (VOP)* videos currently being prepared as a prerequisite. These VOP videos will be released progressively prior to the May dates.

Recognising that the scope of farm hygiene includes more than can be covered in the four short, remote sessions of the mini-series, links to relevant pre-existing videos and relevant resources will also be distributed during the delivery period.

Course trainers Dr Warwick Gill and Judy Allan

TRAINER PROFILES

Warwick Gill graduated from the University of Canterbury (New Zealand) specialising in the mushroom disease 'Drippy Gill'. He undertook postgraduate study of mushroom diseases at the Tottori Mycological Institute (Japan) as a recipient of a JIST Fellowship, followed by a BRAIN research fellowship at the University of Tokyo (Japan), where he studied mushroom cultivation techniques.

In 2000, Warwick was awarded a DIST research fellowship, sponsored by Huon Valley Mushrooms in Tasmania, to study mushroom cultivation techniques at the Tasmanian Institute of Agriculture, University of Tasmania. He then joined Huon Valley Mushrooms as head exotic grower, spawn maker and farm manager.

In 2013 he joined Judy Allan to deliver the Hort Innovation-funded MU12007 (*Development of a pilot mushroom farm disease monitoring scheme*) in which they developed novel and rapid sampling techniques for large porous surfaces such as grow room floors. He then took the lead in the Hort Innovation-funded MU16003 (*Pest and disease management and research services*).

Judy Allan has been involved in the mushroom industry since 1982, initially as a government advisor with the NSW Department of Agriculture and then as a private consultant. As a specialist in pest and disease management and industry risk mitigation, she has performed roles as project manager and/or team member on Hort Innovation-funded projects including: MU13014 (*Implementing industry risk management*), MU11003 (*editorial consultant to the AMGA Journal*), MU12001 (*Mushroom industry knowledge training*), MU12007 (*Development of a pilot mushroom farm disease monitoring scheme*), and MU16003 and MU21007 (*Pest and disease management and research services*).

Judy has served on numerous industry committees and has extensive experience in delivering industry training at farm and whole industry level. She was awarded Life Honorary Membership of the Australian Mushroom Growers' Association in 2003 in recognition of her services to the industry.

In MU21007 Judy utilises her mushroom-specific technical background and in-depth knowledge of the industry to be predominantly responsible for grower liaison and awareness raising, as well as working with Warwick on resource development.

PROGRAM CONTENT

Session 1: Thursday 16th May, 2024

- Farm hygiene and its importance for Integrated Pest Management
- Costs associated with pest and disease outbreaks
- Examples of disease risk factors influenced by farm characteristics
- Events and situations that increase the likelihood of cross contamination on mushroom farms
- Vectors
- First response

Session 2 : Thursday 23rd May,2024

- The 7 stages of effective cleaning
- Choosing the best fit detergent and disinfectant
- Influence of residual organic material on disinfectant efficacy
- Application technology
- Economic thresholds
- Case study

Session 3: Thursday 30th May,2024

- Physical exclusion
- Foot dips and foot dip management
- Monitoring flies
- Dust
- Case study

Session 4: Thursday 6th June,2024

- Hygiene associated with harvesting
- Spot treatment
- End of crop procedures
- Case study

For more information or to register, visit the AMGA Website: https://australianmushroomgrowers.com.au/events/
or contact the event organiser, **Judy Allan,** directly on 0427 671 057 or email judyallan@bigpond.com

Hort Innovation MUSHROOM FUND

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MUSHROOM INDUSTRY OVERSEAS STUDY TOUR SCHOLARSHIP PROGRAM

The AMGA is pleased to announce the launch of the Mushroom Fund Scholarship Program, a new levy-funded program designed to upskill Australian mushroom industry participants by providing funding for overseas study tours in 2024 and 2025.

The Mushroom Fund Scholarship Program is a levy-funded international education study program, which is open to Australian *Agaricus* mushroom growers and compost producers, their employees, and Australian mushroom industry researchers. Partial funding is available for industry participants and emerging leaders to attend conferences, events and training courses, incorporating visits to mushroom farms and compost facilities overseas.

This year, six successful scholarship participants will be awarded partial funding of up to $2,650, to attend the Australia and New Zealand Mushroom Growers Conference, which will be held in Auckland, New Zealand, from 22-24 October this year, with an additional trip to Christchurch on Friday 25 October, to tour Meadow Mushrooms.

This educational project is funded by the Hort Innovation Mushroom Fund and forms the 'outbound' component of the levy-funded research project MU22010 Mushroom International Study Tours - inbound and outbound. The project is managed by the AMGA, with international study tours facilitated by Australian Mushroom industry expert, Judy Allan.

WHAT'S ON OFFER?

Six Scholarships are on offer, which will award successful applicants partial funding (for one person) to attend the Australia and New Zealand Mushroom Growers Conference 2024.

Travel dates are strictly Monday 21st to Friday 25th October 2024.

Each successful applicant will receive funding for:

- One full access ticket to the Australia and New Zealand Mushroom Growers Conference, which includes Mercer Mushroom farm tour, networking dinners and exhibition.
- Additional Farm Tour Package, including flight from Auckland to Christchurch, tour of Meadow Mushrooms and airport transfers.
- 5-nights' accommodation in New Zealand (4 nights in Auckland, 1 night in Christchurch).
- All internal travel costs, while studying in New Zealand.
- All meals while studying in New Zealand.

Total Scholarship funding up to $2,650 per recipient.

*International flights and travel insurance the responsibility of the scholarship participant.

WHAT IS 'PARTIAL FUNDING'?

This levy-funded project funds on-the-ground costs while studying overseas.

The recipient is required to pay for their own travel insurance and return international flights (i.e., from Australia to Auckland, and Christchurch to Australia).

Proof of booking is required to secure scholarship funding. See timeline for further information.

WHO IS ELIGIBLE?

Six Australian mushroom industry participants will be awarded scholarship funding. Participants are eligible based on the following criteria:

- Australian resident
- Over 18 years of age
- Categorised as one of the following:
  - Employee at an Australian *Agaricus bisporus* farm or compost facility
  - Owner of an *Agaricus bisporus* farm or compost facility
  - Researcher for the Australian Mushroom industry

As this is a levy-funded program, applications are not open to exotic mushroom growers or start-up farms.

HOW TO APPLY?

- Visit the AMGA Website to download the application form. https://australianmushroomgrowers.com.au/mushroom-fund-scholarship-program-2024/
- Application forms are to be returned to Leah Bramich, AMGA General Manager, via leah.bramich@amga.asn.au
- Applications must be received no later than 5pm AEST, Thursday 25 April 2024.

(Late application forms will not be accepted.)

HOW IS IT JUDGED?

Six Australian mushroom industry participants will be awarded scholarship funding.

Your application will be fairly assessed by the project reference group, which includes Hort Innovation, AMGA and industry representatives. Conflicts of interest will be managed accordingly.

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

TIMELINE

6 March	Applications open
25 April	Applications close
1 May	Participants notified of successful application
1 June	Signed participant agreements due
1 August	Participants to provide proof of flights booked, and travel insurance
22 October	Leave for Auckland
23 – 25 October	Australia and New Zealand Mushroom Growers Conference (All expenses paid)
26 October	Additional tour to Christchurch, to tour Meadow Mushrooms (All expenses paid)

Full terms and conditions and the application form can be accessed here: https://australianmushroomgrowers.com.au/mushroom-fund-scholarship-program-2024/

For more information about the Mushroom industry scholarship program, please contact AMGA General Manager, Leah Bramich, on 0450 504 675, or email leah.bramich@amga.asn.au

Hort Innovation MUSHROOM FUND

SCHOLARSHIP PROGRAM 2024

AU NZ MUSHROOM GROWERS CONFERENCE 2024

AMGA Australian Mushroom Growers' Assoc.

*Australian mushroom growers and compost producer levy payers can apply for the **MUSHROOM FUND SCHOLARSHIP PROGRAM,** to receive partial funding to attend the **Australia + New Zealand Mushroom Growers Conference in Auckland,** from Tuesday 22 to Friday 25 October, 2024*

Scholarship Recipients Recieve:

- ✓ 3-Day Conference & Expo Tickets
- ✓ Additional Farm Tour of Meadow Mushrooms, including flight from Auckland to Christchurch
- ✓ 5- nights Accommodation
- ✓ Internal travel and meal costs
- ✓ Helping recipients to attend the event, and focus on learning

*International flights and travel insurance to be paid by recipients.

To apply, visit the AMGA Website:
www.australianmushroomgrowers.com.au/events

APPLY NOW

This project is managed by the AMGA, and funded via *MU22010 Mushroom Industry Inbound Outbound Study Tours*. For more information about the project or the scholarships, contact Leah Bramich, AMGA General Manager on 0450504675 or visit the AMGA Website for full terms and conditions.

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CURRENT HORT INNOVATION MUSHROOM FUND PROJECTS

Project Name	Project Code	Organisation	Project Description	Start and expected end date
Development of a biosecurity plan for Australian mushrooms	MU18006	Plant Health Australia	Development of the mushroom industry's biosecurity plan	27/05/2020 – 20/04/2025
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	28/06/2019 – 28/02/2024
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	15/01/2019 – 31/12/2023
Mushroom industry minor use program	MU16002	Hort Innovation	Submit renewals and applications for new minor use permits for the mushroom industry, as required	Ongoing
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.	06/12/2020 – 01/11/2025
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.	30/06/2021 – 01/07/2024
Mushroom industry crisis and reputation risk management	MU20006	AMGA	Maintaining a crisis and reputation risk management plan for the Australian mushroom industry	22/06/2021 – 01/06/2026
Educating the food industry about Australian mushrooms	MU20003	AMGA	Delivering evidence-based information about Australian mushrooms to health and food service professionals in Australia	30/06/2021 – 30/07/2024
Mushrooms and their potential health benefits of lowering blood cholesterol	MU20001	CSIRO	Generating scientific evidence on mushrooms and their ability to lower blood cholesterol	31/07/2021 - 13/02/2026
Consumer behavioural data program	MT21004	Nielsen	Provides regular consumer behaviour data and insight reporting through the Harvest to Home platform (www.harvesttohome.net.au)	20/01/2022 – 20/11/2026
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	22/03/2022 - 31/03/2027
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)	26/06/2022 - 30/3/2024
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	23/06/2022 - 31/5/2025
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	28/06/2022 - 31/07/2023
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	08/07/2022 - 06/06/2027

Project Name	Project Code	Organisation	Project Description	Start and expected end date
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.	01/08/2022 - 30/5/2025
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	30/10/2022 - 16/06/2023
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	01/02/2023 - 31/8/2026
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	16/12/2022 - 01/09/2023
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.	02/02/2023 - 01/02/2025
Mushroom supply chain best management	MU22011	Applied Horticultural Research	Delivers a supply chain best practice guide for the mushroom industry	10/02/2023 - 28/02/2024
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.	13/04/2023 - 31/03/2026
Mushroom industry conference and roadshow program 2023-2026	MU22007	AMGA	This project delivers a national mushroom grower conference and roadshow program that promotes the uptake of best practice to the broader mushroom industry.	22/6/2023 - 30/11/26
Online resource for mushroom health and nutrition science for healthcare professionals	MU22006	Global food IQ (formerly: Nutrition Research Australia)	This project is creating the MUSHRoom (Mushroom Science and Health) online platform that is a one-stop-shop for research and resources on the nutrition and health benefits of mushrooms.	12/05/2023 - 22/06/2026
Mushroom foodservice research and strategy	MU22012	Fresh Logic	This short project is delivering a strategy for the mushroom industry to increase demand for mushrooms within the foodservice sector.	06/07/2023 - 15/12/23

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Scan this QR code to read more about these projects
https://www.horticulture.com.au/growers/mushroom-fund/

MARKETING

Mushroom experiential product sampling goes to the beach

On 26 January, the Australian Mushroom Growers' Association (AMGA) brought the snacks for the Beach 5s Australia and New Zealand beach rugby tournament at Nobbys Beach, Newcastle. Hosting the 'Australian Mushrooms Pitmaster BBQ' sampling event as part of the Hort Innovation-funded marketing program *Experiential Product Sampling and Events* (MU22503), the AMGA and award-winning Pitmaster Adam Roberts tempted spectators with free samples of mushrooms cooked both slow in the smoker and quick-grilled on the BBQ.

For a full run down of this remarkable event, see page 22 of the AMGA Journal.

NEW THREE PILLAR STRATEGY TO GUIDE MARKETING IN FY2025

With the current landscape of consumer behaviour heavily impacted by the cost of living crisis, brands must adapt their marketing strategies to stay competitive.

Aligned with the 2022-2026 Mushroom Fund Strategic Investment Plan (SIP), the Hort Innovation marketing team has devised a new three-pillar strategy.

Marketing Manager Monique Emmi, campaign leader, understands the importance of 'getting inside the head' of main grocery buyers and home cooks.

"Our goal is to drive demand and maintain consumer interest. We want to keep mushrooms top of mind and make sure they are on the shopping list," she said.

To be rolled out over the course of the 2025 financial year, the comprehensive three-pillar strategy aims to not only capture consumer attention but also drive demand creation and invest in future growth opportunities.

The key components of the strategy are *win the mind, win at point of purchase* and *win the future*.

The strategy is evidence based, supported by macro and micro facts that not only affect the grocery category, but specifically mushroom purchasing behaviour. Importantly, it is underpinned by the Ehrenberg-Bass model and also includes approaches to measurement and evaluation to ascertain the success of each activity and ensure levy dollars are well spent.

LEARN MORE

Click here to watch Monique Emmi's webinar on the new marketing strategy.

Vision	Inspire more people to consume more mighty mushrooms in more meals per month		
Business goal	Grow volume and value faster than total vegetables		
Consumer goal	Increase past four weeks penetration from 43%		
Key category benefit	Australian mushrooms instantly transform everyday meals from mundane to mouth-watering		
Strategic pillars	**Pillar 1 WIN THE MIND**	**Pilar 2 WIN AT POINT OF PURCHASE**	**Pillar 3 WIN THE FUTURE**
	Build top of mind awareness pre-store as a tasty and versatile ingredient	Retail inspiration and presence	Lay foundations for the future growth
Key activities	1. Paid media and creative (development and production) 2. Taste and versatility program (PR, social and/or events) 3. Website and program maintenance	1. Sampling 2. Retail media online and instore	1. Kids recruitment and education program 2. Food service strategy

Pillar 1: Win the Mind by building awareness

The first pillar focuses on winning the minds of consumers by enhancing brand awareness through strategic marketing initiatives. Paid media and creative endeavours play a pivotal role in achieving this objective. Potential program elements include developing and producing new radio ads, rolling out new creative executions under the Add The Mighty Mushie campaign across various channels, and utilising talent and influencers effectively for an 18-month period.

An integrated media plan and buy will be implemented, encompassing paid media channels such as screens, radio and paid social media, as well as branded digital panels in shopping centres and within close proximity to the entrance to supermarkets.

These programs commenced in late January 2024.

Pillar 2: Win at Point of Purchase by inspiring shoppers

The second pillar focuses on winning at the point of purchase by inspiring shoppers and increasing conversion rates.

Sampling initiatives will be intensified to boost purchase trial and conversion, with targeted sampling activities planned across major Australian supermarkets during key seasonal timings.

Additionally, retail media and point-of-sale activities will be optimised to increase penetration by attracting light and medium buyers both in-store and online. This includes pre-store engagement strategies, enhanced visibility in the fresh produce section of supermarkets, and comprehensive online retail media plans.

Pillar 3: Win the Future through R&D investment in education and food service strategies

The third pillar entails winning the future through strategic investments in research and development (R&D), children's education, and food service strategies.

By prioritising innovation and education, the aim is to cultivate long-term growth opportunities and stay ahead of emerging trends in the market.

"The marketing strategy and plan aims to help the Mushroom industry win today and win tomorrow so it has a sustainable and bright future," Ms Emmi said.

MARKETING UPDATE: October to December 2023

With an increased media spend in the final quarter of 2023, the reach of the Australian Mushrooms campaign packed a punch.

The campaign's overall objective is to inspire people to consume more mushrooms daily by adding Mighty Mushies to everyday meals. The multi-media approach aims to reach consumers at various touchpoints including radio, out of home environments, for example shopping centre screens in close proximity to supermarkets, social media channels, and while they are shopping online.

The campaign was brought to life by a series of newly recorded radio ads featuring celebrity chef, Miguel Maestre, who has also created three leading recipes.

These recipes inspire consumers to 'Reinvent the Meal' by illustrating how to add mushrooms to everyday meals.

Each of the media channels used has a specific role, as illustrated in Table 1.

MIGUEL ON THE TV AS PART OF THE PR/MEDIA CAMPAIGN

To inspire Australians to reinvent their meals with the Mighty Mushie, the marketing team worked with chef Miguel Maestre to create mushroom recipes for breakfast, lunch, and dinner.

Alongside creating and promoting recipes, data was gathered on how Australians cook their classic meals, how frequently, how many recipes are in their repertoire, and how long they have been cooking them. The findings were used to bolster PR media materials.

The Mighty Mushie campaign was launched with a two-phased plan:

Phase one: Leverage Miguel for Studio 10 segment and appearance at Mushroom Festival to drive awareness of the benefits of mushrooms (see Issue 7 for more about the Mushroom Festival.

Phase two: Pitch stories around how mushrooms and their unique taste and product benefits are reinventing mealtimes to drive consideration of mushrooms.

The PR campaign achieved over 250,000 opportunities to see, with more than 80% of the key messages included in each clip, and a 100% positive sentiment result (meaning that media love the humble mushie and strongly engaged with the campaign assets). The call-to-action to drive Australian consumers to purchase mushrooms was included in over 90% of coverage.

Table 1: Campaign media channels

Channel	Role of channel
Outdoor	Build brand awareness and high reach for mushrooms by being in close proximity to grocery stores or within shopping centres
Radio	Build top-of-mind awareness on our audiences' path to purchase
Social	Drive cost-efficient reach
Retail	Drive purchase of mushrooms both in store and online

Interviews with Australian Mushrooms spokesperson Miguel Maestre, PR research, media release, Miguel's recipes and imagery as well as Australian Mushrooms Grower spokesperson, John Siderakis, who provided a fresh take on the mushroom industry.

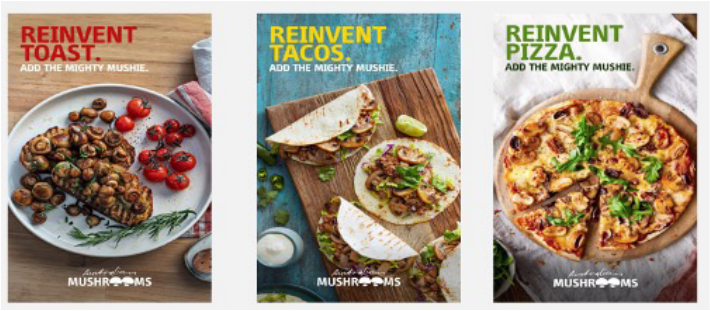
KEY MESSAGING

- The rising cost-of-living has left Australians cooking more basic meals, new research reveals
- Australian Mushrooms has partnered with local chef and personality, Miguel Maestre, to offer inspiration on how to reinvent basic meals using Australian Mushrooms.
- Add the Mighty Mushie to transform breakfast, lunch and dinner into healthy and delicious everyday meals.

MUSHROOMS REINVENTING THE MEAL WITH THE OUT OF HOME CAMPAIGN

Exceeding reach targets in both metro and regional markets, Australian Mushrooms advertisements were strategically placed in the path to purchase outside of major supermarket entrances to prompt shoppers to add mushrooms to their baskets.

Metro out of home reached 3.55M shoppers and regional out of home reached 1.39M shoppers.



MIGUEL TALKING MUSHROOMS ON THE RADIO

The Carrie and Tommy Mushrooms Sponsorship commenced on the 9th of October 2023 across the Metropolitan markets. The sponsorship was a continuation from FY24 July – September 2023 marketing activity.

The sponsorship concluded on the 30th of October 2023, then was replaced by BMAD pre-records utilising chef Miguel Maestre as talent.

The radio campaign reached over 4M grocery buyers 18+, a strong performer driving mass reach.

Listen to the radio spots **here**

MUSHROOMS ON THE SOCIALS

Between October and December 2023, Australian Mushrooms always-on social content featured a mix of seasonal recipes to inspire light buyers to purchase and use mushrooms, as well as educational content highlighting the health and flavour credentials of mushrooms, across Meta platforms (Facebook and Instagram).

Content creation was done in partnership with the following creators:

This content was posted to influencer channels, driving an additional 2.1M impressions (the number of times the ad is shown within the platform).

The partnership with Miguel was supported with his recipes shared across his social media pages as well as on Australian Mushroom social media channels to drive broad reach and engagement with main grocery buyers.

Mushrooms on Instagram. From left: @lukehines - 100K followers, @foodbylucy - 54.5K followers, @cheftomwalton - 350K followers, @gatherandfeast - 347K followers

Mushrooms at retail

Between October and December 2023, retail online advertising focused on giving inspiration to main grocery buyers on the path to purchase, with messaging and imagery featuring mushroom recipes for breakfast, lunch, and dinner. The call-to-action drove consumers to purchase and use mushrooms.

Woolworths-Cartology

New to brand customers	34,100
New to brand value	$256,000
Impressions	904,140

Coles

New to brand customers	68,000
New to brand value	$448,600
Impressions	432,579

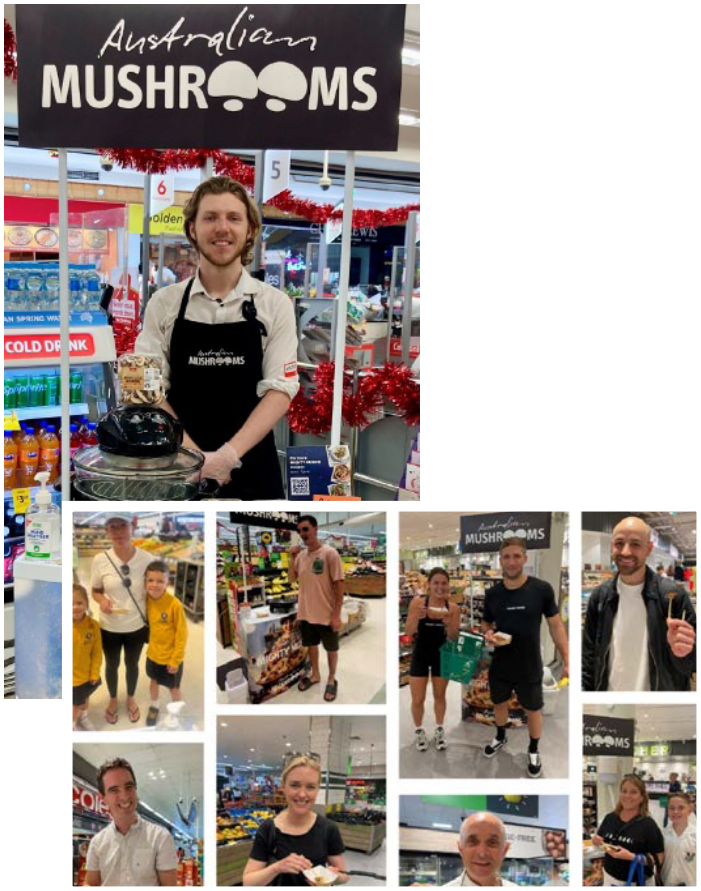
Both major retailers saw an uplift in new to brand customers as a result of the online advertising. Coles achieved $448,000 new to brand value and Woolworths achieved $256,00 new to brand value. Activity delivered over 1.3M impressions, showing it is imperative to continue retail activity to reach and bring in new customers.

SAMPLING MUSHROOMS IN STORE

Australian Mushrooms activated an instore sampling campaign that invited shoppers to trial different recipes featuring mushrooms as the hero ingredient - mushrooms skewers and mushroom pizza. The campaign covered 365 stores in total between Coles and Woolworths nationally and was activated on 3 October 2023 and completed on 14 December 2023.

A total of 29,687 samples were consumed and 41,287 shoppers were exposed to Australian Mushrooms. A predicted total of 7,004kg of pre-packed and loose were sold during the sampling period, which consists of 5,000kg of pre-packed and 2,000kg of loose.

Of those shoppers interacted with, 71% were converted into trying a sample and 38% of customers who sampled were converted to purchase mushrooms.



MARKETING UPDATE: Looking ahead

MEDIA COVERAGE

The media coverage with Miguel Maestre continues, with the following publications to interview the famous chef and feature Miguel's Australian Mushroom recipe content:

- Women's Weekly (**reach: 843K)**
- Better Homes and Gardens **(reach: 1M)**

PAID MEDIA ACTIVITY JANUARY – APRIL

The 'Add the Mighty Mushie' campaign will continue to run January – April 2024 across multiple touchpoints to inspire people to consume more mushrooms daily:

- Out of home panels in close proximity to supermarkets.
- Social always on advertising across Meta platforms (Facebook and Instagram).
- Retail online advertising across Coles and Woolworths websites, with display banners and single tiles.

The creative and messaging continues to focus on inspiring Australians to reinvent their everyday meals with the Mighty Mushie, with a call-to-action driving Australians to purchase mushrooms.

Activity is expected to reach over 15M main grocery buyers 18+.

EVERYDAY GOURMET 2024

Sponsorship of Everyday Gourmet 2024 with Justine Schofield on Network from 10 June – October 2024 is expected to reach over 4M Australians nationally, including 2.29M main grocery buyers.

Australian Mushrooms will receive:

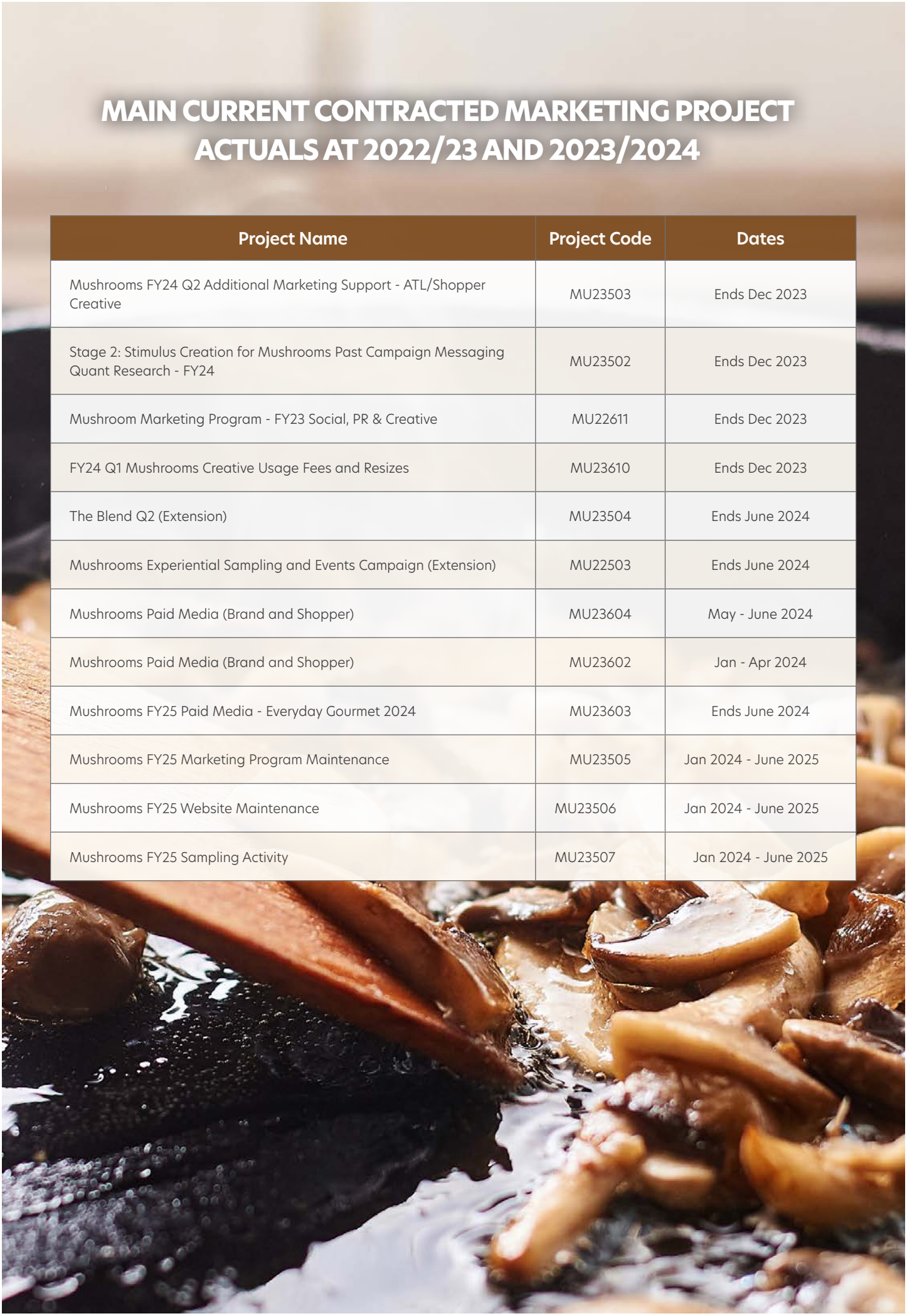
- 12x usage of Australian Mushroom in delicious recipes throughout the series (5x customised recipes, 3x quick bites, 4x usage occasions with Australian Mushrooms as the hero ingredient).
- Australian Mushrooms branding and recipes across Everyday Gourmet website and social media pages.

INSTORE SAMPLING

Due to the success of the 2023 sampling program, a new 18-month sampling campaign will kick off in early March. There will be 4 x bursts across the campaign period and the recipes will be seasonal with a focus on both summer and winter recipes.

MAIN CURRENT CONTRACTED MARKETING PROJECT ACTUALS AT 2022/23 AND 2023/2024

Project Name	Project Code	Dates
Mushrooms FY24 Q2 Additional Marketing Support - ATL/Shopper Creative	MU23503	Ends Dec 2023
Stage 2: Stimulus Creation for Mushrooms Past Campaign Messaging Quant Research - FY24	MU23502	Ends Dec 2023
Mushroom Marketing Program - FY23 Social, PR & Creative	MU22611	Ends Dec 2023
FY24 Q1 Mushrooms Creative Usage Fees and Resizes	MU23610	Ends Dec 2023
The Blend Q2 (Extension)	MU23504	Ends June 2024
Mushrooms Experiential Sampling and Events Campaign (Extension)	MU22503	Ends June 2024
Mushrooms Paid Media (Brand and Shopper)	MU23604	May - June 2024
Mushrooms Paid Media (Brand and Shopper)	MU23602	Jan - Apr 2024
Mushrooms FY25 Paid Media - Everyday Gourmet 2024	MU23603	Ends June 2024
Mushrooms FY25 Marketing Program Maintenance	MU23505	Jan 2024 - June 2025
Mushrooms FY25 Website Maintenance	MU23506	Jan 2024 - June 2025
Mushrooms FY25 Sampling Activity	MU23507	Jan 2024 - June 2025



PESTS & DISEASES

EXCLUSION IS A VITAL COMPONENT OF A MUSHROOM FARM'S IPDM PROGRAM

Warwick Gill, Tasmanian Institute of Agriculture, University of Tasmania, Hobart

Judy Allan, Pest and Disease Management Service

INTRODUCTION

When we think of exclusion principles on a mushroom farm, we immediately think of grow room doors and seals (Figure 1). And for good reason, as grow room doors and seals are the major physical barrier used to keep flies and dust away from the mushroom crops. But doors and seals are not the only exclusion principles that are applied on mushroom farms. In this article we will look at further methods of exclusion appropriate for mushroom farms, how to apply them and why they are applied.

Pest and disease management on a mushroom farm is achieved by an integrated pest and disease management (IPDM) program, a system of complimentary and coordinated activities, which, when performed correctly, suppress pest and pathogen populations in a cost-effective and environmentally sound manner. An effective mushroom farm IPDM program (Figure 2) embraces a range of control and good agricultural practice options including:

- practising stringent general farm hygiene
- providing a highly selective compost for the mushroom mycelium
- applying appropriate grow room environmental management
- encouraging biocontrol agents
- using appropriate pesticides as required.

In addition to controlling pest and disease outbreaks, an effective mushroom farm IPDM program – sometimes referred to as whole farm hygiene or holistic farm hygiene – has the additional benefits of reducing reliance on expensive pesticides, which in turn lowers the health risk to farm staff, reducing the threat to the environment, and eliminating the risk of resistance developing in mushroom pests and pathogens.

Figure 1. Damaged door frames give poor physical exclusion. Image: J Allan

WHAT DO WE MEAN BY 'EXCLUSION'?

The term 'exclusion' implies an external source of infection. Although an external source is possible for the initial introduction of pests and pathogens onto the farm, the enclosed and tightly controlled environment of modern mushroom farms means the source of infection is often from within the farm. However, external sources cannot be ignored, particularly considering the increasing practice of preparing compost in bulk at one location and transporting it to use in another. It has been widely demonstrated internationally that the trend to bulk compost handling has been implicated in the development and expression of both *Trichoderma aggressivum* (compost green mould) and Mushroom Virus X (MVX) Syndrome. Effective exclusion must therefore minimise the risk of introducing infection from outside the farm as well as reducing the chances of infection from within the farm.

One of the most efficient and cost-effective infection control measures in a mushroom farm IPDM program is to physically exclude pests and pathogens from the mushroom grow room. After all, in the absence of a pest or pathogen, there is no disease. Physical exclusion is achieved by:

- establishing physical barriers where they do not yet exist
- ensuring physical barriers are appropriate to exclude the target pest / pathogen and its vectors
- maintaining the integrity of existing physical barriers

In addition to physical exclusion strategies, there are also many farm practices, such as traffic management, farm gate inspections, and cleaning which do not present a physical barrier to pests and pathogens but still result in their exclusion from the crop.

MUSHROOM FARM IPDM

GENERAL FARM HYGIENE

1. Grow room hygiene
- cookout
- removal of organic material
- soap and water wash
- sanitise / disinfect

2. Foot dips

3. Monitoring
- sticky fly traps
- counts of diseased mushrooms
- signage

4. Sanitation of tools

5. Sanitation of machinery
- filling line
- casing line

6. Sanitation of facilities
- including floors
- may include fogging

7. Sanitation of contact surfaces

8. Process scheduling
- emptying and filling done at different times

9. Strict glove policy enforced

10. Clean clothing daily

EXCLUSION/CONTAINMENT

1. Vector control
- door seals
- fly mesh
- sticky fly traps
- foot dips
- signage
- 'traffic control'

2. Dust control
- door seals
- air filtration

3. Spot treatment

4. Disease monitoring & recording

5. Pest monitoring & recording

6. Harvester training
- keep beds clean
- recognise symptoms
- indicate / isolate
- report

7. Strict glove policy enforced

8. Signage

ELIMINATION

1. Highly selective compost

2. Cultural practices

3. Spot treatment

4. Fly control
- electronic fly 'zappers'
- sticky yellow fly traps

5. Pesticide application
- insecticides
- flies
- mites
- nematodes
- fungicides
- dry bubble
- cobweb
- green mould
- adoption of biorayionals

6. Efficient waste disposal protocol

Figure 2. Components of a mushroom farm IPDM program

WHAT ARE WE TRYING TO EXCLUDE?

The most common fungal pathogens of commercial mushroom cultivation in Australia, *Lecanicillium fungicola* (dry bubble), *Cladobotryum mycophilum* (cobweb), *Mycogone perniciosa* (wet bubble) and *Trichoderma* spp. (casing green mould), can all start new infections from spores and individual hyphal cells. But as fungi have no means of mobility, spores and hyphal cells must be carried from the site of infection, often an older crop, to a clean site in a new room. Similarly, the virus particles causing Mushroom Virus X Syndrome (MVX) and La France disease in Australia are not mobile. They must also be carried to sites of new infection as the particles cannot survive outside host *Agaricus* hyphal cells and spores (**Allan 2020a** and **Gill 2020a**). The most common carriers, or vectors, of these pathogens are farm dust (see box below), people, and most significantly, sciarid and phorid flies.

While nematodes and mites are both capable of movement, their range is restricted by their size. In addition to being a common component of farm dust and attaching to people, both pests characteristically form a phoretic association with flies, allowing them to relocate to new rooms and establish new infections (**Gill 2020b** and **Allan 2020b**).

Flies are small and highly mobile; they are attracted to the smell of actively growing mycelium in the mushroom compost over large distances and can quickly establish large populations on-farm if left unchecked. While they can impact mushroom crops in their own right, the greatest impact of flies on mushroom quality and yield is their ability to vector pests and pathogens from older to newer crops. This ability is particularly important in the spread of pathogens with sticky spores such as *Trichoderma* and *Lecanicillium,* which are carried on the legs of flies (Figure 3). Consequently, exclusion plays a significant role in managing fly populations (**Allan 2017**) and is crucial for both crop health and farm profitability.

Effective exclusion is not just targeted at specific pests and pathogens. The vectors and carriers of the pests and pathogens must also be excluded from areas where they will carry infection to the crop.

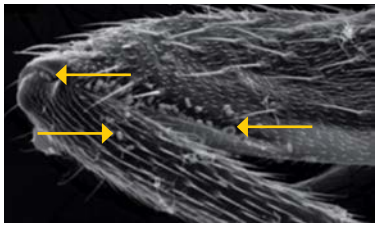


Figure 3. Sticky *Lecanicillium* (dry bubble) spores (examples arrowed) trapped in the knee joint and adhering to the leg and leg hair of a sciarid fly.
Image: Courtesy A Shamshad

WHAT IS 'DUST'?

Dust occurring on-farm is mainly composed of soil from roadways, bare ground, and surrounding fields. But significantly for disease management, farm dust also contains organic material originating from mushroom cultivation.

Sources of on-farm dust include compost and casing dropped onto the ground during filling operations and compost, casing and mushroom debris dropped onto the floor during harvest, and spot treatment, or spread to the floor by watersplash during irrigation (below). This organic matter accumulates under trays and shelves and collects in cracks and joins in the floor. When it dries out, the organic matter becomes airborne through foot traffic, sweeping and air movement.

Grow room organic matter may include:

- spores and mycelium of fungal pathogens and *Agaricus*
- casing and compost, which may or not be contaminated with pathogens and/or colonised by *Agaricus*
- mushroom debris, which may or may not be contaminated with pathogens
- dead flies and the mites, pathogens and *Agaricus* spores and cells they may carry
- mites and the pathogens and *Agaricus* spores and cells they may carry
- dried resistant nematode larvae

In the 'Grogan Experiment', Helen Grogan demonstrated that grow room dust was able to cause dry bubble at the same rate as a low concentration of pure Lecanicillium spores (**Gill 2021**).

GROW ROOM DOORS

The most effective physical barrier to dust and flies is a well-sealed, closed, grow room door. Fortunately, integrity of the door and seals is relatively easy to test – see the box below. Depending on the building design, some door seals may be difficult to access. It is particularly important that these seals are inspected regularly as it is less likely that damaged, difficult-to-access seals will be detected during the everyday work routine.

The most effective door is a closed door. Even a perfectly fitting door with new seals cannot exclude dust and flies if it is constantly open. Do not leave doors open unless necessary and use smaller personnel doors instead of the main door whenever possible. Ensure the doors on newly filled rooms are closed when dirty operations such as room emptying or harvesting in an old room are being performed elsewhere on the farm.

Figure 4. Damaged door seals prevent effective exclusion. Image: J Allan

Shelf farms are at a disadvantage when it comes to filling as the entire back wall is removed during the process and the aroma of actively growing *Agaricus* mycelium in the spawn-run compost are very attractive to flies. With the filling machinery in place, it may not be possible to shut the door even when the production crew takes a break. For these farms, dust must be managed (**Gill 2021**) before and during the process while adult flies will need to be treated once the room is filled and the door closed to prevent them laying eggs in the beds.

On tray and block farms, the grow room door is usually left open to allow spawn-run compost to be loaded into the grow room from the set back or spawn run room. For farms filling from an internal corridor, fly pressure will come primarily from older crops while dust is less of an issue. For tray farms that fill from an external door, dust will need to be managed before and during filling and flies can be treated once the room is filled and the door closed.

HOW TO TEST THE INTEGRITY OF GROW ROOM DOORS AND SEALS

Enter the grow room, shut the door, and turn off the room lights.

Look around the entire outer edge of the door and check there are no patches of light showing through.

If you do see light, examine the pattern of the light. If the light is in unusual shapes and in definite but separate areas, it is most likely that the seals are damaged (Figure 4).

The light entering the room may be caused by an ill-fitting door. If the light patch more or less evenly increases or decreases in size as you look up and down the sides, or along the top and bottom, then the door may not be hanging correctly and the mounting gear will need adjustment.

An ill-fitting door may result in unusual wear in the door seals and these will need to be re-inspected once the door has been adjusted.

Examine the door frame and make sure the edge of the frame is true. Contact with machinery such as forklifts and pallet trucks as they pass in and out of the grow room can damage the frame and prevent a tight seal forming (Figure 1).

Look for other signs of seal and joint failure around the room. For example, wherever external water can enter a room, unfiltered air will also be able to enter (below).

FILTRATION

Irrespective of the air handling system on the farm, filtration of incoming air to the grow rooms is crucial to exclude infective dust, flies, and other pests from the crops. Filtration requirements are unique to each site and are determined by variables such as cultivation process, building configuration, air speed and load. We will confine our comments in this article to ways of attaining effective filtration against mushroom pests and pathogens.

Filters intended for removing bacteria are too fine and too expensive for use in a growing room and are more likely to be used in compost tunnels and Phase II cool down. Because of the very small pore size, bacterial filters clog up very quickly with dust and spores, increasing resistance. This results in increased running costs and will alter the airflow within the grow room to the detriment of the crop.

Because air travels along the path of least resistance, it is important that the main filter sits snugly against the mounting gasket within the filter box to create an airtight seal, forcing all contaminated air through the filter and preventing flies from bypassing it. Because main filters are expensive to replace, their lifespan can be extended by using a coarse pre-filter to capture large dust particles, pests, and other insects before they reach the main filter and clog the fine pores. Coarse filters not only entrap particles in their fibres, but they also retain particles by electrostatic attraction.

The ducting of incoming air systems must be regularly inspected for leakages. Regularly check:

- for holes in the ductwork
- that nuts and bolts are secure and are tight against the steel
- to ensure bolt heads fit snugly in the hole drilled for them and that there is no gap around the bolt head
- that there are no stresses, such as vibration, on the ductwork that would cause a bolt hole to 'stretch'
- that the gaskets (if fitted) in the flexible joints are in good condition and have not perished
- on external fan units that the pipework hasn't degraded or perished

FLY MESH

Many washable filters are quite porous to flies, particularly phorids, and although they are not able to fly against overpressure to enter rooms, they can walk through the filter (Figure 5), and once out of the main airstream, fly as usual. Flies can be prevented from entering grow rooms through vents and other wall penetrations by fitting a quarantine mesh (maximum aperture size of 0.3mm) over the hole. When installing quarantine mesh, be aware that the fly mesh:

- must fit tightly over the opening being screened as flies are strongly attracted to the smell of fresh compost and they will find any small gaps (Figure 6)

Figure 5. Flies can penetrate some washable fibrous pre-filter material. Image: J Allan

Figure 6. Badly fitted fly mesh does not protect the crop. Note the fly mesh pulling away from the frame (arrow). Image: W Gill

- may make it harder for air to exhaust so the exhaust may need to be increased to ensure that the air circulation in the rooms is not compromised

Consider placing fly mesh over the drains, particularly if drains are shared between rooms. While preventing flies from entering a room, this will also prevent the flies escaping to other rooms when steam is introduced at cookout.

FLY TRAPS

The most commonly available fly traps are electronic 'zappers' with an attractant UV light (Figure 7a) and yellow sticky traps (**Gill 2020c**) which can be purchased as either a long and wide strip (Figure 7b) or small individual squares (Figure 7c). As monitoring tools, these traps are extremely useful provided they are inspected at regular time intervals and fly numbers are noted, so that the number of flies in a specific location can be recorded over time. An increase in flies recorded in the traps is advanced warning of disease incidence inevitably increasing.

When fly populations are low, fly traps can be useful in vulnerable areas of the farm to keep the population down to controllable levels. But when the fly population escalates in summer, fly traps are not very effective as a method of exclusion. Unlike other agricultural industries which use similar traps to control flies, mushroom farms hold hundreds of tonnes of compost in a warm and moist environment – ideal conditions for breeding flies. The number of flies caught in these traps will have little impact on the rate of reproduction or the population at its peak. When fly populations flourish, growers will need to an apply alternative IPDM tool – hit the population hard with appropriate biological or chemical insecticides to reduce fly numbers to a level that can be maintained by fly traps.

FOOT DIPS

Standard cultivation practices such as harvesting and watering spread pests and pathogens from infected beds onto the floor in dropped casing, in mushroom debris, and by watersplash. Consequently, the grow room floor is a significant reservoir of disease which can easily be transferred onto the beds and spread around the farm on footwear (Figure 8, p34). Well-maintained and suitable foot dips (**Gill 2019**) are therefore an important component of an effective farm exclusion strategy. There are many proprietary foot dip designs available but not all are appropriate for use on mushrooms farms; furthermore, one design may not be suitable for all on-farm situations.

Some considerations for effective foot dips are:

1. Safety
    - foot dip has a reservoir with a non-slip base and low sides
    - use a non-slip disinfectant if possible when the foot dip is on a painted concrete floor
2. Cleanliness
    - wash out the foot dip and totally replace the disinfectant at least daily in high traffic volumes

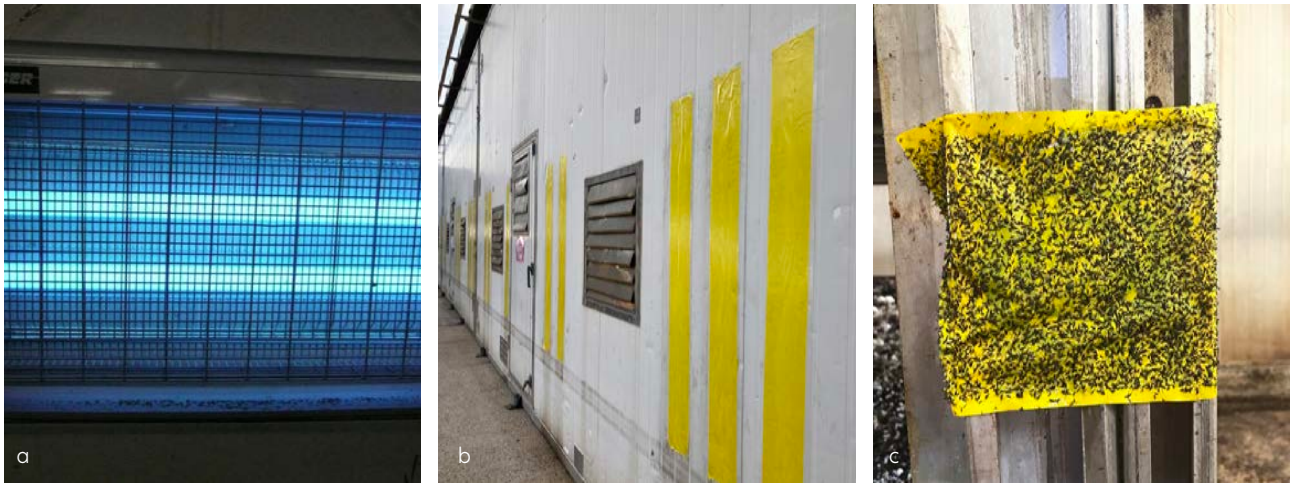


Figure 7. Examples of fly exclusion methods a) electronic fly 'zapper' b) long lengths of wide yellow sticky paper positioned around known fly entry points c) individual fly traps require frequent replacement especially when fly populations are high. Images: J Allan

- do not 'top up' the reservoir – this dilutes and diminishes efficacy of the disinfectant
- dispose of the dirty disinfectant in compliance with local environmental guidelines

3. Suitability – the foot dip is appropriate for the situation
    - while perhaps suitable for a smaller farm, a moulded foot bath (Figure 9a) is not appropriate for a larger farm. In areas of high traffic volume, the organic content builds up quickly and activity of the disinfectant is very reduced
    - use a large mat-type foot dip (Figure 9b) or disinfectant mat (see next section) in grow room doorways
    - the foot dip reservoir must be deep enough to cover the soles of footwear

In addition to being an effective exclusion tool, foot dips are also a constant reminder to staff that they are working in a vulnerable area and that they need to be mindful of hygiene at all times. Once a foot dip is no longer in use, it must be cleaned and put away out of sight and not left dirty and abandoned in plain view (Figure 9c).

To be an effective exclusion tool, it is critical that foot dips are closely monitored and maintained particularly on high traffic days. Organic matter severely reduces the killing power of disinfectants and published studies have demonstrated that in environments with a high organic load, footwear can actually become contaminated from the foot dips if they are not cleaned and the disinfectant replaced routinely. Given the potential for floor-borne pathogens to infect mushroom crops, the resources required for foot dip maintenance is a good investment. Clean and well-maintained foot dips ought to be located at every grow room door irrespective of the cropping cycle and at the entrance to the facility so visitors and tradespeople do not track infection in from outside.

DISINFECTANT MATS

Disinfectant mats are particularly useful for excluding pests and pathogens on tray farms, where forklifts travel in and out of new rooms. Disinfectant mats can be carpet offcuts or lengths of artificial turf which are impregnated with a disinfectant and laid across the entire grow room doorway (Figure 10). The offcut must be long enough to span the whole doorway and it must be wide enough to allow the largest vehicle wheel a full rotation in contact with the mat to ensure disinfection. The formula to calculate how wide the mat must be for your vehicles has been published previously (**Gill and Allan 2015**).

There are a number of benefits in using disinfectant mats instead of foot dips:

- they do not have side walls as foot dip reservoirs do (trip hazard), so they are much safer for staff
- they are stable and do not move on the floor even if laid over painted concrete

Figure 8. Examples of transmission routes of pathogens from grow room floor to mushroom bed a) shelves are sometimes used to climb on during crop inspections b) mushrooms along the outer edges of trays are sometimes knocked by harvesters' feet overhanging picking trolleys. Images: J Allan a); W Gill b)

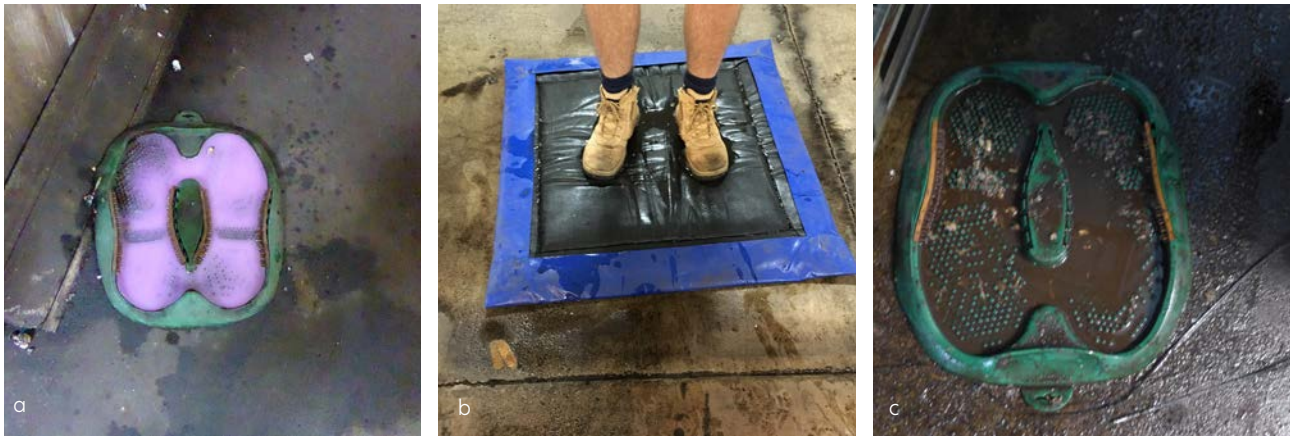


Figure 9. Foot dip qualities a) moulded foot dips are not suitable for high traffic areas such as rooms being harvested b) a low-sided mat-type foot dip is safe and better suited to wheeled equipment c) make sure unused foot dips are cleaned and stored out of sight when not in use. Images: J Allan

- laden forklifts can drive directly onto a mat and make a turn without disturbing it
- all wheeled vehicles and equipment used in a grow room get their wheels disinfected every time they pass over the mat
- small, wheeled equipment such as box trolleys and pallet jacks can be pushed over the mat very easily
- harvesters cannot avoid disinfectant mats as they can foot dips

Figure 10. A disinfectant mat in front of a grow room doorway to disinfect staff footwear and the wheels of vehicles, trolleys , and other wheeled equipment. Image: W Gill

'TRAFFIC' MANAGEMENT

Traffic management cannot be strictly considered physical exclusion as it is not a tangible object that prevents pests and pathogens from entering mushroom crops. But good traffic management plays an important role by excluding the potential infections carried by staff and their equipment from older crops.

Harvesters are the most significant vectors of mushroom pests and disease, second only to flies. Consequently, staff rosters and cropping cycles must be coordinated to prevent harvesters from picking an older room – which will naturally have a greater probability of higher pest and pathogen populations – then moving to pick a younger room. Harvesters must wear freshly laundered clothes daily as the first pick must be from the newest crop. This is to prevent the pests and pathogens encountered in the older rooms at the end of the previous day's shift from being carried on the previous day's clothing to the new crop.

Staff working in clean areas such as filling and casing must also begin their shift in freshly laundered clothes as the crop at this stage is highly vulnerable to contamination. Because of some of the biological properties of mushroom pests and pathogens, clean area staff must not share facilities with harvest staff for the well-founded fear of transferring pathogens, particularly *Lecanicillium* and *Trichoderma*, to the casing and fill line.

There are a number of other practices that harvesters are trained to follow to ensure pests and pathogens are excluded from mushroom crops. Some examples of these practices are:

- understand and follow the farm's glove policy
- ensure knives and buckets are thoroughly cleaned and disinfected at the end of each shift
- ensure picking equipment is thoroughly cleaned and disinfected at the end of shift
- recognise disease symptomology and report it correctly so that the affected mushrooms can be marked and other harvesters avoid touching them

AT THE FARM GATE

All goods and services which pass through the farm gate must at least be visually inspected as a minimum before they are delivered to sensitive areas on the farm. Off-site personnel such as tradespeople and company reps must be signed in to comply with current on-site WHS policy upon arrival. This is a good opportunity to determine if previous jobs involved agricultural properties or other mushroom growing sites. Deliveries should be inspected at the office for contaminants and organic material before being sent onto the farm. Incoming trucks need to be inspected, particularly those coming directly from other mushroom farms or agricultural sites, and cleaned, if necessary, before entering the farm. To prevent potential sources of infection from entering the farm (Figure 11) and affecting the crop, check that:

- spawn and casing materials are examined carefully on arrival and immediately before use. Even commercial spawn makers get infections (Figure 12)
- re-usable crates and boxes are clean and free of biofilm, insect larvae, and mouldy mushroom material
- re-usable crates are disinfected before they are introduced into cropping rooms
- pallets used to transport inward goods are free of organic material
- cardboard boxes from inward goods have not become wet and mouldy
- signage to direct tradespeople, company reps and casual visitors to the office before entering vulnerable areas is clearly visible
- tradespeople account for their previous service visit when signing in at the office e.g., nursery? Farm?
- clean foot dips or disinfectant mats are located at the entrance to vulnerable areas of the farm
- incoming delivery and waste removal vehicles are assessed, particularly if they are servicing multiple farms.
    - do they need to be cleaned before entering the property?
    - can they be restricted to a specific area of the farm away from growing rooms and vulnerable procedures?

Figure 12. A *Penicillium* infection (green growth) beneath a filter patch in a bag of commercial *Agaricus* spawn. Image: W Gill

Figure 11. Sources of potential infection carried across the farm gate a) spent compost in the back of a delivery truck which had arrived from another mushroom farm b) compost packed into the wooden pallets following a peat delivery from another mushroom farm c) mouldy cardboard box used to deliver mushroom farm supplies. This box originated from overseas. Images: W Gill

A NOTE ABOUT CONTAINMENT

When a disease outbreak occurs on-farm, we respond by **containing** the pathogen or pest to the affected grow room. It is no coincidence that many of these containment measures, such as air filtration, foot dips, secure doors and seals are the same as our exclusion measures. This is because the enclosed nature of mushroom growing facilities means that the restriction of pests and pathogens in one direction (exclusion) is equivalent to the restriction of pests and pathogens in the other direction (containment). This overlap is acknowledged and reflected in the mushroom farm IPDM system diagram (Figure 2).

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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

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OPTIMISE YOUR SANITISER AND DISINFECTANT

Warwick Gill, Tasmanian Institute of Agriculture, University of Tasmania, Hobart

Judy Allan, Pest and Disease Management Service

INTRODUCTION

With mounting consumer opposition to pesticide residues in food products and the increasing awareness of their environmental impact, industry access to traditional disease control chemicals is declining world-wide. Achieving effective on-farm disease management is therefore becoming increasingly reliant on whole-farm preventative hygiene.

One of the fundamental aims of preventative hygiene is to 'start clean'. That is, to begin a new crop in a grow room free of mushroom pests and pathogens. Effective grow room sanitation is achieved by a multi-stage process **(Gill 2017)** with disinfection being a key step. Because it is the disinfectants and sanitisers which kill mushroom pathogens, it is important that these products are given optimal conditions to work.

SANITISER OR DISINFECTANT?

When talking about mushroom farm hygiene, we often use the terms 'cleaning', 'sanitising' and 'disinfecting' without thinking about what they mean. But they do mean different things and it is important to understand these differences in what we are trying to achieve with our farm hygiene. Broadly speaking, cleaning removes organic material from a surface, sanitisers reduce the number of microbes on a surface to a safe level depending on the situation, while disinfectants kill all the microbes on a surface. It is useful to think of the relationship between cleaning, sanitising, and disinfecting as an activity spectrum, with cleaning at one end and disinfection at the other (Table 1).

For some situations such as medical research facilities, hospital operating theatres, and food contact surfaces, the total removal of microbes, or disinfection, is required. But on a mushroom farm, effective disease management

is all about keeping the populations of mushroom pathogens below the farm's threshold level for disease expression. In addition to cleaning, we therefore ought to talk about sanitising as part of our hygiene program rather than disinfecting, noting that some farms may have post-harvest operations requiring a disinfectant. Nevertheless, both 'disinfectant' and 'sanitiser' are also used interchangeably on the farm and for our purposes this is acceptable. In fact, the terms 'disinfectant' and 'sanitiser' are used interchangeably by the government agrichemical regulatory body, the Australian Pesticide and Veterinary Medicines Authority (APVMA) on its website, sometimes at odds with the manufacturer's product label.

WHICH SANITISER OR DISINFECTANT CAN I USE?

Because sanitisers and disinfectants claim to kill, they must be registered for use in association with food crops. The sanitisers and disinfectants that

Table 1. Hygiene processes compared

CLEANING	SANITISING	DISINFECTING
• Cleaning physically **removes** most microbes, dirt, soil, and other organic material from objects and surfaces • Use soap or detergents with water to scrub, wash, and rinse	• Sanitising **reduces** the number of microbes on objects and surfaces to levels considered safe for a specific application • Objects and surfaces should be **cleaned** first before sanitising	• Disinfecting **kills** remaining microbes on surfaces. Killing microbes can further lower the risk of spreading disease • Objects and surfaces should be **cleaned** first before disinfecting

Adapted from the Centre for Disease Control, USA

are registered by the APVMA for use on Australian mushroom farms and their recommended applications are presented below (Table 2, p40). Note that not all products are recommended for use in all situations and the legally acceptable method of application may vary; for example, not all products are registered for fogging.

OPTIMISING MY SANITISER

Effective grow room sanitation follows a described process **(Gill 2021)**, but the efficacy of the sanitiser can be affected by the physical characteristics of the farm which can vary from site to site. However, one factor that severely impacts *all* registered sanitisers, irrespective of the farm, is the presence of organic material (Table 2). Organic material reduces the activity of disinfectants and sanitisers by adhering to the microbe's surface, blocking the adsorption sites necessary for the disinfectant to act or by forming inactive chemical complexes with components of the disinfectant. For disinfectants and sanitisers to work effectively, organic material – mushroom farm compost, casing, mushroom debris, and dust – must first be removed and the sanitiser applied to the clean surface.

By physically removing the organic material, good cleaning eradicates up to 85% of the microbes – including mushroom pathogens that are both living inside and adhering to the outside of soil particles – from the grow room environment. This allows disinfectants to work at full killing power and to also attack pathogens directly rather than through a protective barrier of organic material. Effective cleaning also removes pathogen reservoirs present as established biofilms, prevents the establishment of new ones, and removes macromolecules which may serve as a nutrient source for mushroom pathogens.

While the presence of organic material impacts the efficacy of all sanitiser products registered for use on mushroom farms, other factors such as the presence of rubber and plastic, pH and water may affect the efficacy of specific products. These factors will be discussed in a later article.

EFFECTIVE CLEANING REQUIRES DETERGENT

If you feel your sanitisers are not performing very well, it is highly likely that your cleaning is not thorough enough. Detergents are a critical component of effective cleaning as they lift organic matter from surfaces and hold it in suspension so that it can be rinsed away. Because they do not claim to kill, detergents do not need to be registered so there is a wide range of products available. For mushroom farms, the composition of the detergent is important **(Gill 2021)**. Be aware of detergents that claim to also sanitise or disinfect as any claim to kill may require registration by the APVMA and use of them can be problematic.

Table 2. Disinfectants registered for use on Australian mushroom farms

REGISTERED PRODUCT	ACTIVE CHEMICAL GROUP	APPLICATION	IMPACT OF ORGANIC*
Bacrasan phenolic sanitiser	Phenol	Knives, tools, machinery, benches, floors, walls, footbaths, and most other surfaces	Severe
Des-O-Germ disinfectant	Quaternary ammonium	Mushroom sheds as a spray or fog For control of *Trichoderma atroviride*	Severe
Hypochlor chlorine cartridge	Chlorine *as calcium hypochlorite*	For control of bacterial blotch (*Pseudomonas tolaasii*)	Severe
Pathocide sanitiser/disinfectant	Chlorine *as sodium hypochlorite*	For control of bacterial blotch (*Pseudomonas tolaasii*)	Severe
San-i-mush foaming iodophor sanitiser	Iodine complexes *inc. phosphoric acid*	Growing trays, sheds and service areas, misting of walls, ceilings, fixtures etc, foot baths, and hand baths	Severe
Vibrex Horticare sanitiser	Chlorine *as chlorine dioxide*	Terminal sanitising rinse for stainless steel tanks, transfer lines, on-line equipment, picking baskets, picking utensils and other food contact surfaces Control of mould and slime forming bacteria on walls, floors, ceilings, and post-crop mushroom growing surfaces	Severe
Zydox PC2 sanitiser	Chlorine *as chlorine dioxide*	Terminal sanitising rinse for stainless steel tanks, transfer lines, on-line equipment, picking baskets, picking utensils and other food contact surfaces Control of mould and slime forming bacteria on walls, floors, ceilings, and post-crop mushroom growing surfaces	Severe

* Collated from Gilmore et al (2011)

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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

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GROWING & TECH

COLD MUSHROOMS ARE **QUALITY MUSHROOMS**

Postharvest temperature management.

By Dr Jenny Ekman

My old professor at university used to say that the three most important things in postharvest management were Temperature, Temperature and..... Temperature.

Temperature is certainly the key factor determining the storage life of fresh mushrooms. It affects weight loss, colour change, firmness, stipe elongation, cap opening, bacterial growth and overall freshness. While there are many things growers can do to improve quality at harvest (see MushroomLink Summer p11, *Best practice in mushroom supply chains* for more on this), it is the temperatures that mushrooms experience afterwards that are key to determining the quality consumers experience.

WHAT IS TEMPERATURE, ACTUALLY?

Temperature is a measure of the kinetic energy carried by molecules within an object or material. Any collision between a molecule with high kinetic energy, and one with lower kinetic energy, transfers energy from one to the other. To us, this translates as the warmth or coolness of an object or material, whether mushrooms, their packaging, or the air around them.

Unlike mass or volume, temperature (i.e. the kinetic energy of molecules) cannot be measured directly. Rather, we gauge temperature by observing its effects on other materials, such as the expansion of metals, or reflection of infrared radiation.

Einstein said, "*Energy cannot be created or destroyed, it can only be changed from one form into another*".

Heat is one such type of energy.

Respiration by harvested mushrooms converts the energy stored in sugars and carbohydrates into forms that can be used by cells. Some of that energy is also converted into heat. The faster mushrooms are respiring – due to their temperature, development stage or damage – the more heat energy is produced.

For example, using mean respiration rates of mushrooms, it can be calculated that a kg of mushrooms at 19°C produces nearly 21 kJ heat/kg/day. However, respiratory heat drops to 3.5 kJ/kg/day once the mushrooms are cooled to around 5°C (Figure 1). Every degree of cooling decreases respiration, and therefore the heat produced, just a little more.

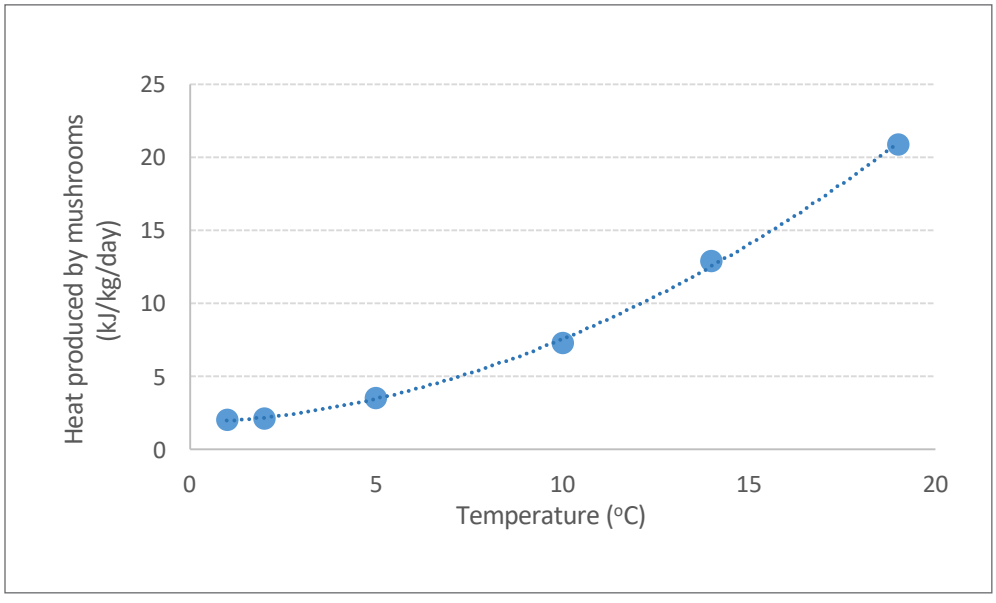

Figure 1. Effect of air temperature on respiratory heat produced by mushrooms. Respiration rates are average values from authors own data. Note this calculation is based on 6 moles CO_2 generating 2,667kJ heat (USDA, 1986), which is not verified for mushrooms.

PRINCIPLES OF COOLING

Cooling is what happens when heat energy is transferred from mushrooms into other media, whether water, air, packaging, or other mushrooms.

As a general rule, the speed at which energy is transferred depends on:

- the medium
- the object's surface area
- the object's thermal conductivity and
- the temperature differential between the object and the cooling medium.

The medium

By the 'medium', we are mainly referring to the air or water that surrounds the mushrooms. However, packaging can also form part of the medium, conducting heat to, or from, the mushrooms.

Air is a poor conductor of heat. Water is a better conductor of heat, transferring energy 24 times as efficiently. If you need proof of this, just think how cold you are likely to get ocean swimming in winter compared to going for a brisk walk. Even though both air and water may be 15°C, that swim is going to be a lot shorter!

Hydro-cooling (immersion in cold water) is clearly not an option for mushrooms. However, just as water can transfer heat away during cooling, it can also allow warming.

A key example is cold room insulation. Like a puffer jacket, cold room insulation works because of the air trapped in layers of foam inside the panelling. This prevents transfer of heat from the outside of the room to the inside.

Older rooms often have poor door and floor seals, or damage where forklifts have punctured the panel skin. If this allows moisture to penetrate the internal foam, the insulation will be ineffective. Likewise, wet, non-insulated concrete floors can allow heat to penetrate the cold room. Poor insulation means increased energy consumption, poor temperature control and lower relative humidity overall.

Surface area

Individual mushrooms have a large surface area relative to their volume. This means they can cool very quickly indeed. However, once mushrooms are packed into a punnet or carton, the effective surface area is reduced to that of the packed product.

If the punnets are placed inside crates on a pallet and the whole load is wrapped with cling film, the effective surface area is only that of the outside of the loaded pallet. The surface area is now low compared to volume, making it hard to remove heat from the mushrooms inside.

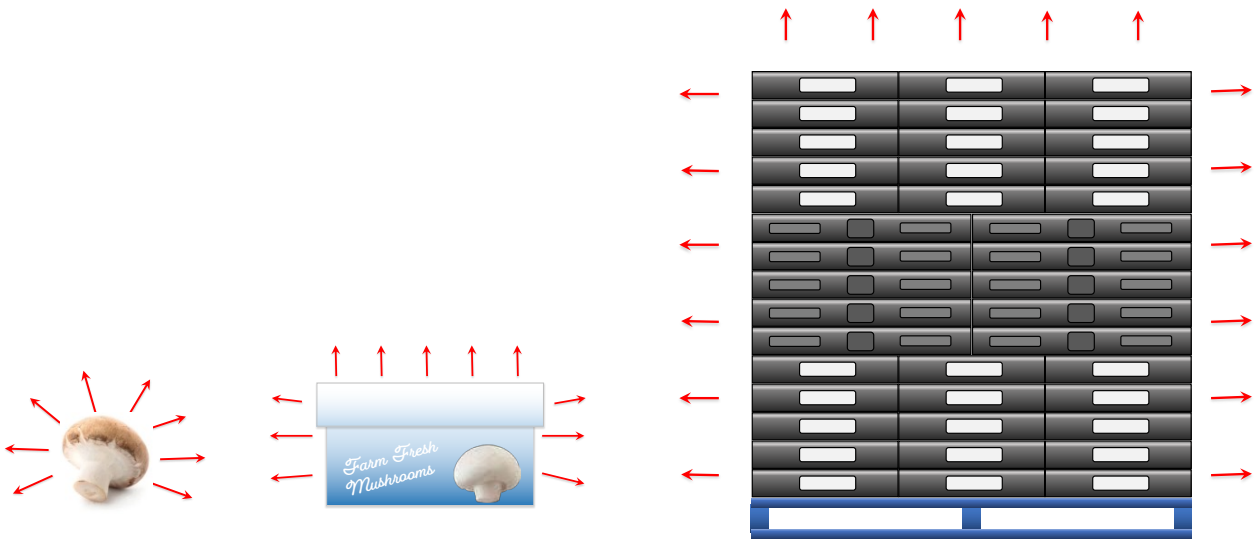

Figure 2. Surface area is a key factor in the speed of cooling. Whereas a single mushroom has a very high surface area compared to its volume, mushrooms inside a carton have only a medium surface area to volume ratio, while stacking onto a pallet reduces surface area to volume even further.

Thermal conductivity

Thermal conductivity is a measure of how easily products lose heat. For example, cabbages are hard to cool because the layers of air trapped in between the leaves prevent heat from moving from the core to the surrounding air.

In contrast, mushrooms have a relatively loose internal structure and lack a true skin. Their thermal conductivity is therefore high, making them easier to cool (Figure 3).

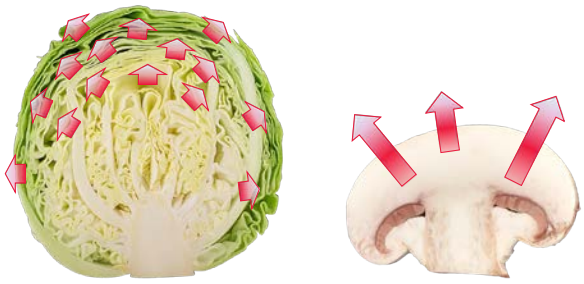

Figure 3. The layers of trapped air between cabbage leaves make it difficult for heat energy to escape. In contrast, the porous structure and lack of a true skin of mushrooms means their thermal conductivity is high, and heat can more easily be removed.

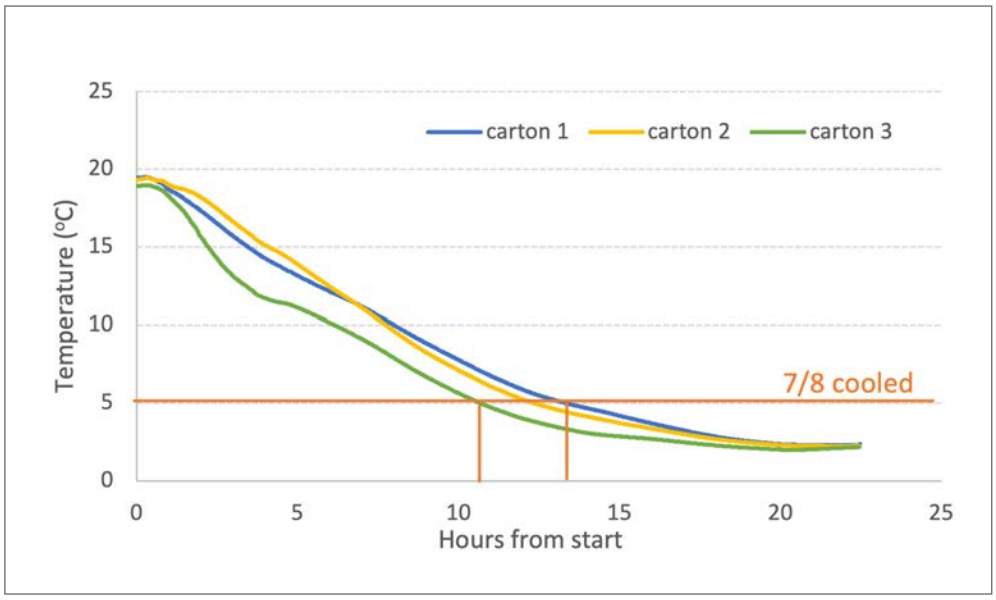

Figure 4. Pulp temperatures inside three cartons of loose mushrooms placed inside a cold room. Temperature fell from 19°C at harvest to a target of 3°C; mushrooms were 7/8 cooled once they reached 5°C, which took 11 to 13 hours.

Temperature differential

Products cool fastest when there is a big difference between them and the cooling medium. As mushrooms approach the temperature of, for example, the cold room air, the cooling rate will slow.

Because the last few degrees take the longest, it is difficult to compare rates of cooling between different systems. It is easier to compare the time taken to '3/4 cooled' or '7/8 cooled'. That is, when 3/4 or 7/8 of the temperature differential between the product and the air has been eliminated.

For example, if the mushrooms are 18°C at harvest, and the temperature target is 2°C, the temperature differential is 16°C.

The mushrooms will be ¾ cooled when they are 6°C and 7/8 cooled when they are 4°C:

$$18°C - (3/4 \times 16°C) = 6°C$$

$$18°C - (7/8 \times 16°C) = 4°C$$

COOLING METHODS

Room cooling

The easiest way of cooling mushrooms is to simply put them into the cold room. However, the cold room air has to remove both their latent heat and the heat generated by respiration, which is faster while mushrooms are warm. This means that cooling can be slow, even when fans are moving air around the room.

If the mushrooms are already packed into cartons or punnets, then cooling will be even slower.

Cooling ratees are important because mushrooms will continue to lose moisture while they are warmer than the cold room air, even if the air is humidified to 85%RH or more.

This is because the warm, moist air spaces inside the mushrooms are essentially 100%RH. This means the air inside the mushrooms can hold a lot more water vapour than the cold room air, even if both are saturated.

Molecules always move from areas of high to low concentrations, and water vapour is no exception. This difference in the partial pressure of water vapour between the warm inner tissues and the cold air effectively pulls moisture out of the mushrooms.

The relationship between the partial pressure of water vapour, temperature and humidity is described by the psychrometric chart. As shown in Figure 5, there is a significant vapour pressure deficit between warm mushrooms and cold room air.

Room cooling is also likely to result in condensation. As warm air cools, it is able to hold less water vapour. The point at which moisture condenses out of the air is the dewpoint. Temperature gradients result in condensation on mushrooms, the inside of packages, and even in different parts of the cold room.

Forced air cooling

Forced air systems pull cold room air through packed product. In effect, this reduces the surface area from the outside of the carton or pallet to that of the mushrooms inside. Forced air cooling rates can be 10 times faster than simply placing the packed mushrooms in the room.

Moreover, as air always moves from cold areas to warmer ones, there is no risk of condensation. Despite the increased volumes of air moving past the product, faster cooling means that weight loss is reduced.

It is important to note that even high amounts of air movement within the room cannot achieve the same effect as forced air cooling. Air is lazy and will take the path of least resistance. Forced air systems **pull** the air

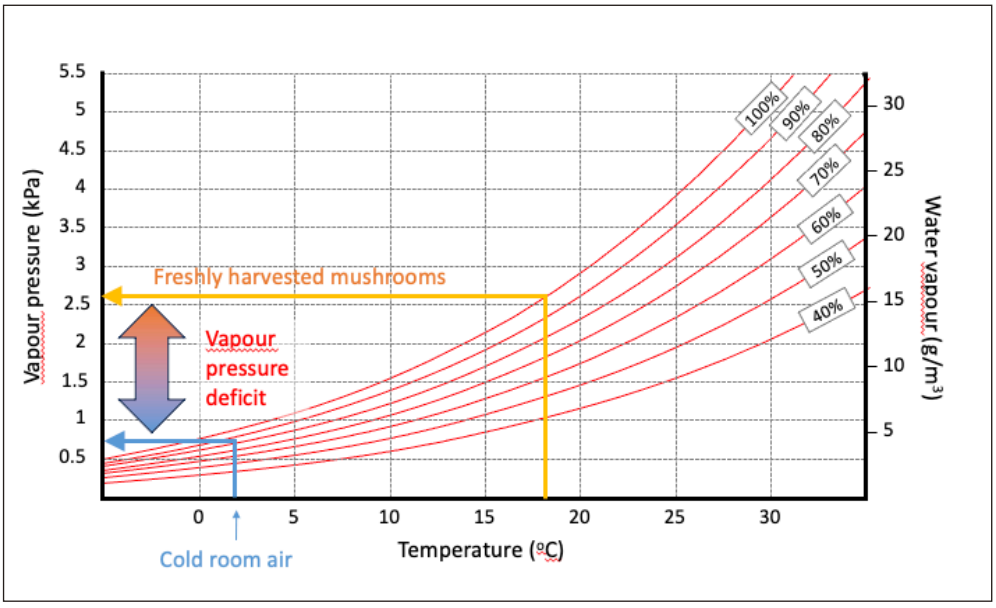

Figure 5. The relationship between temperature, humidity and water vapour pressure is described by the psychrometric chart. In this example, the vapour pressure deficit between mushrooms (18°C + 100%RH) and the room air (3°C + 85% RH) is approximately 1.8 kPa.

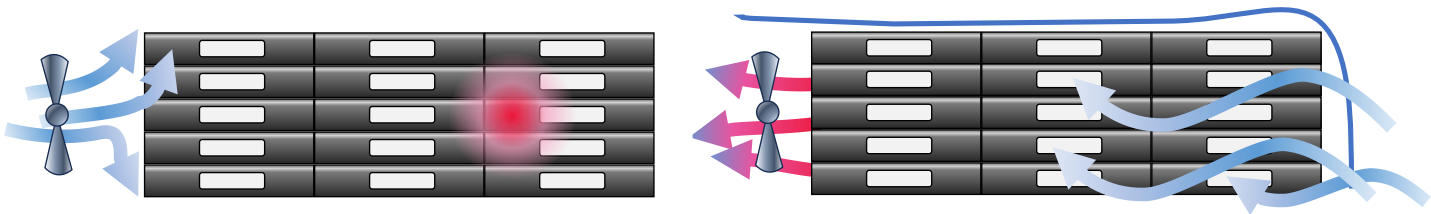

Figure 6. Although blowing air around the cold room can help remove heat from the outside of packed product, warm areas can persist within the consignment (left). Forced air systems pull air through the packed product, cooling product evenly and efficiently while avoiding condensation (right).

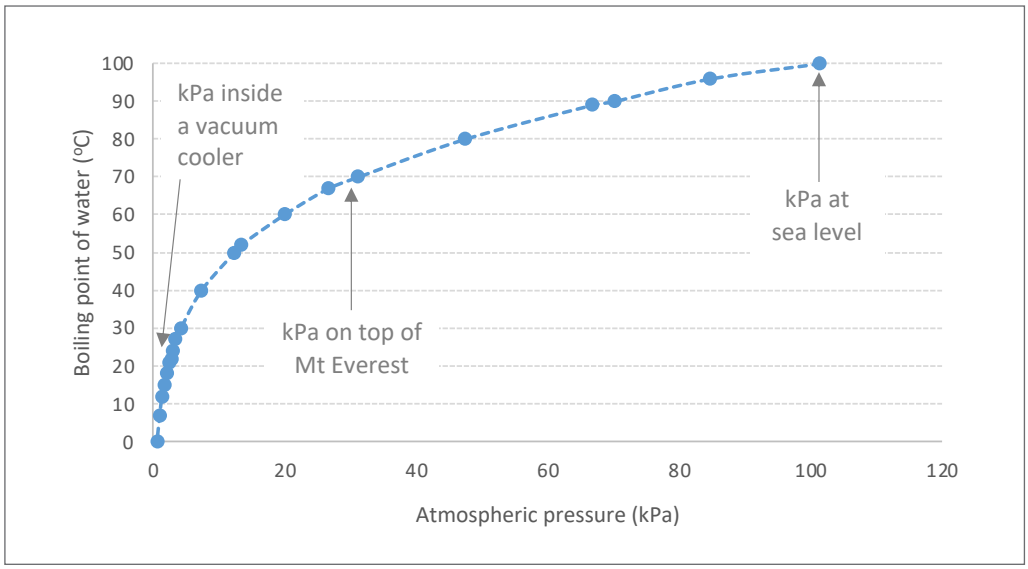

Figure 7. Effect of atmospheric pressure on boiling point of water. Data from myengineeringtools.com.

through the cartons. Fans will simply **blow** it around the outside (Figure 6).

Forced air cooling is widely used for other fresh products. Although rarely used for mushrooms, it does provide a low cost cooling strategy for some growers.

Vacuum cooling

The fastest and most energy efficient way to cool mushrooms is vacuum cooling. Vacuum coolers work by evaporating water from fresh produce. For this reason they work best with products that lose water easily, like leafy greens, herbs – and mushrooms.

At normal atmospheric pressure (around 101.3 kPa) water boils at approximately 100°C. This phase change (liquid into gas) for water absorbs energy. Changing 1ml of liquid water into vapour absorbs 2.26kJ of energy.

This is why water or sweat drying from your face feels cooling in hot dry weather.

As water changes from liquid to gas it not only absorbs energy but also increases volume 1,671 times.

At high pressure the transformation from liquid to gas is more difficult, so more energy needs to be put in to make phase change occur. In effect, water's boiling point increases. Conversely, reducing the pressure means that water changes more easily into vapour.

On top of Mt Everest, reduced atmospheric pressure means that water boils at around 70°C. At 10kPa (1/10th normal atmospheric pressure), water boils at 45°C, while at 1kPa water boils at only 6.7°C (Figure 7).

Commercial vacuum coolers can exert a pressure of close to -100.7kPa, dropping water's boiling point to just

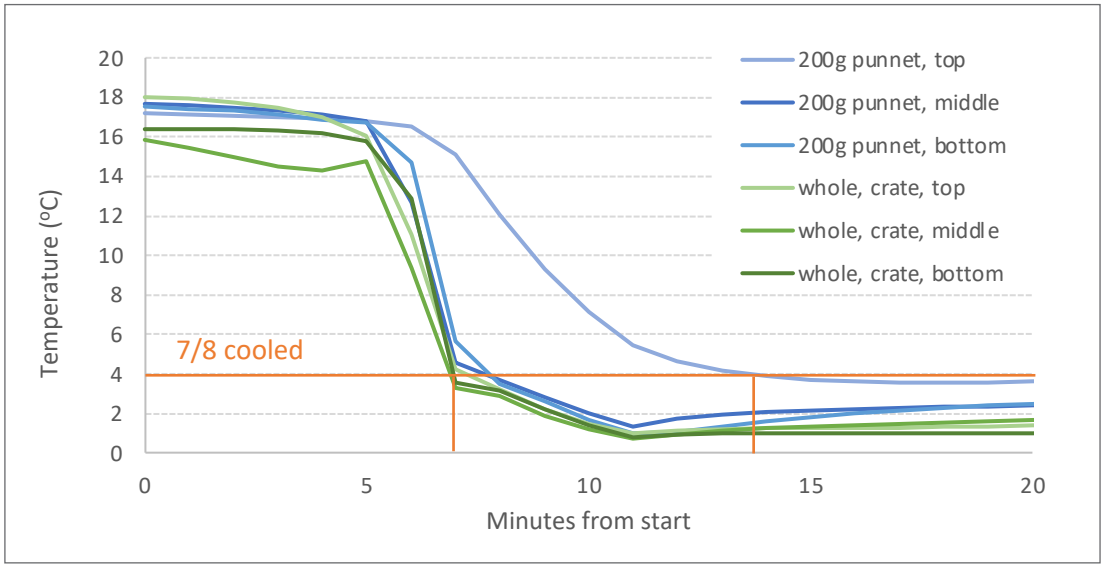

Figure 8. Pulp temperatures during vacuum cooling of packed punnets and loose crates of mushrooms in the top, middle and bottom of pallets. Temperature fell from 17°C at harvest to a target of 2°C; mushrooms were 7/8 cooled once they were 4°C; most reached this in 7 to 8 minutes.

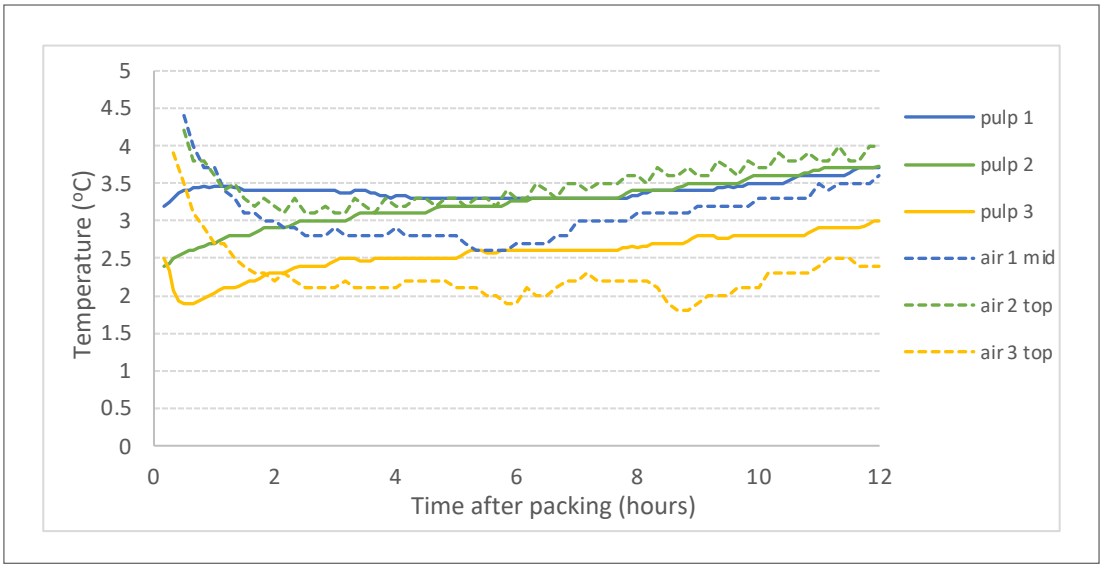

Figure 9. Pulp and air temperatures inside cartons containing sliced mushrooms on three pallets in a single storage room. Cartons were located centrally in the stack (pallet 1) or two from the top (pallets 2 and 3). The cold room was running at approximately 2.2°C.

above zero. It is important to not go any lower as this will freeze the mushrooms.

As cooling is by evaporation, mushrooms inevitably lose some moisture during vacuum cooling; approximately 1% for every 6°C change. However, they can easily lose more weight during room cooling, as the process is much slower.

Unlike other cooling methods, vacuum coolers are unaffected by packaging (as long as water vapour can escape), with cooling fairly uniform through the load.

Vacuum coolers can operate based on a timed cycle or using a probe inserted into the product. The cycle stops once the probe reaches the target temperature. Using a probe prevents 'overcooling', avoiding excess weight loss and energy consumption.

However, if a probe is used, it is essential it is inserted into the largest size mushroom being cooled, with the tip accurately located in the mushroom core.

In this example shown in Figure 8, mushrooms in 200g punnets cooled at the same rate as those in open crates – with a single exception. While 5 of 6 probes reached 7/8 cooled in less than 8 minutes, one took nearly 14 minutes.

The most likely reason for this is that the probe was not fully in contact with the mushroom flesh. Probes measure temperature right at their tip, so if this does not have good contact with the flesh, it will measure air temperature instead. In a vacuum cooler, air temperature falls more slowly than product temperature, so this is not a good measure of cooling.

It is notable that 7/8 cooling was achieved in a few minutes using a vacuum cooler, compared to around 12 hours with room cooling. This difference is likely to have significant impact on quality and shelf life.

ENERGY EFFICIENCY

Cold rooms are good for storing mushrooms, but inefficient at cooling them.

Typically, 5 to 15% of the total load on the cold room is due to transmission of heat through the roof, walls, and floor. If the walls are exposed to direct sunlight this will be much higher. Another 10 to 20% of energy load can be due to internal factors such as people, machinery, lights, fans, and equipment. Depending on how often the door is opened, there may be up to 10% additional load due to warm air infiltration.

This means that only around 55 to 75% of the total energy used by the cold room is actually cooling the mushrooms. If this is not enough to remove the heat energy produced by respiration, the room will be unable to maintain its setpoint, let alone provide cooling.

Using a forced air system dramatically reduces cooling time. Cooling products faster increases the energy efficiency of cooling from 10 to 30% (room cooling) to an estimated 70 to 75%.

However, forced air is still less efficient than vacuum cooling, which is 80 to 85% energy efficient. This is because nearly all of the energy consumed extracts heat from the mushrooms, rather than cooling the air and materials around them.

KEEPING MUSHROOMS COLD

Cooling mushrooms can be thought of as adding value with electricity. Allowing the mushrooms to warm back up cancels that value.

However, this can be harder than it seems, especially once mushrooms are punnetised, packed, and palletised. Their rapid respiration rate can easily increase temperature inside the unventilated punnet.

If heat cannot readily transfer to the surrounding air, then the mushrooms will start to warm up. Higher temperatures mean faster respiration, creating a heat 'snowball'.

In the example shown in Figure 9, pulp temperatures of sliced mushrooms packed into cardboard cartons

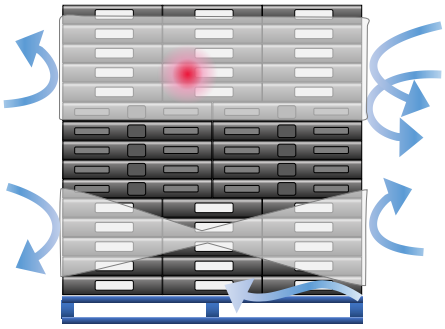

Figure 9. There is little airflow through pallets of packed stock, especially if they have been plastic wrapped to stabilise the load. Without airflow, heat energy produced by the mushrooms cannot be removed, potentially allowing hot spots to develop.

were warmer than the surrounding air in two of three monitored pallets. Both air and pulp temperatures trended upwards during storage, even though the room remained at 2 to 2.5°C and there was good airflow around the pallets. This demonstrates the difficulty of removing heat from packed mushrooms, especially when inside wrapped pallets.

MANAGE THE RISK OF WARMING

Techniques to help reduce risk include:

- Handle mushrooms gently, especially sliced product, as damage increases respiration rate
- Cool mushrooms thoroughly, preferably using vacuum cooling
- Don't wrap pallets until despatch, so as to allow air movement through the crates / cartons
- Maintain air flow around pallets
- keep them well spaced inside the cold room
- leave a gap of at least 20cm between pallets and the walls
- Add a fan to circulate air around the room
- Check the room insulation, making sure it is sealed against moisture
- Minimise door opening and consider adding air curtains or airlocks to reduce ingress of warm external air
- Ensure the room cooling capacity is sufficient to remove the heat generated by respiration at peak loading

This project is a Hort Innovation Mushroom Fund strategic levy investment: MU22011 Mushroom supply chain best practice management.

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

Key points

- Temperature is a measure of the kinetic energy carried by molecules.
- Temperature is the primary factor affecting mushroom storage life and quality, influencing weight, colour, firmness, and bacterial growth.
- Mushroom respiration generates heat, with higher temperatures increasing respiration rates and, therefore, heat.
- Cooling rate depends on the cooling medium, product surface area, thermal conductivity, and temperature differential.
- Room cooling, forced air, and vacuum cooling are common cooling methods, with vacuum cooling being the fastest and most energy efficient.
- Room cooling is slow and likely to result in condensation, reducing mushroom quality and storage life.
- Once mushrooms are cold, preventing re-warming is crucial for maintaining quality.
- Strategies to limit re-warming include thorough pre-cooling, maintaining airflow through and around pallets, reducing ingress of warm air and ensuring the cold room is operating efficiently.

REGULAR FEATURES

Research from around the *World*

Oxidation-driven lignin removal by *Agaricus bisporus* from wheat straw-based compost at industrial scale (a)

Katharina Duran, Jeanne Miebach, Gijs van Erven, Johan J.P. Baars, Rob N.J. Comans, Thomas W. Kuyper, Mirjam A. Kabel. Int. J. Biological Macromolecules. 246:125575.

The secretome of *Agaricus bisporus*: Temporal dynamics of plant polysaccharides and lignin degradation (b)

Katharina Duran, Joris Magnin, Antoine HP America, Willem JH van Berkel, Thomas W Kuyper, Mirjam A Kabel. iScience 26, 107087.

WHAT'S IT ABOUT?

Once upon a time, *Agaricus* mushrooms were just another fungi, albeit widely distributed. They grew from Alaska to the Congo, and from coastal grasslands to mountain forests. This adaptivity was due in part to their natural diet, which was based on partially degraded leaf litter and other organic materials in soil.

Farmed *Agaricus* feeds primarily on wheat straw, degrading the tough celluloses, hemicelluloses (xylan) and lignin that together form plant cell walls. One key purpose of composting is to strip away straw's waxy cuticle and start to break down the linkages between carbohydrates and lignin, making these materials easier for the mycelium to digest – as would have occurred in the natural environment.

At the end of Phase II composting, 50-60% of celluloses and xylans in the starting material have already been degraded. However, lignin largely remains intact. Lignin interacts with cellulose and forms cross linkages with xylans, forming a complex, hard to break down network of polymers. The mycelium therefore need to at least partially break down lignin in order to access what have been assumed to be more energy-rich food sources (Patyshakuliyeva A. 2015).

Despite the abundance of lignin in the substrate, and its' likely importance in the *Agaricus* diet, it has been difficult to definitively characterise how it is broken down. Lignin in compost is not only structurally complex, but also insoluble, composed of aromatic rings and well integrated with other compounds. This makes it difficult for fungi to break down, as well as difficult to measure in the laboratory.

However, researchers at Wageningen University have developed a new, accurate method for measuring lignin. This combines pyrolysis (heating to high temperatures without oxygen) and GC-MS analysis, with carbon-13 labeled lignin used as an internal standard. Unlike other methods, measurements exclude lignin held within dead microbes, or which has already been partially degraded. This means it avoids overestimating the lignin remaining in substrate.

In 2023 PhD candidate Katherina Duran published two papers relating to her work (and that of the Wageningen team) on lignin. The aim was to determine whether there were biological bottlenecks during utilization of the substrate by *Agaricus*, and whether these could be addressed by changing composting technique or adding enzymic amendments.

The first (a) describes the different processes used by Agaricus to break down lignin. The team found that lignin remained stable during the first six days of mycelial growth. This is likely due to the young mycelium consuming the more easily accessible carbohydrates present – a bit like going straight to the cheese and biscuits at a dinner party. However, as the mycelium began to more fully colonise the substrate, delignification began in earnest.

Between days 6 and 10, 19% of total lignin was removed by the mycelia, with an additional 17% removed between days 10 to 13. Interestingly, after this there was little further change. This could indicate that the remaining lignin was in forms more difficult for the mycelia to break down, or that other biochemical bottlenecks limit continued extraction from the substrate.

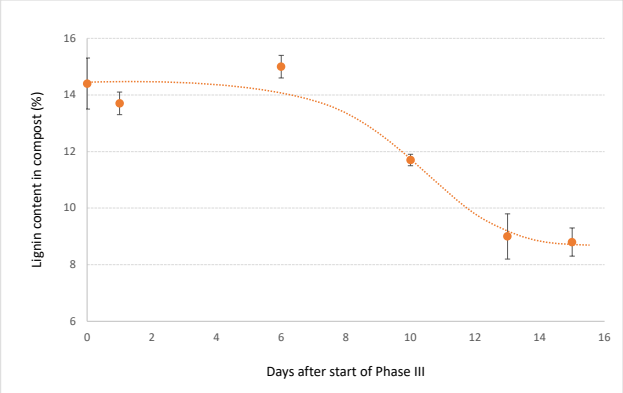

Figure 1. Total lignin (% dry weight) in substrate during phase III. Bars indicate the standard error of each mean. Dotted line approximates best fit to data. Derived from data presented in Duran et al, 2023a

In total, less than half (43%) of the total lignin present in the substrate was broken down, suggesting that availability of lignin is not the key factor limiting productivity.

This is consistent with results published in 2017; Vos et al. genetically engineered Agaricus to overexpress manganese peroxidase (MnP), with the aim of increasing lignin breakdown. It was hypothesised that this would improve total carbohydrate availability in compost. Although enzyme activity was tripled, total lignin content and yield were unaffected. This was thought due to lack of peroxidase, which is essential for MnP activity against lignin.

In the second paper, the Wageningen team explored the Agaricus secretome, and the effects of these compounds on lignin degradation. The "secretome" describes the set of proteins produced by the mycelia which are secreted into the surrounding substrate.

The paper confirms the earlier finding that lignin is an important food source for Agaricus; during Phase III the celluloses, xylans and lignin that make up wheat straw cell walls declined by 20%, 18% and 40% respectively.

This breakdown is catalysed by enzymes. Enzymes are types of proteins and consist of strings of amino acids linked together in polypeptide chains. It is therefore not surprising that degradation of materials in the straw was associated with a huge increase in protein expression.

At the start of phase III, the young hyphae were only secreting 11 proteins into the secretome. However, protein production exploded as the mycelia colonised the substrate. By day 10 the mycelia were expressing 116 different proteins, increasing to 187 identified proteins on day 13 (Figure 2).

Around 40% of these exudates were identified as enzymes associated with degradation of lignin (carbohydrate active enzymes or CAZymes). Another 15 to 19% were proteases. That is, enzymes that break down proteins, recycling nitrogen from organic sources. This reflects the substrate environment, where organic materials are already partially broken down. In contrast, only 2 to 7% of exudates in the secretomes of wood rot fungi (e.g. oyster mushrooms) are proteases.

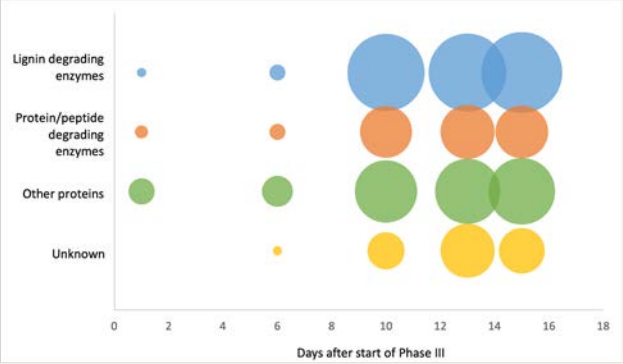

Figure 2. Number and types of proteins found in the secretome of *Agaricus bisporus* during Phase III. Size of circles indicates the number of proteins found. Derived from data presented in Duran et al., 2023b.

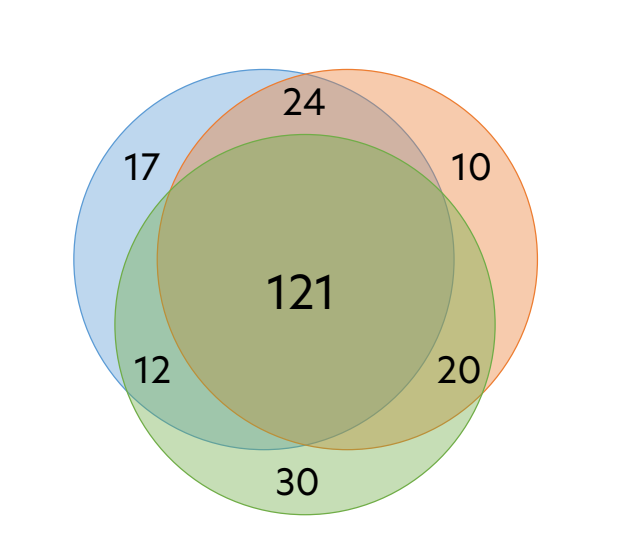

Figure 3. Venn diagram of proteins found in the secretomes of normally cultivated *Agaricus* mycelia 15 days after the start of Phase III (D15), compared to mycelia grown in sterilised media with straw particles included (CDF) or removed (CWS). Numbers indicate the total number of proteins found that are common to one, two or all three growing systems. From Duran et al, 2023b.

The researchers also compared the secretomes produced by Agaricus grown in normal compost with secretomes from Agaricus growing in a sterilised, boiled compost extract from which the solid straw particles had (CDF), or had not (CWS), been removed.

Only 16% of the proteins produced by Agaricus growing in normal compost were absent from either or both of the two sterile cultures. This confirmed that the proteins recorded were definitely produced by Agaricus and not by other microbes present in the compost (Figure 3).

This work has demonstrated the importance of lignin degrading enzymes in fuelling growth of the Agaricus mycelia. These enzymes, secreted into the surrounding substrate, are clearly essential for efficient extraction of nutrients from straw's tough cell walls.

Despite this, less than half of the nutrients available in the compost are transformed by Agaricus mycelia. Understanding the bottlenecks that limit further breakdown of lignin two weeks after the start of Phase III could help optimise extraction of energy held in the substrate, increasing productivity.

This work is only a small part of that submitted by Katherina Duran in defence of her thesis in late 2023. The remaining research is embargoed until the results have been published. MushroomLink will wait with interest to see what further light is shed on the complex process of feeding Agaricus.

Additional references:

Patyshakuliyeva, A. 2015. Unravelling the mystery of commercial cultivation of *Agaricus bisporus*: Plant biomass utilisation and its effect on mushroom production. Thesis submitted to Utrecht University. https://dspace.library.uu.nl/handle/1874/320601

Vos AM et al. 2017. H2O2 as a candidate bottleneck for MnP activity during cultivation of Agaricus bisporus in compost. AMB Express. 7, 124. https://doi.org/10.1186/s13568-017

Ideas?

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The Marsh Lawson Mushroom Research Unit is available to the industry for research projects and small proof-of-concept trials.

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Geoff Martin drmush@iinet.net.au

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