REVIEW AND EVALUATION OF MUSHROOM PACKAGING OPTIONS

Project MU22008

—

May 2023

Hort Innovation
Strategic levy investment

MUSHROOM FUND

Contents

1

EXECUTIVE SUMMARY

The adoption of sustainable packaging alternatives is likely to increase operating costs for Australian mushroom producers

Australian mushroom producers are currently facing market pressures from regulators, supply chain partners and customers to enhance the sustainability of packaging solutions. This review identified that sustainable alternatives to packaging components, such as punnet trays and film closures, present considerable operating cost increases to Australian mushroom producers. Furthermore, whilst there are viable punnet options currently available, existing film closure solutions are less suited to mushroom packaging and thus there are a number of supply chain challenges to overcome to ensure a fully-compliant packaging. Further efforts are required to increase the commercial and operational viability of adopting sustainable packaging solutions.

Key project findings

There are considerable adoption costs for sustainable packaging

This report indicates that the adoption of sustainable packaging alternatives by Australian mushroom producers presents an additional cost burden of 47-106% when compared with currently adopted solutions (PET punnet trays; see right).

There is limited evidence of viable alternatives to PVC cling film

PVC cling film is a critical component of pre-packaged mushroom products. However, PVC has been identified as a problematic packaging material by the 2025 National Packaging Targets, and there is currently no method with which it can be recycled domestically.

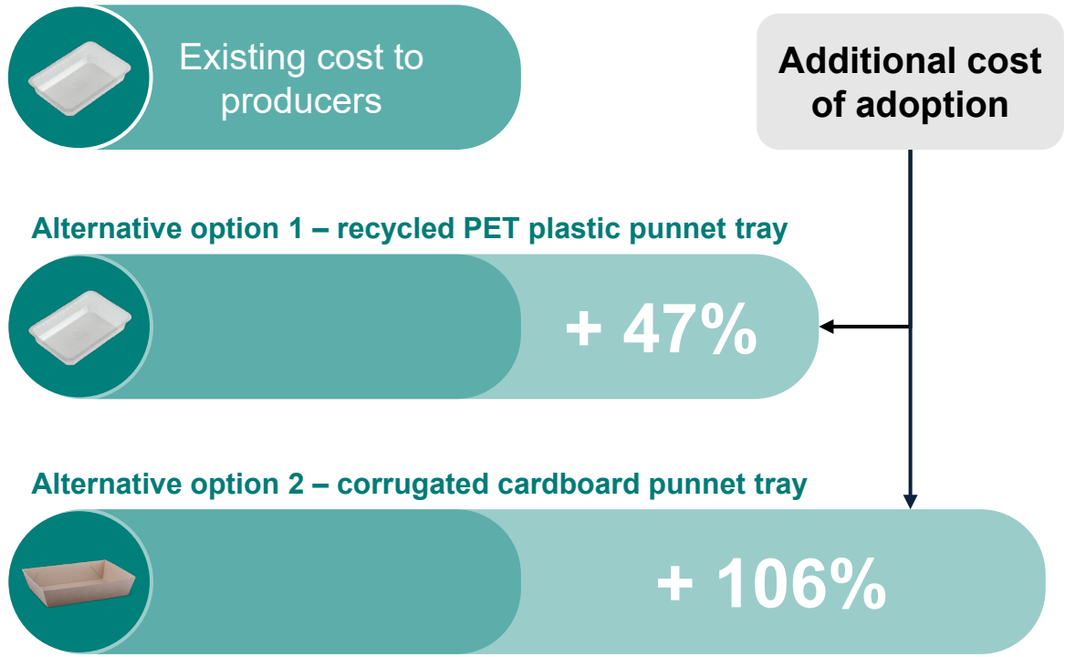
PVC alternatives, such as PO and PLA, are in the order of 200-230% more expensive and are yet to be subjected to robust trials in the Australian mushroom industry to ensure alternatives are fit-for-purpose from a biochemical standpoint.

Significant progress is required to meet 2025 packaging targets

The 2025 National Packaging Targets have set goals for reducing the amount of plastic waste generated by packaging. These targets are broadly endorsed by major food retailers.

This review suggests that significantly more work is required to improve the commercial viability, affordability and accessibility of sustainable packaging materials in order for the industry to meet and exceed the expectations of regulators, retailers and customers.

Cost of alternative packaging solutions[1]



1. Please refer to Appendix 2 for a detailed description and methodology to determine price for each option

Several factors are driving a need to consider alternatives to current packaging formats in the Australian mushroom industry

Regulation, consumer preferences and the sustainability targets of supply chain partners have created a need for the Australian mushroom industry to consider the sustainability of current packaging formats. This report outlines the potential suitability of alternative mushroom packaging options for the Australian mushroom industry.

Regulatory pressures

The impact of plastics on the natural environment has become a prominent issue globally, including in Australia. In 2018, the National Packaging Targets[1] were established - designed to lead a systematic change to food packaging, including developments in circular economies.

AUSTRALIA'S 2025 NATIONAL PACKAGING TARGETS

1. **100% reusable, recyclable or compostable packaging**
2. **70% of plastic packaging being recycled or composted**
3. **50% of average recycled content included in packaging**
4. **The phase out of problematic and unnecessary single-use plastics packaging**

Buyer pressures

The expectations of buyers, with regard to sustainability reporting and transparency, have increased significantly in recent years. As a result, collaboration throughout the supply chain is required to ensure compliance with company, regulatory and national targets.

Major retailers including Woolworths, Coles Group, Harris Farm and Aldi, have implemented plastic reduction targets for suppliers. They have acknowledged that a systematic effort across the value chain will be necessary to achieve national targets.

- Woolworths is working towards transitioning all own brand ranges to recyclable, compostable or reusable packaging by 2023[2]
- Coles target is for all Own Brand products to be 100% recyclable, reusable or compostable by 2025[2]
- Oxo-degradable plastics and all other problematic plastics have been banned in most major retailers from 2022

End consumer pressures

Consumers are becoming increasingly aware of the impact their purchasing behaviour has on social, environmental and economic sustainability. Therefore there is an increasing preference for sustainability to be considered in the manufacturing and sale of goods that they purchase.

82% of Australians value sustainable packaging, with environmental concerns driving their purchasing preferences[4].

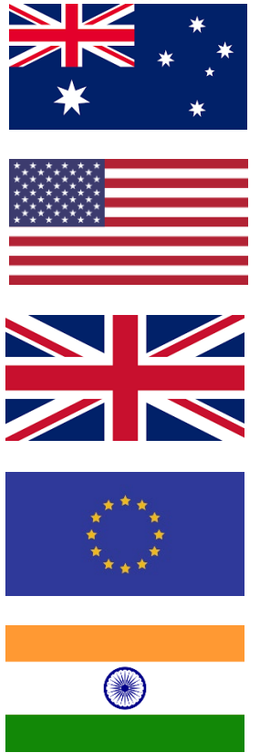
There is a need to investigate and consider alternative packaging formats that have a lower environmental footprint, are of acceptable cost to mushroom growers, and maintain/improve the product quality attributes of mushrooms.

1. Australia's 2025 National Packaging Targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets
2. Sustainable Packaging - Woolworths Group. (n.d.). Retrieved February 7, 2023, from https://www.woolworthsgroup.com.au/au/en/sustainability/Product/sustainable-packaging.html
3. Environment | Coles Group. (n.d.). Retrieved February 7, 2023, from https://www.colesgroup.com.au/sustainability/?page=environment
4. Toluna. (2021). Consumer shift towards sustainability Going green is going strong. [Editorial]. *Toluna Corporate*. Retrieved March 17, 2023, from https://tolunacorporate.com/wp-content/uploads/2021/02/ANZ-Sustainability-eBook_02-17-FINAL.pdf

This project sought to understand the suitability of a wide range of alternative packaging formats for the industry

The objective of this project was to provide an overview of available packaging formats for the Australian mushroom industry, to understand the commercial, operational and ESG-based suitability of each option. To do so, a global and local scan was conducted to identify best practice as it relates to sustainable packaging formats in the fresh produce sector.

Markets Investigated



1 Global scan

From the five countries investigated, **82** solutions were originally identified.

From the initial 82, 26 companies were removed as they did not have the near-term potential to meet the requirements of the Australian mushroom industry.

The global scan indicated that alternatives to stretch wrapping had not reached the commercial maturity required to meet demands of the Australian Mushroom industry.

2 Evaluation

An evaluation criteria framework was created, using feedback from the Project Advisory Group (PAG), to rank all the solutions identified against the requirements of the Australian mushroom industry. The criteria included considerations of cost, sustainability, product quality and safety parameters, logistics requirements and consumer acceptability.

Consultations indicated that as stretch wrap alternatives are not yet viable, further analysis is to focus primarily on punnet solutions.

The evaluation criteria were applied to **56** solutions and **12** companies were identified as top scorers.

3 Shortlisting

The top **12** solutions were presented to the Project Advisory Group in the form of short solution profiles (Appendix 1.3-1.4).

From the feedback collected by the advisory group, the profiles were refined and circulated with the group for further evaluation.

4 Prioritisation and high-level cost benefit analysis

The Project Advisory Group submitted a raked vote considering all 12 solutions.

In conjunction with further learnings from consultations run during the voting process, **2** solutions were identified and validated with the Advisory Group for progression to a high-level cost benefit analysis.

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

- Recycled polyethylene terephthalate (rPET)
- Corrugated/ Fluted cardboard

Two packaging formats were prioritised for further analysis, based upon the multi-criteria assessment and input from mushroom industry stakeholders

Recycled PET (rPET) and corrugated cardboard packaging options were selected from the multi-criteria analysis and stakeholder input, as their attributes reflect desirability, feasibility and viability considerations for implementation in the Australian mushroom industry. These options were analysed further through a high-level cost benefit analysis to draw comparisons between currently adopted packaging formats.

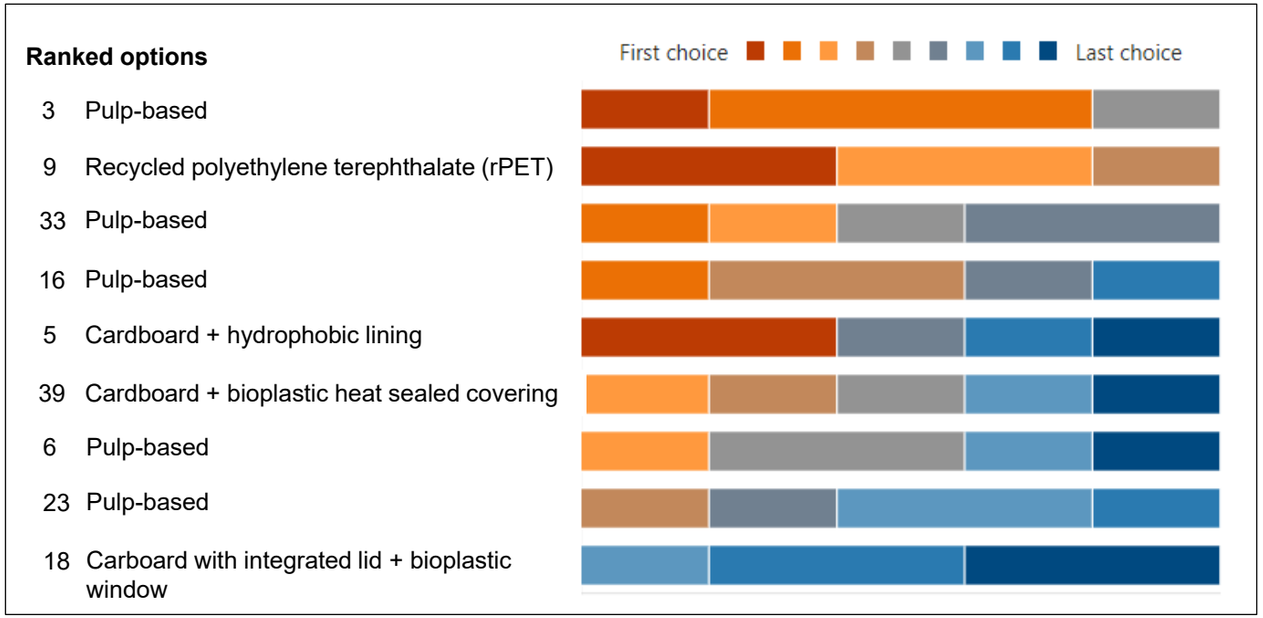
Selection of two prioritised solutions

From initial feedback from the Project Advisory Group, 9 solutions were provided to the group for final voting. From the voting results and consultation findings, an rPET and cardboard solution were identified as the top solutions to conduct a high-level cost-benefit analysis.

Rationale for selection

1. rPET and cardboard were the two options with the majority of first-choice votes.
2. It was highlighted in consultations that pulp-based products are not suitable for use in the mushroom industry without a polymer/hydrophobic lamination.
3. In the overall rankings, cane pulp (bagasse) based solutions with no lamination were removed from consideration. All pulp-based products without a lamination option and were hence discounted.

The PAG also indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry. Therefore, the focus of further analysis was primarily on prioritised punnet tray solutions.



Outcomes of Project Advisory Group voting to select the top two solutions.

A high-level cost benefit analysis was conducted to identify the costs, benefits and broader adoption considerations for alternative packaging solutions

The high-level cost benefit analysis sought to compare the commercial viability of the two prioritised punnet trays (rPET; corrugated cardboard) with an industry reference standard, a PET punnet tray. Based on discussions with the PAG, the analysis held constant the size and closure methods for the punnet tray across each option. An additional supplementary analysis sought to identify the cost of adopting wrap and seal alternatives to PVC cling film.

High-level cost benefit analysis

A high-level cost benefit analysis was conducted to identify the relevant costs, benefits and considerations of adopting alternative packaging solutions in the mushroom industry.

The analysis compared the costs and benefits of prioritised packaging alternatives (rPET; corrugated cardboard) to an industry reference standard (PET).

Base case: Industry packaging reference

PET (polyethylene terephthalate) punnet solution

Options evaluated against base case

1

rPET

rPET (recycled polyethene terephthalate) punnet

2

Corrugated cardboard

Corrugated/fluted cardboard solution

Supplementary analysis

A supplementary analysis was performed to understand the cost considerations of adopting alternative packaging seal solutions to PVC cling film.

PVC cling film was identified as a priority material for consideration in a cost analysis by the PAG. Therefore costs of transitioning to alternative materials, such as a polyolefin cling film, was modelled to identify the cost considerations for growers, despite the lack of priority solution in-market being identified during the global scan phase.

Cost of materials evaluated and compared

1

PVC cling film

Polyvinyl chloride (PVC) film.

2

PO cling film

Polyolefin (PO) film.

rPET punnet tray solutions were identified as an alternative, compliant packaging solution with likely lowest cost and greatest benefits to growers

The high-level cost benefit analysis indicated that PET punnet trays present the lowest-cost packaging option of the three assessed for the Australian mushroom industry. However, if the industry and broader mushroom supply chain is to comply with emerging regulations, a shift to rPET punnet trays is an option that appears to demonstrate the lowest cost and greatest benefit.

Rationale for selection

The results of the high-level cost benefit analysis indicate that the rPET punnet tray solution is the lowest cost option that presents the greatest level of benefit for growers whilst meeting emerging packaging targets set by APCO. Qualitative results also suggest that both packaging options present an improvement in sustainability impact, with rPET (option 2) presenting the greatest reduction in terms of emissions footprint.

Cost of adopting alternative packaging solutions

Estimated additional costs incurred by growers for the adoption of alternative punnet trays compared to PET tray. Results suggest rPET is the lower cost option.

Solution	Large producer	Medium producer	Small producer	% increase from PET
Option 1 – rPET	$3,027,830	$908,350	$18,924	147.46%
Option 2 – Cardboard tray	$6,786,133	$2,035,841	$42,413	206.36%

Estimated costs incurred by growers for the adoption of alternative closures suggest alternatives to PVC film attract a significant cost increase (200% increase).

Packaging solution	Large producer	Medium producer	Small producer
PVC film	$187,200	$78,000	$7,800
PO film	$561,600	$234,000	$23,400
Difference	*$374,000*	$156,000	$15,600

Option 1 – rPET performed well in several cost and benefit categories

Cost and benefit category	Description of performance
Quality and shelf life	Acts the same as PET trays – preserves the shelf of life of mushrooms for 5-7 days. Does not create issues with substantial moisture and provides sufficient structural integrity.
Consumer preference	Meets consumer preference for pre-packaged and value added mushrooms, the fastest growing category. Transparency of punnet tray and cling film combination allows consumers to assess quality of the product.
Adherence to APCO criteria	rPET adheres to APCO criteria of packaging designed for circularity. The prioritised rPET option contains 70% recycled material and can be recycled in existing recycling facilities in Australia.
Customisation costs	The manufacturing of rPET trays benefit from efficiencies of scale. Customisation of packaging formats requires unique designs known as ‘tools’ to be developed at significant cost to the customer.
Adjustments to packhouse processes and operations	rPET is the same functional material as currently adopted PET punnet trays. rPET demonstrates a high readiness to be integrated into existing packhouse operations and processes with little to no adjustment required by the grower.

Sustainable packaging will be a long-term consideration for the Australian mushroom industry

Both retailers and regulators are setting increasingly ambitious sustainable packaging targets. This creates a continued need for the Australian mushroom industry to consider the sustainability credentials of packaging formats. At present, commercially viable packaging can only address a portion of the 2025 National Packaging Targets. Innovation in packaging is likely to increase the availability and commercial viability of sustainable formats in the longer term.

2023 Short-term packaging considerations

Several alternative packaging formats comply with retailers and regulatory targets

Findings from the global scan indicate that there is a substantial number of alternatives to plastic (PET) punnet trays that comply with current targets set by regulators (2025 National Packaging Targets) and major retailers.

Evidence suggests rPET is the most suitable packaging solution

Alternative packaging formats identified in the global scan were observed to have varied commercial suitability for the Australian mushroom industry.

A high-level costs benefit analysis and stakeholder input indicated that recycled plastic (rPET) punnet trays demonstrate the highest level of commercial suitability out of the options assessed due to their comparative affordability and preferred material characteristics.

Findings indicate that alternatives to PVC wrap are not commercially viable

The global scan and additional stakeholder consultation indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry due to high cost and lack of available supply. PVC film is identified as a problematic material by the 2025 National Packaging Targets.

2030 Long-term packaging considerations

Increased availability and number of sustainable packaging formats

The transition towards a circular economy is likely to attract increased investment and resources. It can therefore be expected that the waste and packaging industries will be better equipped to manufacture, distribute and process sustainable packaging formats.

This includes the development of the supply chains capabilities, infrastructure and intellectual capital that will enable the production of sustainable packaging solutions that have a lower environmental footprint, are of acceptable cost to mushroom growers, and maintain/improve the product quality attributes of mushrooms.

As a result, sustainable packaging formats may become more widely available and commercially viable for mushroom industry participants in the medium to long-term.

Continued evolution of packaging targets

The transition towards a circular and more resource efficient economy will also include increasingly ambitious target setting by regulators and retailers.

By 2030, the 2025 National Packaging Targets will have elapsed. Revised targets will exceed current standards for recyclability and problematic packaging. Retailers are likely to adopt new targets as they are set.

Potential next steps for Hort Innovation are to support the development, commercialisation and credibility of alternative sustainable packaging

To ensure that Hort Innovation supports industry with embedding sustainable packaging options, key focus areas involve running effective packaging trials and gathering relevant data to substantiate the packaging solution's efficacy as a sustainable and fit for purpose option.

	1 Insights	2 Recommendations
	There has been significant growth and development in the innovative sustainable packaging industry, though a significant number of these companies are in their infancy and are not yet commercially viable to fulfil the demands of the Australian mushroom industry, particularly including the alternative lid/wrapping alternatives.	It is recommended that an updated review takes place in 12-24 months' time and then on an ongoing basis, with a 5-10 year longer term perspective, to re-evaluate the sustainable packaging landscape. Hort Innovation may also leverage mechanisms, such as the Horticulture Frontier Funds, to proactively support sustainable packaging solution providers to accelerate the availability of commercially viable solutions.
	The demand for sustainable packaging among regulators, retailers and consumers is likely to continue increasing. As this occurs, there is a need to objectively compare the sustainability credentials of packaging formats with consistently measured and reported metrics.	It is recommended that Hort Innovation supports the industry to gather sustainability data on packaging solutions in a consistent and targeted manner. For example, simplified life cycle analysis covering sourcing, manufacturing and recommended end-of-life processes.
	The end-of-life outcomes for fresh food packaging are dependent on the behaviours of the consumer. If a product is designed to be recycled or composted, that outcome is reliant on the consumer actively processing that unit of waste into the correct stream.	It is recommended that Hort Innovation takes a leading role in consumer behaviour/marketing and supports a whole of industry approach to contribute to the consumer knowledge uplift in packaging disposal. This may include supporting packaging suppliers to add clear disposal information to packaging at the manufacturing stage.
	Assessment of the quantitative and qualitative results of the high-level cost benefit analysis indicate that the rPET punnet tray solution is the lowest cost option that presents the greatest level of benefit for growers whilst meeting emerging packaging targets set by APCO.	It is recommended that Hort Innovation lead the transition by trialing and supporting the implementation of rPET packaging solutions for the Australian mushroom sector.

1. ACCC – Australian Competition and Consumer Commission

2

INTRODUCTION AND METHODOLOGY

The objective of MU22008 is to identify alternative sustainable packaging options for the Australian mushroom industry

The project commenced in early 2023, and investigated alternative packaging options for the Australian mushroom industry when considering ESG and the evolving packaging regulatory environment.

Background

The horticulture industry is facing increasing pressure to adopt more sustainable packaging solutions, which stems from three main external factors:

1. Introduction of the National Packaging Targets for 2025[1] has set goals for reducing the amount of plastic waste generated by packaging.
2. Major retailers such as Coles and Woolworths are developing specific targets that required suppliers to apply more sustainable packaging.
3. Consumer demand for more sustainable products.

To respond to these pressures, the mushroom industry requires guidance on which packaging options are currently available in the market, as well as what alternatives are viable to replace existing plastic packaging.

Scope

This report aims to provide guidance to Hort Innovation on the available options for sustainable fresh mushroom packaging by answering the following key questions:

1. What is international best practice for sustainable fresh mushroom packaging?
2. What alternative packaging solutions are available in the market?
3. What new research and development has been developed in mushroom packaging?
4. What are the most viable alternative packaging solutions in the market to improve the sustainability of the mushroom industry?

Outputs & Recommendations

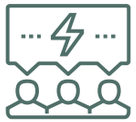
The outcomes from the analysis include an **Options Paper** covering:

- A comprehensive market scan of available sustainable packaging options evaluated against selected compatibility criteria.
- An overview of the key findings and two prioritised packaging solutions.
- A high-level cost-benefit analysis of the two selected packaging solutions, and;
- Recommendations to the industry based on research findings, growers and other industry consultations, and workshop feedback.

1. Australia's 2025 national packaging targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets

The project has been underpinned by a five stage method of analysis

A phased approach has been adopted to identify, assess and make recommendations on alternative packaging solutions in a logical and clear way.

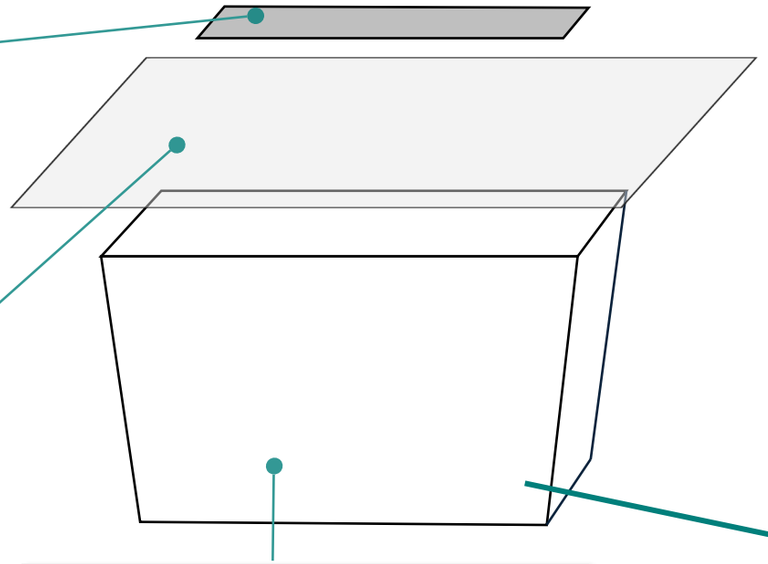

Desktop Review	Project Advisory Group consultation	Subject matter expert interviews	Value chain interviews	High-level cost-benefit Analysis
Systematic desktop study to identify local and global alternative packaging options for Australian mushrooms. From initial research it was decided to focus on five markets for analysis, Australia, USA, EU, UK and India due to innovation trends identified. Desktop review contributed to the creation of: • Evaluation criteria • Global scan	Industry workshops were conducted to ensure that the evaluation criteria were appropriate, the market scan findings were socialised, and the most suitable packaging options were selected, via a survey, to meet the specific requirements of the Australian mushroom industry.	Interviews with subject matter experts were facilitated to share, validate, and test the learnings from the desktop review and to gain further insight into the domestic and international landscape of alternative packaging solutions.	Stakeholder interviews with members of the mushroom value chain were conducted to inform the project of industry-specific requirements for mushroom packaging solutions.	A high-level cost benefit analysis was conducted to assess the commercial suitability for the adoption of the two prioritised packaging options, informing the outcomes and recommendations provided in this report.

The focus of the global scan is on pre-packaged or punnet mushroom packaging

This project targeted alternative packaging solutions for fresh pre-packaged mushrooms. This report primarily considers packaging for fresh mushrooms as comprising three components: tray, covering film, and labels. Packaging trays were not considered to be primary packaging.

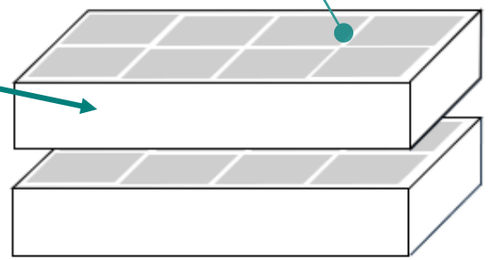
Label
Function: Relay product information to the consumer.
Material: Paper with adhesive backing
Characteristics: Sticker format
Notes: usually an additional component in the form of a sticker.

Covering
Function: hold and cover mushrooms in the punnet
Material: PLE punnet lid or a PVC cling film
Characteristics:
- Transparent
- Hydrophobic
- Lightweight
- Breathable



Punnet
Function: hold and protect mushrooms
Material: PLE punnet
Characteristics:
- Sturdy structure
- Hydrophobic
- Lightweight
- Transparent

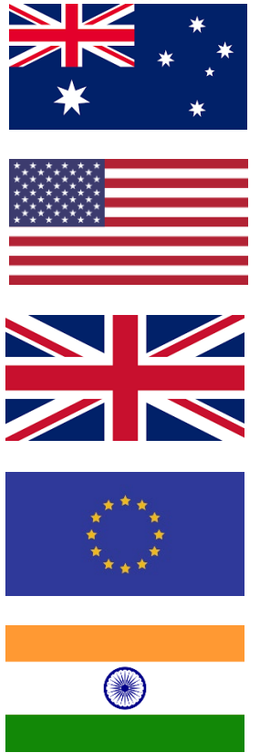
Packing tray
Function: shipping of pre-packaged punnets, designed for one level of product.
Material: Corrugated cardboard
Characteristics:
- Recyclable
- Sturdy
- Eases transport of single punnets
- Lightweight
- Stackable



From the desktop review, a global scan was conducted, covering five countries, to identify suitable packaging solutions for the mushroom industry

The global scan was partnered with a carefully constructed evaluation criteria to filter 82 solutions down to two targeted packaging designs for the cost-benefit analysis.

Markets Investigated



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2 Evaluation

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The evaluation criteria were applied to **56** solutions and **12** companies were identified as top scorers.

3 Shortlisting

The top **12** solutions were presented to the Project Advisory Group in the form of short solution profiles (Appendix 1.3-1.4).

From the feedback collected by the advisory group, the profiles were refined and circulated with the group for further evaluation.

4 Prioritisation and high-level cost benefit analysis

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

- Recycled polyethylene terephthalate (rPET)
- Corrugated/ Fluted cardboard

The suitability of prioritised packaging solutions for the Australian mushroom industry was then evaluated for their high-level respective costs and benefits

The suitability of the prioritised packaging solutions for the Australian mushroom industry was evaluated against a industry reference standard, a plastic (PET) punnet tray with cling film. The costs, benefits and considerations of adopting each prioritised packaging option were compared using a high-level cost-benefit analysis.

A PET Punnet Tray

B rPET Punnet Tray

C Fluted cardboard tray

Costs and benefits of adoption

- Cost of implementation
- Process and operational changes
- Suitability and robustness in supply chain
- Quality implications
- Environmental impact of packaging solution

Suitability of option for mushroom industry

Further analyses was conducted to identify the influence of wrapping solutions on the costs and benefits of adopting alternative packaging

A scenario analysis was conducted to identify the influence of scale on the estimated costs and benefits of adopting alternative packaging solutions. Further supplementary analyses were also performed to understand the cost impact of adopting alternative closure solutions. More detailed information on the scenario and supplementary analyses are provided in Appendix 2.

Scenario analysis

A scenario analysis was conducted to understand the influence of production scale on the costs and benefits of adopting alternative packaging.

To do so, the analysis was performed using the pre-pack production volumes representative of a small, medium and large producer. Production volumes were identified through stakeholder consultation, and confirmed by the PAG.

Small grower:
20 tonnes per week

Medium grower:
50 tonnes per week

Large grower:
120 tonnes per week

Supplementary analysis

A supplementary analysis was performed to understand the cost considerations of adopting alternative packaging seal solutions to PVC cling film.

PVC cling film was identified as a priority material for consideration in a cost analysis by the PAG. Therefore costs of transitioning to alternative materials, such as a polyolefin cling film, was modelled to identify the cost considerations for growers, despite the lack of priority solution in-market being identified during the global scan phase.

Cost of materials evaluated and compared

1 **PVC cling film**
Polyvinyl chloride (PVC) film.

2 **PO cling film**
Polyolefin (PO) film

3

BACKGROUND AND OPERATING ENVIRONMENT

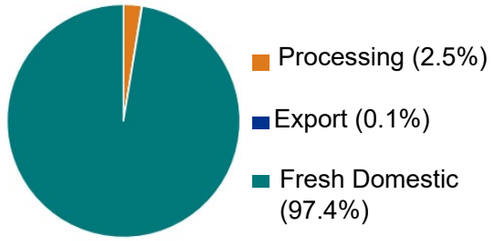
Fresh domestic consumption is the primary focus of the Australian mushroom industry, with retail channels accounting for the majority of sales

The Australian mushroom industry is highly geared towards the Australian domestic market, with 99.99% of production servicing the domestic market. Further to this, the majority (78%) of mushrooms are distributed to consumers through domestic retail channels. Demand growth has remained relatively consistent for several years, with relatively small changes in the annual volume and value of industry production.

Industry background

Mushroom production occurs in most states and close to population centres, in particular the Sydney Basin, metropolitan Melbourne and Adelaide[1].

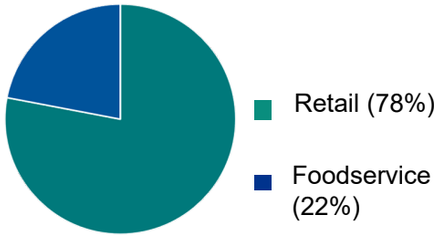
Production distribution



Production window

Year-round

Retail vs Food Service



Varieties

Agaricus bisporus
(Button, cup, flat and brown mushrooms)

Exotic mushroom varieties
(shimeji and oyster)

Key industry insights and trends

Production has been relatively stable, with no significant change over the past several years. The 2012-13 financial year yielded 65,268 tonnes in comparison to 68,823 in 2019-20[1].

Offerings centred around convenience are experiencing greatest demand. This is reflected in the prepacked and value-added mushrooms segment.[1]

Demand creation is key to growing the mushroom category in Australia. There is a need to prioritise segments where there is demand and growth-potential.

1. Hort Innovation Mushroom Fund. (2022). *Mushroom Strategic Investment Plan 2022-2026* [Brochure]. Author.

Pre-packaged and value added mushroom product offerings are key to domestic market demand creation and achievement of the industry's strategic objectives

Prepacked and value-added mushrooms, such as sliced mushrooms, are the fastest growing market segments in the domestic retail market. Further developing these product segments will be key to achieving the industry's ambition to maintain and strengthen consumer demand – this includes packaging innovation to both attract and retain customers.

Pathways to demand creation in the mushroom industry

60%

Of store-bought mushrooms are pre-packed[1]

COVID-19 encouraged consumers to eat from home, increasing the demand for fresh produce, including mushrooms.

Concerns for safety and the demand for convenience during COVID-19 resulted in a shift towards pre-packaged fresh produce purchases, with market growth driven by 80% by pre-packaged goods[1].

Delivers against Mushroom industry strategic objectives

Outcome – Demand creation

Offerings centred around convenience and value-added products for the mushroom industry are expected to have the biggest impact on industry growth. Packaging plays a significant role in driving convenience for the consumer.

However, industry surveys have indicated the sustainability of packaging is beginning to influence consumer purchasing behaviour in Australia and will need to be addressed in the near future.

Current state of packaging in the mushroom industry

>90%

of pre-packaged mushrooms in Australia are packaged in PET-based packaging[2].

Packaging solutions that are fit-for-purpose, meet consumer needs and expectations and uphold product quality will be a key enabler to supporting demand creation and retention in mushroom product segments.

1. Norris, M. (2022). Hort innovation | nielseniq. Retrieved March 22, 2023, from https://www.harvesttohome.net.au/fruitmushroomnuts/case-studies/mushroom
2. Advised by Project Advisory Group

Regulation, consumer preferences and the drive for corporate sustainability has created a need to consider alternative packaging formats

Changes in the broader retail and regulatory landscape have created the need to consider the sustainability credentials of mushroom packaging formats, namely the use of polyethylene terephthalate (PET) punnet rays and polyvinyl chloride (PVC) cling film. The mushroom industry must assess the availability of commercially viable alternatives.

Drivers for change in the broader operating environment

Regulatory and policy change

The emergence and evolution of regulation targeting waste and the transition to a circular economy is prominent globally, and Australia is no exception. In 2018, the National Packaging Targets[1] were established – designed to lead a systematic change to Australian packaging, including developments towards establishing circular economies.

Supply chain partners

The expectation of buyers, with regard to sustainability reporting and transparency, have increased significantly in recent years. As a result, collaboration throughout the supply chain is required to ensure compliance with company, regulatory and national targets.

Failure of the sector to adapt to these targets may threaten domestic market access, critical to the Australian mushroom industry accounting for 99% of product sales.[2]

Consumer demand

Consumers are becoming increasingly aware of their purchasing behaviour's impact on social, environmental and economic sustainability. Therefore there is an increasing demand for sustainability to be considered in the manufacturing and sale of goods that they purchase.

82% of Australians value sustainable packaging, with environmental concerns driving their purchasing preferences.[3]

There is a need to investigate and consider alternative packaging formats that have a lower environmental footprint, pose acceptable costs to mushroom growers and maintain/improve the product quality attributes of mushrooms

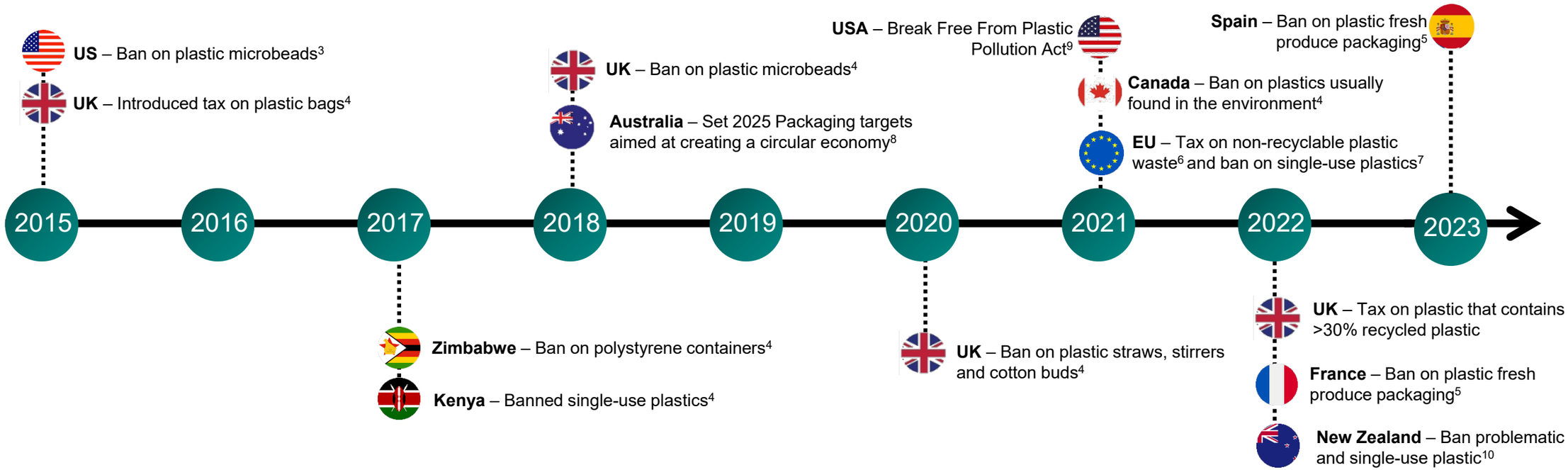
1. Australia's 2025 National Packaging Targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets
2. Hort Innovation Mushroom Fund. (2022). Mushroom Strategic Investment Plan 2022-2026.
3. Toluna. (2021). Consumer shift towards sustainability Going green is going strong. [Editorial]. *Toluna Corporate*. Retrieved March 17, 2023, from https://tolunacorporate.com/wp-content/uploads/2021/02/ANZ-Sustainability-eBook_02-17-FINAL.pdf

Emerging packaging regulation is seeking to phase out ‘problematic’ materials, such as certain plastics, and increase circularity of supply chains

Globally, packaging regulation is evolving rapidly, supporting the drive for plastic waste to be eliminated. Over 77 countries in the world have implemented some level of a ban on plastic goods[1] with a draft global commitment expected to be released in 2024[2].

170 nations have pledged to “significantly reduce” the use of plastics by 2030 as part of the **UN Environmental Assembly** in Nairobi, in 2022[2].

Intergovernmental Negotiating Committee (INC) commenced work after 2022 pledge’s in Nairobi with the ambition of completing a draft global legally binding agreement by 2024 to address the full life cycle of plastics[2].



1. Chart: The countries banning plastic bags | statista. (2021). Retrieved January 30, 2023, from https://www.statista.com/chart/14120/the-countries-banning-plastic-bags/
2. Historic Day in the campaign to beat plastic pollution: Nations commit ... (2022, March). Retrieved January 30, 2023, from https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop
3. PRITCHETT, L. (n.d.). 11 most impressive plastic bans around the world - livekindly. Retrieved February 23, 2023, from https://www.livekindly.com/impressive-plastic-bans-around-the-world/
4. Masterson, V. (n.d.). Which countries have bans on single-use plastics? | world economic forum. Retrieved February 23, 2023, from https://www.weforum.org/agenda/2020/10/canada-bans-single-use-plastics/
5. That’s a wrap: French plastic packaging ban for fruit and veg begins ... (n.d.). Retrieved February 23, 2023, from https://www.theguardian.com/world/2021/dec/31/thats-a-wrap-french-plastic-packaging-ban-for-fruit-and-veg-begins
6. The 2021-2027 EU budget – what’s new? - commission.europa.eu. (n.d.). Retrieved March 7, 2023, from https://commission.europa.eu/strategy-and-policy/eu-budget/long-term-eu-budget/2021-2027/whats-new_en
7. EU restrictions on certain single-use plastics - environment. (n.d.). Retrieved March 13, 2023, from https://environment.ec.europa.eu/topics/plastics/single-use-plastics/eu-restrictions-certain-single-use-plastics_en
8. Australia’s 2025 national packaging targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets
9. All info - S.984 - 117th Congress (2021-2022): Break free from plastic ... (n.d.). Retrieved March 13, 2023, from https://www.congress.gov/bill/117th-congress/senate-bill/984/all-info
10. Guidance on plastic products banned from October 2022. (n.d.). Retrieved March 13, 2023, from https://environment.govt.nz/publications/plastic-products-banned-from-october-2022/

Domestically, the National Packaging Targets are a key driver in the shift towards circular economy and sustainable packaging formats

The 2025 National Packaging Targets are supported by the Australian industry and government to deliver a new and sustainable approach to packaging. They apply to all packaging that is made, used, and sold in Australia.

National Packaging Targets[1]

Outcome	2025 Target
Outcome one **Packaging designed for circularity**	100% of Australia's packaging will be reusable, recyclable, or compostable
	Problematic and unnecessary single-use packaging will be phased out
Outcome two **Improved collection and recycling systems**	70% of Australia's plastic packaging will be recycled or composted
Outcome three **Expanded markets for used packaging**	50% average recycled content will be included across all packaging

Implications for the Mushroom Industry

The mushroom industry will need to identify alternatives to current packaging solutions to meet the National Packaging Targets.

There will be a shift away from plastic and non-circular packaging solutions, and single-use packaging will no longer be an acceptable packaging option.

Stretch wrap is predominantly composed of polyvinylidene chloride (PVC) and falls under the category of problematic and unnecessary packaging and is set to be phased out by 2025. PVC wrap is the primary wrap and seal solution utilised in the mushroom industry.[2]

Under current targets it is expected that packaging solutions are required to have an average of 50% recycled content. PET has the potential to be recycled to rPET and is included in packaging designed for circularity. Mushroom industry participants must therefore understand the impacts of transitioning from PET to rPET.

1. Australia's 2025 National Packaging Targets. (n.d.) Retrieved March 28, 2023, from https://apco.org.au/national-packaging-targets
2. Informed through consultation with the Project Advisory Group

Retailers are also setting waste and recycling targets to foster a transition to circular and more resource-efficient supply chains

Australia's largest supermarkets all have waste and recycling commitments, with specific targets related to the use of packaging. Each retailer has subscribed to the 2025 National Packaging Targets, which seek to deliver a new and sustainable approach to packaging by creating a complete and systematic change to the way Australia creates, collects and recovers product packaging.

Woolworths[1]

APCO

Committed to meeting the National Packaging Targets of 2025 before the deadline.

Own-brand targets

100%	Of packaging to be recyclable, compostable or reusable.
HALF	The use of virgin plastic packaging.
CEASED	Sale, supply or distribution of oxo-degradable and other problematic plastics.
	Promoting the inclusion of the Australasian Recycling Label (ARL) on 100% of products

Coles[2]

APCO

Committed to meeting the National Packaging Targets of 2025 before the deadline.

Own-brand targets (2025)

100%	Of packaging to be recyclable, compostable or reusable.
	All packaging carries the Australasian Recycling Label (ARL).
Phase-out	Problematic and unnecessary single-use plastics.
50%	Recycled content is included in packaging.

Aldi

APCO

Committed to meeting the National Packaging Targets of 2025 before the deadline.

25by25 strategy targets

25%	Reduction in plastic packaging by 2025.
	Actively reduce the amount of plastic packaging in fresh produce.
	Transition to more sustainable alternatives providing no increase in food waste.
100%	Of exclusive band packaging to be recyclable, reusable or compostable by 2025.

Hort Innovation Strategic levy investment | MUSHROOM FUND

1. Sustainable Packaging - Woolworths Group. (2023). Retrieved March 23, 2023, from https://www.woolworthsgroup.com.au/au/en/sustainability/Product/sustainable-packaging.html
2. Together to zero waste | Coles group. (2023). Retrieved March 23, 2023, from https://www.colesgroup.com.au/sustainability/?page=environment
3. Plastics & packaging - Aldi Australia. (2023). Retrieved March 23, 2023, from https://corporate.aldi.com.au/en/corporate-responsibility/environment/plastics-packaging/

The need to consider alternative packaging formats in mushroom supply chain aligns with a rapidly transforming waste and materials industries

The Australian waste and materials sector is also responding to the calls for circular and more resource efficient supply chains with rapidly evolving policy and investment dynamics. This presents opportunities for the mushroom industry to capitalise on increased packaging innovations and the emergence of novel packaging materials.

Trends in the packaging and waste sectors

The past few years have been transformative for the waste management and packaging sector. Policymakers and industry participants are increasingly supportive of the transition away from linear and supply chains towards circular and closed-loop systems.

This has seen increased investment and resources deployed to catalyse and accelerate this transition:

Circular economy policies are widely accepted and endorsed by Australian Governments at a State and Federal level[1]

- Commitment has progressed to action, with governments seeking to increase the reusability and recyclability of materials to reduce the need for extraction of virgin materials.

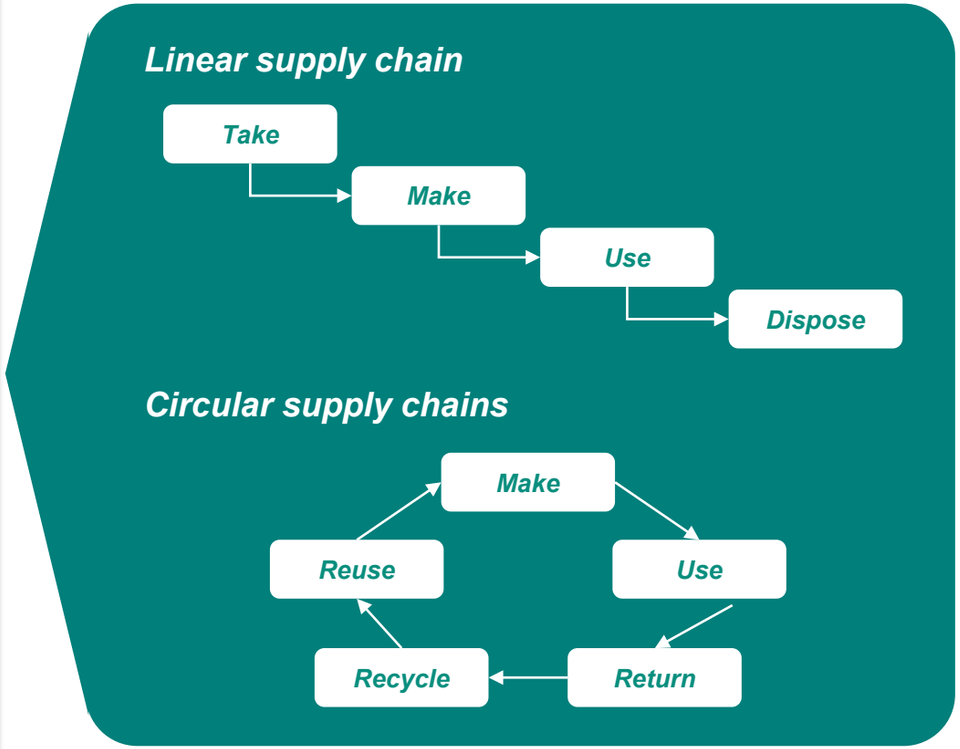
Early research indicates strong potential commercial opportunity and economic benefits[2]

- The transition to a circular economy represents a potential economic benefit of $3bn in present value GDP by 2025 for the Australian economy.[2]

Capital is already being deployed towards circular economy packaging solutions

- The Australian Government has invested more than $1bn to 'turbocharge waste management and recycling capabilities'.[3]
- Industry participants, including Cleanaway and PACT group have collaborated to invest $45m in a purpose-built recycling facility.[4]

The transition to circular supply chains



1. National Waste Report, Department of Climate Change, Energy, the Environment and Water. (2023). Retrieved March 23, 2023, from https://www.dcceew.gov.au/sites/default/files/documents/national-waste-report-2022.pdf
2. Potential circular economy pay off Australia, KPMG Australia. (2020). Retrieved March 23, 2023, from https://kpmg.com/au/en/home/insights/2020/05/potential-economic-pay-off-circular-economy-australia.html
3. Circular Economy, Global Australia. (2023). Retrieved March 23, 2023, from, https://www.globalaustralia.gov.au/industries/net-zero/circular-economy.
4. The race to circularity: can Australia meet the 2030 deadline, Westpac. (2023). Retrieved 23 March, 2023, from https://www.westpaciq.com.au/thought-leadership/2023/01/the-race-to-circularity-can-australia-meet-the-2030-deadline

4

Summary of alternative packaging solutions for mushrooms

4.1

Methodology and multi-criteria assessment process

A four-stage multi-criteria assessment approach has been followed to prioritise packaging solutions for Australian Mushrooms

Determine evaluation criteria and markets for scanning

- A series of five evaluation criteria were formed against which to assess the identified packaging solutions. These were tested with the Project Advisory Group (PAG) for suitability, with scoring thresholds also agreed.
- Furthermore, five markets were selected to be the focus of the analysis, given their existing progression in sustainable packaging developments. The markets chosen were USA, EU, UK, India and ANZ.

Conducted global scan

- The agreed focus markets were then analysed, with public sources such as annual reports, databases, journals, and industry content being utilised to form a long-list of solutions per jurisdiction that could be applicable for consideration.
- Relevant key phrases, such as 'packaging for Agaricus bisporus' and 'packaging for fresh produce,' were employed to locate pertinent information on companies involved in the manufacture of packaging materials and products.

Filtering of long-list

- Of 82 solutions identified, 56 were deemed at a level of commercial readiness that could be progressed to the assessment stage.

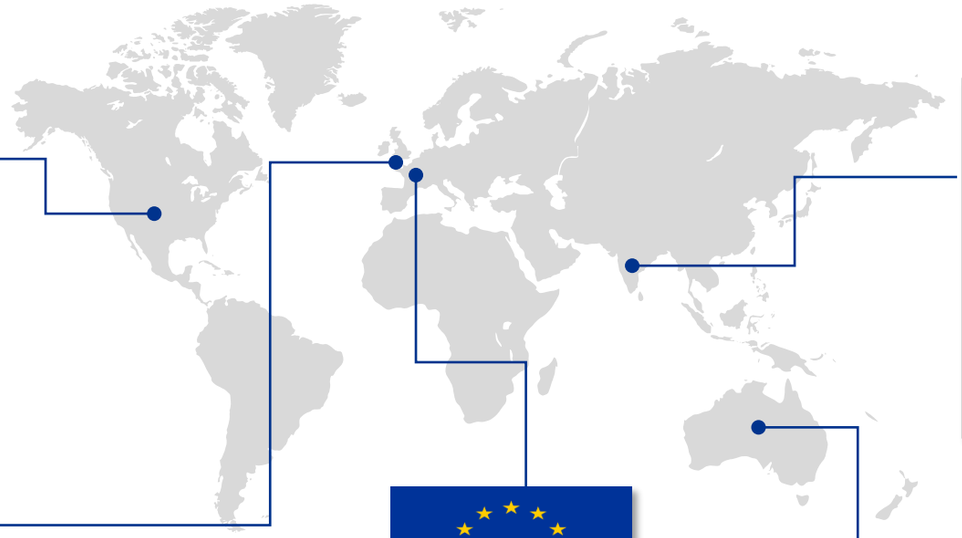
Options assessment and prioritisation

- The 56 long-listed packaging solutions were then analysed using the agreed evaluation criteria. Ratings were allocated based upon the scoring thresholds, allowing for an initial short-list to be formed.
- The top scoring solutions with a ‘7’ or above in the rating system were selected for profiling. Short profiles (see later section) were created for these options, to present to the Project Advisory Group for consideration.
- Additional information was sought on particular solutions following consultation with the Project Advisory Group, who then voted on the two solutions to prioritise for progression to the next stage of the project.

Form evaluation criteria → **Agree focus markets** → **Identify long-list of 82 companies** → **Initial cut to 56 solutions that fit the project scope** → **Prioritisation of 12 highly ranked solutions** → **Select 2 options for high level cost benefit analysis**

Five markets were selected as the focus of the global scan, to reflect geographic diversity and significant packaging innovation

At the beginning of the process, five markets were chosen based on market innovations and regulatory mandates to eliminate single-use plastics.



United States

The United States is witnessing significant packaging innovation as a result of pressure from consumer groups, the government, and the media, which is driving many companies to shift away from plastic[1].

United Kingdom

The UK's established recycling system ensures that packaging waste is properly collected, sorted, and processed.

The UK also has extended producer responsibilities around packaging to hold manufacturers responsible for the entire lifecycle of their products[3].

European Union

Regulatory requirements and clear targets, such as achieving 100% recyclable packaging by 2030, are driving a shift in packaging practices across the European Union[5]. Some countries, like France, have banned single-use plastic for certain fruits and vegetables in supermarkets[6]. Additionally, there are several large-scale sustainable packaging companies with a significant level of experience and expertise in the field.

India

India is one of the largest and fastest-growing economies in the world and is also considered to be one of the low-cost manufacturing nations of the world.

The country's waste management system is under significant pressure, alongside the introduction of a nation wide ban on single use plastics, making sustainable packaging solutions a high priority within the nation[2].

Australia (and New Zealand)

The Australian packaging industry is highly innovative and is trending towards a push for greener more sustainable options, driven by government legislation.

National targets have been set with the overarching goal of achieving a circular economy by 2025[6].

1. Packaging industry in United States - growth, trends,. (n.d.). Retrieved March 15, 2023, from https://www.globenewswire.com/news-release/2022/05/02/2433641/0/en/Packaging-Industry-in-United-States-Growth-Trends-COVID-19-Impact-and-Forecasts-2022-2027.html
2. India packaging market analysis - industry report - mordor intelligence. (n.d.). Retrieved March 15, 2023, from https://www.mordorintelligence.com/industry-reports/packaging-industry-in-india
3. Plastic packaging market analysis - industry report - trends, Size & Share. (n.d.). Retrieved March 15, 2023, from https://www.mordorintelligence.com/industry-reports/plastic-packaging-market
4. The latest trends for New Zealand's plastic packaging in 2020. (n.d.). Retrieved March 16, 2023, from https://bonsonpackaging.com.au/the-latest-trend-for-new-zealands-plastic-usage-in-2020/
5. Press Corner | European Commission - ec.europa.eu. (n.d.). Retrieved March 16, 2023, from https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7155
6. Australia's 2025 National Packaging Targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets

Five evaluation criteria areas were confirmed following consultation with the Project Advisory Group (PAG)

Criteria were selected to be applied to the identified long-list of packaging solutions to facilitate an evaluation of each option for its suitability. Criteria were developed in close consultation with PAG stakeholders and interviews with key members of the supply chain. A detailed description of the criteria listed below is provided in Appendix 1.1.

DESIRABLE CRITERIA	CRITERIA DESCRIPTION	PERFORMANCE THRESHOLD		
		POOR	MODERATE	STRONG
Cost	The packaging solution is cost effective. Hence, it costs the same per unit as a comparable plastic packaging solution or less than a comparable plastic packaging solution	The cost per unit of packaging is more than 10% higher than a comparable plastic packaging solution.	The cost per unit of packaging is up to 10% higher than a comparable plastic packaging solution.	The cost per unit of packaging is the same or lower than a comparable plastic packaging solution.
Sustainability	The packaging solution contributes to sustainability goals and targets considers whether the solution can be disposed of sustainability and the origin of the solution material is sustainable and/or circular in nature.	The packaging solution does not meet criteria related to end-of-life processing and sustainable material requirements.	The packaging solution meets only one criteria related to end-of-life processing and sustainable material requirements.	The packaging solution meets sustainability expectations, including those related to end-of-life and material use.
Product quality and safety parameters	The packaging solution has features that ensure shelf-life maintenance/extension and spoilage mitigation, to target atmospheric, temperature, and humidity regulation. This also supports food safety standards compliance.	The packaging solution is able to control one of the following; optimal breathability, optimal humidity, or adequate temperature.	The packaging solution is able to control two of the following; optimal breathability, optimal humidity, or adequate temperature.	The packaging solution is able to control all of the following; optimal breathability, optimal humidity, or adequate temperature.
Suitability for logistics processes	The packaging solution meets the logistics requirements of the entire mushroom value chain (including on-farm production, cold chain logistics, etc.).	The packaging solution meets none or one criteria related to durability, ease of handling and scalability.	The packaging solution meets two criteria related to durability, ease of handling and scalability.	The packaging solution meets three criteria related to durability, ease of handling and scalability.
Consumer acceptability	The packaging solution does not impede the consumer's ability to view the product, access product information or conveniently transport product.	The packaging solution only offers limited viewing, product information and does not provide convenience.	The packaging solution meets some, but not all, expectations regarding appearance, information and convenience.	The packaging solution meets all expectations regarding product appearance, information and convenience.

1. Australia's 2025 national packaging targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets
2. Ares, G., Lareo, C., & Lema, P. (2007). Modified atmosphere packaging for postharvest storage of mushrooms. A review. *Fresh Produce*, *1*(1), 32-40.

4.2

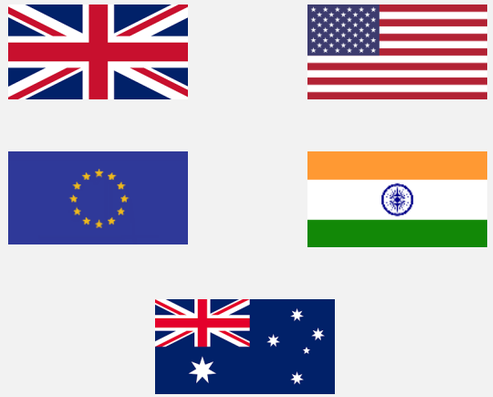
Global market scan insights

The evaluation criteria were applied to a long-list of 56 companies across five geographies

Out of a global market review of 82 solutions, 56 were identified as potential options that could meet the requirements of the Australian mushroom industry. The following section presents the scores of these 56 solutions for a breakdown of each solution and how they scored against the evaluation criteria (Appendix 1.1).

A comprehensive approach to identifying alternative packaging solutions

Global and local markets scanned



81

Total solutions identified in global scan

56

Total solutions long-listed for further evaluation

Market	Long-listed solutions
Australia	11
European Union	13
India	10
United States	11
United Kingdom	11

The top twelve scoring solutions were short-listed

After scoring all 56 companies against the criteria (Appendix 1.2), a short-list of 12 solutions emerged as high potential alternative packaging options (Appendix 1.3-1.4). These solutions largely featured sustainable alternatives to plastic materials, but recycled and recyclable plastic options were also included. The following section provides short profiles of these 12 short-listed solutions.

Solution number	Country of Origin	Material Qualities	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability	Total
3	Australia	Cane Pulp - Bagasse	2	2	2	2	2	10
16	India	Sugarcane Bagasse Base	2	1	2	2	2	9
9	Australia	rPET (recycled PET)	2	1	2	2	2	9
33	Europe	Pulp Fibre Based Punnet	1	2	2	2	2	9
23	Europe	Sugarcane Bagasse Base	1	1	2	2	2	8
5	Australia	Corrugated Fluted Board	1	2	2	1	2	8
18	India	Paper Based Punnet	1	2	2	1	2	8
6	Australia	Cane Pulp - Bagasse	1	2	1	2	2	8
40	United States	Original PLA material	1	1	2	2	2	8
4	Australia	Bamboo Fibre – Bagasse	0	2	2	1	1	7
39	United States	Fibre Paper Board	N/A	1	2	2	2	7
32	Europe	Paper Based Punnet	N/A	1	2	2	2	7

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

rPET and corrugated cardboard options were identified as the top solutions as by the Project Advisory Group in conjunction with consultation insights

The short-list of 12 solutions was presented to the Project Advisory Group (Appendix 1.3-1.4). Post-workshop, the profiles were edited to reflect the feedback from the group and a survey was circulated for the group to rank the solutions presented. Below is the results of that survey that was completed by a range of representatives from across the supply chain, including retailers, growers and packaging specialists.

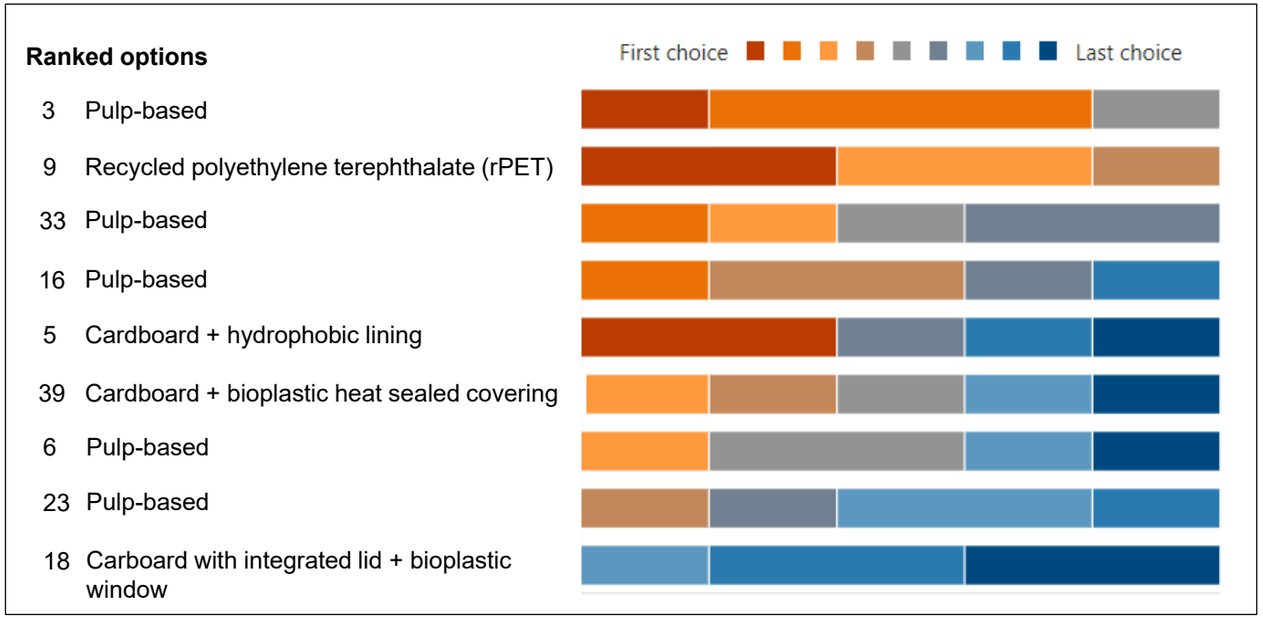
Selection of two prioritised solutions

From initial feedback from the Project Advisory Group, 9 solutions were provided to the group for final voting. From the voting results and consultation findings, an rPET and cardboard solution were identified as the top solutions to conduct a high-level cost-benefit analysis.

Rationale for selection

1. rPET and cardboard were the two options with the majority of first-choice votes.
2. It was highlighted in consultations that pulp-based products are not suitable for use in the mushroom industry without a polymer/hydrophobic lamination.
3. In the overall rankings, cane pulp (bagasse) based solutions with no lamination were removed from consideration. All pulp-based products without a lamination option and were hence discounted.

The PAG also indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry. Therefore, the focus of further analysis was primarily on prioritised punnet tray solutions.



Outcomes of Project Advisory Group voting to select the top two solutions.

The global scan also considered packaging solutions that provide an alternative to commonly used PVC plastic wrap

The scan for alternative sustainable packaging solutions considered a breadth packaging formats. This included a range a solutions that wrap, seal or enclose mushroom products. The scan identified two categories of packaging solutions that achieve this goal; punnet and lid, and punnet and wrap. A complete list of solutions is provided in Appendix 1.

Global and local market scan

Solutions to enclose product identified

Number of solutions identified

10	17
Wrap or Foil	Lid

PVC Wrap

Tray and lid combination

Alternative wrap solutions

The scan identified limited alternatives to current plastic wrap and seal solutions that are commercially viable for the Australian mushroom industry

The global scan also identified a range of available alternatives to currently adopted PVC plastic wrap. The marketplace for sustainable alternatives to existing PVC plastic wrap solutions is nascent, with limited commercially viable solutions available that are able to meet the needs of the mushroom industry and its participants. A detailed overview of each solution below is provided in Appendix 1.

Solution number	Country of Origin	Material qualities	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
58	Australia	Bioplastic stretch wrap made from potatoes - compostable	0	1	1	1	2
59	Australia	Bioplastic resin wrap - compostable	N/A	1	1	N/A	1
60	Europe	Corn derived PLA wrap – compostable	N/A	1	1	N/A	1
61	United Kingdom	Plastic heat sealed lidding	N/A	0	2	2	2
62	United Kingdom	PVC – biodegradble. Not compostable or recyclable	N/A	0	2	N/A	1
63	Europe	PLA heat seal	N/A	2	2	1	2
64	United States	PET heat seal	N/A	1	2	0	2
65	United States	Bio and fossil fuel based seal lid and bag	N/A	1	2	0	2
66	United Kingdom	rPET heat seal	N/A	1	2	1	2
67	United States	Plastic	N/A	1	2	1	2

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

The global scan identified several tray and lid solutions, however, these solutions also failed to meet sustainability and supply chain expectations

The global scan identified a range of the punnet and lid options, four of these solutions made the shortlist of options. The majority of the these solution failed to expectations regarding sustainability credentials and suitability for the mushroom supply chain. Further consultation with industry experts suggest that tray and lid formats contribute to increased product damage and shortened shelf life.

Solution number	Country of Origin	Material qualities	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
1	Australia	Plastic base – plastic resealable lidding	N/A	1	2	2	1
4	Australia	Bamboo fibre baggase – plastic heat seal lid	0	2	2	1	2
18	India	Cardboard paper base with PLA transparent window in lid	1	2	2	1	2
22	Europe	Areca palm leaf	N/A	2	2	1	1
25	Europe	Cardboard CartonShell® - PLA Cellulosic Lid	N/A	1	2	1	2
32	Europe	Paper based punnet – Glassine Paper or PLA Lid	N/A	1	2	2	2
39	United States	Fibre paper board – PLA or plastic heat seal	N/A	1	2	2	2
43	United States	Paper board punnet – PLA lid	N/A	1	2	1	2
47	United Kingdom	Paper based punnet – plastic and PLA lid option	N/A	1	2	1	2
55	United Kingdom	Seawead Based Punnet	1	1	1	1	1
56	United Kingdom	PLA Punnet	1	1	2	0	1
54	United Kingdom	Plastic	N/A	1	2	1	2
27	Europe	Carboard punnet with plastic coating – Plastic heat seal	N/A	1	2	1	2

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

As a result, it was agreed that the high-level cost benefit analysis would focus on the viability of punnet tray alternatives, given global scan suggested there is a lack of currently suitable replacements for PVC wrap

The global scan and additional stakeholder consultation indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry. Alternatives were identified as lacking supply chain suitability and cost effectiveness. As a result, further analysis focused primarily on alternative punnet tray solutions, with wrap, seal and lid packaging components considered as part of supplementary analysis. It is recommended that industry continues to monitor developments in this space for longer term options.

Drawbacks of alternatives to PVC wrap

Alternatives are less cost effective than PVC

Currently available alternatives to PVC wrap, such as biodegradable plastics, are significantly more expensive. Desktop research indicated that these alternatives are up to 2-3 times more expensive than traditional PVC.

Alternatives are not suitable for the mushroom supply chain

Stakeholder consultation indicated that punnet and lid solutions were not readily compatible with mushroom supply chains.

Punnet and lid solutions pack mushrooms less firmly than punnet and wrap solutions, leading to increased bruising, blemishes and quality degradation of mushrooms.

Lack of scale and availability

Desktop research suggested that the manufacturing of alternatives to PVC are not at the scale required to service large mushroom growers.

Industry stakeholders indicated that the decreased availability of packaging materials may therefore be incompatible with current packhouse operations and processes.

Considerations for high-level cost benefit analysis

The global scan and additional stakeholder consultation indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry.

Therefore, the high-level cost benefit analysis will focus primarily on the commercial viability alternative punnet tray solutions.

A sub-component of the high-level cost benefit analysis seeks to identify the costs associated with adopting sustainable alternatives to PVC. This will ensure the study considers the commercial viability of alternatives to PVC film.

4.3

Two selected prioritised solutions

Solutions were presented to the project advisory group for consideration and the following solutions were selected as the top two priority solutions.

Option 1 – rPET punnet tray

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Manufacturer supplies sustainable packaging in the Australasian region, catering to a range of industries such as food and beverage, healthcare, household, and bulk packaging industries[1].
- Founded in 2002, the Melbourne-based company has posted annual revenues of $1.8 billion and has a footprint in New Zealand and South East Asia[2].
- Core strategy for this solutions provider's output is facilitating a sustainable 'whole-of-product lifecycle' approach. All materials manufactured are recycled and recyclable[1].
- The focus on a circular product cycle has seen the company dedicate a division to recycling its discarded product. The solution provider co-created a recycling infrastructure initiative with a major waste manager company and beverage companies, a facility to supply their production with circular (recycled) materials. Once complete, the facility will process 120,000 tonnes[3] of discarded plastic into recycled plastic or rPET.

Packaging solutions – Punnet & Tray Range

- Punnet is made from rPET and is completely recyclable[4].
- Punnet is not compostable or biodegradable[4].
- The punnet option incorporates a moisture lock technology that effectively captures and stores excess fluid. In the event that this product component is chosen for additional review by the PAG, its application to mushrooms will undergo further analysis[4].
- Product is currently used in packaging of fresh meat, chicken and fish. However, the company has a wide variety of products that package fresh vegetables and the ability to customise its product.

Solutions available

500mg tray

- 175x175x70mm

Relevance for Australia Mushroom Growers

1. **Very similar to current packaging product used by major mushroom producers in the market.**
2. **Contributes to the circular economy as product is made from recycled rPET and is fully recyclable.**
3. **Ensure mushroom quality to same level as current packaging solutions.**

Assessment against core criteria

Cost	2	Quoted on an individual order basis. Price range from $0.11 to $0.16 cents
Sustainability	1	Manufacturer's products are made from recycled materials and are recyclable.
Product quality and safety parameters	2	The product is currently in the market. Complemented by shrink or stretch wrapping.
Meets logistic requirements	2	Durable, scalable, and able to be easily integrated into current processing.
Consumer acceptability	2	Open tray. Dependent on seal option.

1. Analysis of packaging solution provider, via publicly available website
2. Analysis of packaging solution provider, via publicly available website
3. Analysis of packaging solution provider, via publicly available website
4. Analysis of packaging solution provider, via publicly available website

Option 2 – Corrugated Fluted Cardboard Tray

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- The manufacturer is a global packaging company that provides sustainable packaging solutions to a wide range of industries, including food and beverage, retail, healthcare, and more. The manufacturer offers over 1000 packaging solution products locally and into Singapore and South East Asia[1].
- The manufacturer has developed a range of packaging solutions specifically designed for the fresh produce industry. Products are engineered to protect and preserve the quality of fresh fruits and vegetables while reducing waste and minimising environmental impact.
- Product range includes breathable bags, punnets, trays, and boxes made from eco-friendly materials such as recycled paper and bioplastics. These materials are designed to allow for optimal airflow, preventing the build-up of moisture and gases that can lead to product deterioration. The manufacturer supplies large food producers such as McDonalds, Subway, Jurlique, Dicos, Zambrero and Woolworths.

Packaging solutions – Endura Tray

- Punnet tray is made of a corrugated fluted board.
- Material is sourced and manufactured from renewable materials.
- Punnet is recyclable, compostable, and biodegradable. Certified compostable in an industrial setting (EU EN13432)[2] and home compostable (AS 5810-2010)[3].
- Customisable solutions available[1].
- The punnet is part of a larger product line that supplies solutions to the food services and fresh food industry. As the solution provider continues to focus products for fresh vegetables it has developed a moisture barrier coating technology that achieves the Australasian Recycling Label, meaning it can be placed into kerbside recycling bins[2].

Solutions available

500g Tray	1kg Market Punnet	1kg Market Tray
• 200X130X40mm	• 166X94X101mm	• 220X140X50mm

Relevance for Australia Mushroom Growers

1. **Product is easily integrated into current industry operation. The solution has similar size and shape options packaging currently used in the Australian industry.**
2. **Recyclable and compostable solutions with no plastic inputs. Company holds a Home Compostable Logo Licences from ABA[3].**

Assessment against core criteria

Cost	1	A punnet unit costs $ 0.21 cents. Cost varies with distributors.
Sustainability	2	Renewable source. Raw materials are fully compostable, biodegradable & recyclable.
Product quality and safety parameters	2	The product is suitable for fresh produce. Complimented by wrap seal.
Meets logistic requirements	1	Acceptable structural integrity through there is a high chance for the structure to be compromised due to the potential of moisture exposure along the supply chain.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website
2. Analysis of packaging solution provider, via publicly available website
3. Who is Certified In Australia & NZ | Australasian Bioplastics Association. Retrieved March 10 March, 2023, from https://bioplastics.org.au/certification/who-is-certified-in-aus-nz/#toggle-id-4

5

High-level cost benefit analysis

5.1

Overview of methodology and approach

A high-level cost-benefit analysis was conducted to identify the adoption considerations of alternative packaging solutions for mushroom growers

A high-level cost benefit analysis was conducted to understand the suitability of alternative packaging formats for the Australian mushroom industry and its participants. To do so, the two prioritised packaging solutions identified through the global scan were compared with an industry reference standard with the objective of identifying any additional costs over and above currently adopted solutions. A detailed methodology and approach is provided in Appendix 2.

Objective and scope

Objective:

- To identify the relevant costs, benefits and considerations of adopting alternative packaging solutions in the mushroom industry.
- The analysis compared the costs and benefits of alternative packaging solutions to an industry reference standard.

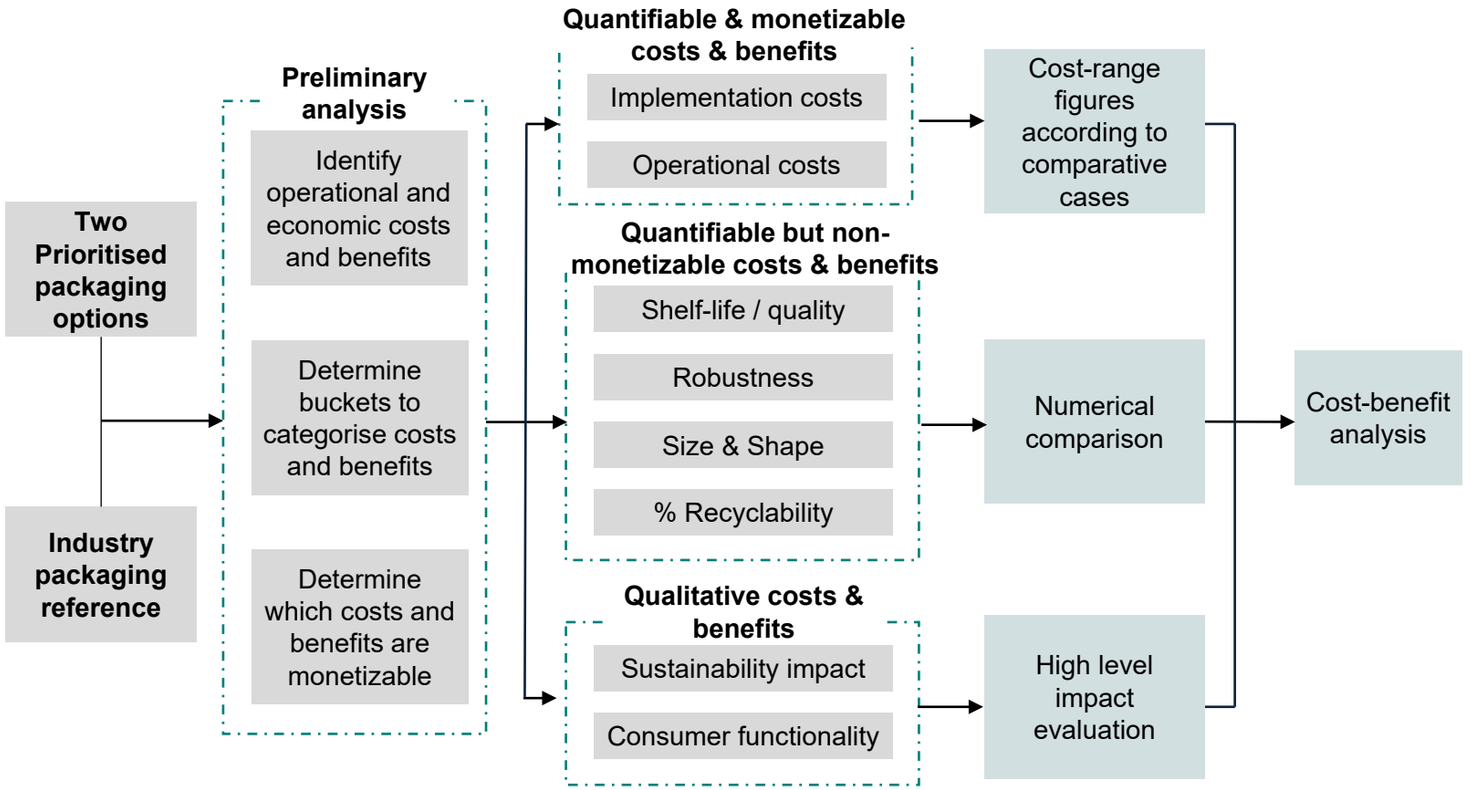
Approach and method:

- The overview on the right illustrates the process with which costs and benefits have been identified.
- Cost and benefit ‘buckets’ are identified to reflect the operational, commercial and strategic considerations of adopting alternative formats.
- Data has then been gathered to determine the likely commercial viability of the packaging option.

Scope:

- Compare two prioritised punnet tray solutions with an industry reference standard.
- Understand the cost impact of adopting alternative wrap and seal combinations.

Overview of methodology and approach



The analysis considered the costs, benefits and broader adoption considerations of the two prioritised solutions against an industry standard

The high-level cost benefit analysis sought to compare the commercial viability of the two prioritised punnet trays (rPET; corrugated cardboard) with an industry reference standard, a PET punnet tray. Based on discussions with the PAG, the analysis held constant the size and closure methods for the punnet tray across each option.

Parameters and assumptions[1]

- Packaging format is assumed as a 500g punnet tray
- Closure method is assumed as PVC cling film (considerations made in supplementary analysis)
- Costs and benefits are framed over a 5-year timeframe
- Mushrooms are pre-packed white button mushrooms (Agaricus bisporous)

Overview of options

Base case: Industry packaging reference

PET (polyethylene terephthalate) punnet solution

Options evaluated against base case

1

rPET tray

rPET (recycled polyethene terephthalate) punnet (70% recycled content)

2

Corrugated cardboard tray

Cardboard solution

1. Detailed description of assumptions provided in Appendix 2.

A simplified process map of the mushroom packhouse was developed to identify categories of costs and benefits relevant to growers

A process map for mushroom packing was created to ensure that the operational, implementation, commercial and strategic considerations of adopting alternative packaging solutions were captured in the high-level cost benefit analysis. The process map was used to identify relevant cost and benefit categories that are included in the analysis.

A process map of the mushroom supply chain

Operations and processes

Inputs	Harvesting	Packaging	Packed Product	Sale of goods
Tool design and customisation	Punnet loaded into harvesting unit	Punnet transferred to packaging machine	Metal detector applied to wrapped punnet	Logistics and transport
Punnet order and manufacturing lead time	Harvested mushrooms loaded into punnet	Punnet weighed with major variance in specified weight redirected away from wrapping machine	Label applied	Retail processes and operations
Punnet delivery			Wrapped punnet packed into storage and transportation box	Consumption and disposal of materials
Storage of packaging materials as inventory				

Identified costs and benefits

- Customisation costs
- Cost of packaging format
- Transport of packaging solution
- Capital expenditure associated with new machinery of equipment for packhouse operations
- Operational expenditure associated with adjusted, additional or more efficient operations and processes
- Shelf life
- Consumer preference
- Cost of estimated lifecycle carbon emissions
- Robustness of packaging solution throughout mushroom supply chain

Further analyses was conducted to identify the influence of wrapping solutions on the costs and benefits of adopting alternative packaging

A scenario analysis was conducted to identify the influence of scale on the estimated costs and benefits of adopting alternative packaging solutions. Further supplementary analyses were also performed to understand the cost impact of adopting alternative closure solutions. More detailed information on the scenario and supplementary analyses are provided in Appendix 2.

Scenario analysis

A scenario analysis was conducted to understand the influence of production scale on the costs and benefits of adopting alternative packaging.

To do so, the analysis was performed using the pre-pack production volumes representative of a small, medium and large producer. Production volumes were identified through stakeholder consultation, and confirmed by the PAG.

Small grower:
20 tonnes per week

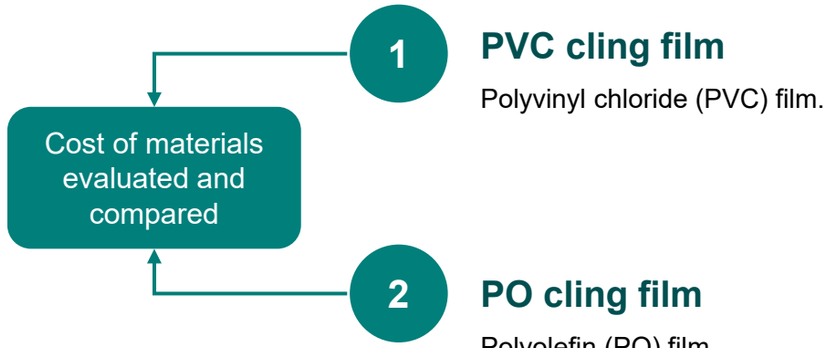
Medium grower:
50 tonnes per week

Large grower:
120 tonnes per week

Supplementary analysis

A supplementary analysis was performed to understand the cost considerations of adopting alternative packaging seal solutions to PVC cling film.

PVC cling film was identified as a priority material for consideration in a cost analysis by the PAG. Therefore costs of transitioning to alternative materials, such as a polyolefin cling film, was modelled to identify the cost considerations for growers, despite the lack of priority solution in-market being identified during the global scan phase.



5.2

Detailed overview of options

Packaging option #1 provides an alternative to single-use, while maintaining many of the benefits of the incumbent PET option

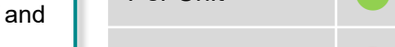
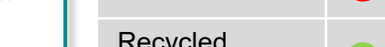
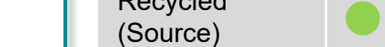
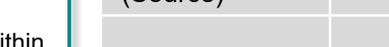
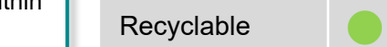
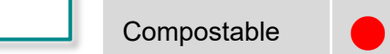
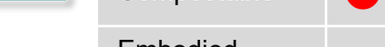
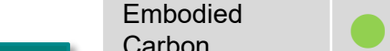
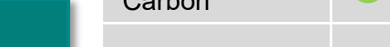
Like PET, rPET is a thermoplastic and can be implemented in the mushroom industry with minimal adjustment to packhouse operations and processes.

Key Benefits

- There is minimal difference between the properties of PET and rPET, especially when utilised in the packaging of fresh produce[2]. As a result, and as per findings, the adoption of an rPET offers minimal disruption to the current packaging process.
- rPET offers the opportunity to establish a fully closed-loop product lifecycle, or alternatively, to phase out packaging within the single-use category.

Key Challenges

- The end-of-life side of rPET is dependent on many factors that are unable to be controlled by any one stakeholder.
  - Consumer dependant – the ability for rPET to remain in circularity is dependent on the correct disposal of the packaging.
- Ensuring credibility in the rPET input. Recycled plastic can be both virgin recycled plastic and post consumer recycled plastic. Virgin recycled plastic is offcut from virgin plastic and is not included in the APCO targets.

Criteria		Supporting Rationale and Research
Per Unit		Cost of a per unit product is dependant on contract negotiations with the manufacturer, standard practice for the wholesale packaging industry. This punnet price is within the $0.15 cents per unit range.
Transition Cost		If customisation is required, the thermoform moulding tool is to be developed. The cost of tooling can range up to $150k depending on the size and dimensions of the punnets.
Recycled (Source)		The rPET is sourced from multiple plastic recycling facilities across NSW and Victoria. This ensures the material is post-consumer recycled as opposed to virgin material recycled.
Recyclable		rPET is fully recyclable. Recycle rPET can be collected by kerbside pickup[1]. The recycling procedure involves rejuvenating to a level of fit for purpose similar to PET. As a result, the products made from rPET can be infinitely circular[2].
Compostable		Recycled polyethylene terephthalate is not compostable or biodegradable. Its formation is the product of refining hydro-carbons[3].
Embodied Carbon		For every kilogram of rPET production, an equivalent of 0.68kg of carbon dioxide is created. The use of rPET instead of PET reduces the carbon footprint by 40%[4].
Recyclability Certification		As a PET or rPET material, the product will meet Australasian Recycling Label specifications for on packaging fully recyclable instructions. Other recyclability certifications in Australian are implied within plastic identification code. For PET and rPET the PIC is #1.
Breathable and Humidity		The rPET and PET have similar characteristic in regards to moisture control and breathability when stretch wrap is applied. The plastic film allows the punnet to breath[5].
Structural Integrity		rPET and the punnet design ensure structural integrity is maintained throughout the product life cycle, including the stretch wrap process. The product is currently used for packaging heavy products, such as meat.
Process Integration		The product is able to be integrated into the current on-farm process of pre-packaging mushrooms that utilise machines such as the Ossid 500Si and the Omori STN 8500[5].
APCO Targets		APCO Target of 100% recyclable is obtained APCO Target of 50% recycled content obtained with the option a 100% rPET

1. Sydney recycling - city of Sydney. (2023). Retrieved March 27, 2023, from https://www.cityofsydney.nsw.gov.au/waste-recycling-services
2. Insight from stakeholder consultations
3. Fact sheet - an introduction to pet (polyethylene terephthalate ... (2023). Retrieved March 27, 2023, from http://petresin.org/news_introtoPET.asp
4. Fraunhofer-publica :: Home. (2023). Retrieved March 27, 2023, from https://publica.fraunhofer.de/home
5. Insights from Project Advisory Group

Corrugated fluted cardboard offers a disposable alternative to plastic, however issues arise with quality and shelf-life in mushrooms

There are a number of additional considerations regarding fluted cardboard to effectively manage moisture, thereby preventing impacts to structural integrity.

Key Benefits

- Corrugated fluted cardboard is able to be recycled, composted and is biodegradable. This allows for the product to be single use and to break down to environmentally friendly compounds. This also allows the product to be fully recycled and continue in circulation.

Key Challenges

- Humidity regulation is a significant consideration when dealing with fibre-based materials such as cardboard, which possess absorbent properties. It has been observed that utilising cling film effectively curbs the loss of humidity and serves as a viable solution to address this concern.
- Structural integrity is a concern as the absorbent properties compromise the rigidity of the cardboard. The lining put forward by the solution provider is a highly mineralised resin that provides an equal barrier to a traditional plastic polymer lining, negating any structural compromise from available moisture.

Criteria		Supporting Rationale and Research
Per Unit	🟡	Cost per unit is $0.21 cents. This does not include the cost of a moisture-resistant coating.
Transition Cost	🟢	Minimal transition costs with the assumption that packaging is stored in dry conditions.
Recycled (Source)	🟢	Corrugated fluted cardboard is a fibre-based material that has a theoretically infinite recycle rate.
Recyclable	🟢	The fibre-based material is completely recyclable with continuous recyclability. Australia recycles 87% of recycled paper[1] with developed cardboard or paper-based collection and processing infrastructure.
Compostable	🟢	Material is home compostable.
Embodied Carbon	🟡	Like most recyclable materials in circulation, the carbon footprint of corrugated flute cardboard decreases with every usage or every time it is recycled. Virgin fluted carbon has a carbon dioxide equivalent of 1.14kg, this decreases to 0.82kg if the material in recycled once[3].
Certification	🟢	Fluted cardboard and the optional mineralised resin coating has been approved by the Australian Recycling Label. The manufacture holds a home compostable logo licence from the Australian bioplastic association.
Breathable and Humidity	🟡	Although cardboard is currently used in mushroom packaging, research has provided evidence that it does not manage the high moisture environment of mushroom production and transportation. Innovative solutions are continually being developed to address this issue.
Structural Integrity	🟡	The structural integrity of the fluted cardboard for the packaging of mushrooms is disputed within the industry[2]. While a number of major producers utilise the punnet, moisture absorption saturates the materials and compromises structural integrity.
Process Integration	🟢	Fluted cardboard is currently utilised by large producers in New Zealand and Australia. These operations use a stretch wrap system. The product is able to be customised to a required dimension.
APCO Targets	🟢	Carboard meets all APCO targets as the solution is 100% reusable, recyclable or compostable.

1. Study confirms the excellent carbon footprint of recycled pet. (n.d.). Retrieved March 27, 2023, from https://packagingeurope.com/study-confirms-the-excellent-carbon-footprint-of-recycled-pet/1923.article
2. Insights from Project Advisory Group
3. Recycling Facts Australia needs to know 2023. (n.d.). Retrieved March 27, 2023, from https://waster.com.au/recycling-facts-australia/

5.3

Finding and insights

The analysis demonstrated that adopting alternative packaging solutions presents a cost increase when compared to a PET reference standard

The high-level cost benefit analysis identified that the adoption of alternative packaging solutions is more costly to mushroom growers when compared to a PET punnet tray reference standard. Information gathered through stakeholder consultations and desktop analysis could not identify cost savings associated with the transition to alternative, sustainable packaging formats. Refer to Appendix 2 for analysis methodology and detailed results.

Option	Reviewed scenarios		
	1 – Large producer	2 – Medium producer	3 – Small producer
Base case – PET punnet tray	$6,380,182	$1,914,054	$39,876
Option 1 – rPET punnet tray	$9,408,012	$2,822,404	$58,800
Option 2 – Corrugated cardboard punnet tray	$13,166,315	$3,949,895	$82,289

Interpretation of the results

Quantitative and qualitative assessment of options:

- The results indicate that the Base Case (PET punnet tray) is the lowest cost method for packaging mushrooms. This is followed by rPET and then corrugated cardboard.
- This analysis is limited by the absence of information to support quantification and monetisation of benefits presented by alternative packaging solutions, such as adherence to APCO targets and addressing consumer preferences for sustainable packaging. These qualitative benefits are presented in more detail on the following slide (slide 53).

Adjustment to packhouse operations and process across each option:

- Stakeholder consultations and desktop review indicated that there are no substantial processing and operational changes required to transition to either of the alternative packaging solutions. As a result, there appears to be no operational or process related costs or benefits associated with transitioning to rPET or corrugated cardboard when compared to the base case.

However, if the industry and broader mushroom supply chain is to comply with emerging packaging regulations, a shift to rPET is the lower cost option

The analysis of costs and benefits indicated that a recycled PET punnet is the lower cost packaging option that complies with emerging packaging regulation, such as the National Packaging Targets. The assessment also indicated that rPET punnet tray solutions present a superior option to corrugated cardboard across several qualitatively described benefit categories. Refer to Appendix 2 for a detailed description of results.

A rPET plastic punnet tray	Benefit category	Corrugated cardboard punnet tray B
Acts the same as PET trays – preserves the shelf of life of mushrooms for 5-7 days. Does not create issues with substantial moisture and provides sufficient structural integrity.	Quality and shelf life	Corrugated cardboard punnet trays will allow for the build-up of moisture in the packaging environment. Excess moisture will impede the packaging solutions' structural integrity leading to a reduction in shelf life and quality attributes of the final product.
Meets consumer preference for pre-packaged and value added mushrooms, the fastest growing category. Transparency of punnet tray and cling film combination allows consumers to assess quality of the product.	Consumer preference	The combination of cardboard punnet tray and cling film impedes the visual appearance of the product to the consumer. The consumer will not be able to assess the visual quality of the product prior to purchasing.
rPET adheres to APCO criteria of packaging designed for circularity. Option 1 contains 70% recycled material and can be recycled in existing recycling facilities in Australia.	Adherence to APCO criteria	A corrugated cardboard material adheres to APCO's criteria of packaging designed for circularity. Cardboard is designed for recovery and can be recycled through existing infrastructure streams in Australia.
The manufacturing of rPET trays benefit from efficiencies of scale. Customisation of packaging formats requires unique designs known as 'tools' to be developed at significant cost to the customer.	Customisation costs	Cardboard solutions included in the cost benefit analysis allow for customisation of packaging solutions if a minimum order quantity is met. All three producers were able to meet this threshold.

Strong performance
Moderate performance
Low performance

The supplementary analysis suggests that the adoption of wrap and seal alternatives would present significant increases to grower operational costs, in addition to their lack of current suitability and production scale

An assessment of the relative costs of adopting alternative wrap and seal solutions indicates that alternatives to PVC have the potential to present an operational expenditure increase of 200 percent for growers of all scales. Refer to Appendix 2 for a detailed description of the results.

Wrap and seal solution	Modelled scenarios		
	1 – Large producer	2 – Medium producer	3 – Small producer
Industry reference standard - PVC cling film	$187,200	$78,000	$7,800
Alternative solution – PO cling film	$561,600	$234,000	$23,400
Cost premium for alternative solution	**$374,400**	**$156,000**	**$15,600**

Interpretation of the results

Label and wrap complementarity:

- The complementarity between labelling and wrapping materials is a key consideration for ensuring the sustainability of the packaging format as a whole. Stakeholder consultation with packaging experts highlighted the importance that both the label and wrap obtain the same end-of-life processing properties. For instance, it is most beneficial if both the labelling and wrap are kerbside recyclable, or both compostable, to ensure ease of processing and prevent contamination in recycling steams or composting.
- Transitioning to alternative wrap solutions, such as PO cling film, will introduce the need to procure PO labelling materials and adhesive as well. This may add further costs to a growers' packaging operations.

Commercial availability of alternative wrap and seal solutions:

- Desktop research suggests that sustainable alternatives to PVC film are not yet available at the scale or price point necessary to foster broad adoption in the Australian mushroom industry.
- The analysis demonstrates that currently available PO wrap alternatives to PVC film are estimated to be approximately 200% more expensive than existing solutions.

Currently available alternatives to PVC stretch wrap lack commercial viability required for broad adoption in the mushroom industry

The market for alternatives to PVC stretch wrap is nascent. There are few currently available alternatives, with no solution meeting the criteria to be considered commercially viable. Solutions, such as polyolefin wraps, lack the scale, cost parity and compatibility with packhouse operations when compared to PVC. Therefore, it is recommended that this forms a longer term consideration for industry and solutions are tracked on an ongoing basis.

A PVC stretch wrapping	Benefit category	PO wrap alternative B
The current cost of PVC stretch wrap is approximately $0.03-$0.05 per metre of material on average.	Cost of solution	The current cost is estimated to be in approximately $0.14-$0.16 per metre of material on average. This equates to a price increase of ~200% when compared with currently adopted PVC film.
Currently, PVC stretch wrapping is widely available to the industry at a low cost. There are no significant costs to the industry in its use when considering availability and or supply lead times.	Commercial availability	To date, many manufacturers of PO stretch wrapping are not at the commercial readiness to meet the demands of the entire Australian mushroom industry volume demand. The quality of PO stretch wrap as it relates to mushroom shelf life and quality also requires further investigation.
PVC cling film can be procured in a number of formats and roll sizes to best fit the growers method of packaging. Available formats ensures compatibility with a wide range of packaging processes and operations.	Compatibility with packhouse operations	PO stretch present many similar characteristics as PVC cling film with regards to strength, moisture and temperature resistance. Stakeholders from the packaging industry suggest that early commercial trials have indicated compatibility with existing packhouse operations and equipment.

Strong performance
Moderate performance
Low performance

Size and material factors are also critical to consider when evaluating alternative packaging formats in the Australian mushroom industry

There are several additional adoption considerations when assessing alternative packaging solutions, such as the size of punnet, labelling and material composition. These factors influence the overall commercial viability and sustainability credentials of packaging formats and should be considered by mushroom growers.

1 Packaging consideration	2 Impact on packaging characteristics
 **Packaging size –** pre-packaged mushrooms are sold in various container sizes, predominantly in 200g and 500g punnet trays. The high-level cost benefit analysis modelled the cost of a 500g punnet trays using PET, rPET and corrugated cardboard.	The results presented in this report present both the marginal and estimated cost increases for 500g punnet trays. Stakeholder consultation suggests that the marginal costs can be scaled down for smaller packaging sizes, such as the 200g tray size. Based on the findings of this report it is suggested that adopting 200g rPET and corrugated cardboard punnet packaging solutions are estimated to cost 47% and 106% more than PET respectively.
 **Labelling –** the labelling of mushroom packaging can influence recyclability and processing. Packaging and labelling materials must be complementary and processed using the same end-of-life treatments.	Transitioning to alternative wrap or punnet tray materials will introduce the need to procure labelling materials and adhesive that are complementary. This may add further costs to transitioning to a new, more sustainable packaging format. Alternative labelling and adhesive materials may also lack the commercial viability or maturity for application in the mushroom industry. In 2023, APCO have introduced a labelling committee to focus on the complexities that labels bring to the recyclability of other materials and seek new opportunities to create labels from recycled materials.[1]
 **Material composition** – the composition of rPET can vary according to the percentage and source of recycled materials. Recycled PET can be sourced from both pre- and post-consumer recycled sources, with different sources varying in terms of emissions-related lifecycle impacts.	The 2025 National Packaging Targets demand a minimum of 50% recycled content in packaging materials. Blends of PET with higher percentages of recycled content will attract premium prices, and increase the cost to growers. Should the packaging targets posed by regulators or retailers increase required recycled content there is likely to be increased cost implications for mushroom growers.

1. Working groups, APCO. (n.d.). Retrieved May 11, 2023, from https://apco.org.au/working-groups

6

Outcomes and summary of recommendations

rPET punnet tray solutions were identified as the alternative, compliant packaging solution with likely lowest cost and greatest benefits to growers

The high-level cost benefit analysis indicated that PET punnet trays present the lowest-cost packaging option of the three assessed for the Australian mushroom industry. However, if the industry and broader mushroom supply chain is to comply with emerging regulations, a shift to rPET punnet trays is an option that appears to demonstrate the lowest cost and greatest benefit.

Rationale for selection

Assessment of the quantitative and qualitative results of the high-level cost benefit analysis indicate that the rPET punnet tray solution is the lowest cost option that presents the greatest level of benefit for growers whilst meeting emerging packaging targets set by APCO.

Cost of adopting alternative packaging solutions

Estimated additional costs incurred by growers for the adoption of alternative punnet trays compared to PET tray. Results suggest rPET is the lower cost option.

Solution	Large producer	Medium producer	Small producer	% increase
Option 1 – rPET	$3,027,830	$908,350	$18,924	147.46%
Option 2 – Cardboard tray	$6,786,133	$2,035,841	$42,413	206.36%

Estimated costs incurred by growers for the adoption of alternative closures suggest alternatives to PVC film attract a significant cost increase (200% increase).

Packaging solution	Large producer	Medium producer	Small producer
PVC film	$187,200	$78,000	$7,800
PO film	$561,600	$234,000	$23,400
Difference	*$374,000*	$156,000	$15,600

Option 1 – rPET performed well in several cost and benefit categories

Cost and benefit category	Description of performance
Quality and shelf life	Acts the same as PET trays – preserves the shelf of life of mushrooms for 5-7 days. Does not create issues with substantial moisture and provides sufficient structural integrity.
Consumer preference	Meets consumer preference for pre-packaged and value added mushrooms, the fastest growing category. Transparency of punnet tray and cling film combination allows consumers to assess quality of the product.
Adherence to APCO criteria	rPET adheres to APCO criteria of packaging designed for circularity. Option 1 contains 70% recycled material and can be recycled in existing recycling facilities in Australia.
Customisation costs	The manufacturing of rPET trays benefit from efficiencies of scale. Customisation of packaging formats requires unique designs known as ‘tools’ to be developed at significant cost to the customer.
Adjustments to packhouse processes and operations	rPET is the same functional material as currently adopted PET punnet trays. rPET demonstrates a high readiness to be integrated into existing packhouse operations and processes with little to no adjustment required by the grower.

Sustainable packaging will be a long-term consideration for the Australian mushroom industry

Both retailers and regulators are setting increasingly ambitious sustainable packaging targets. This creates a continued need for the Australian mushroom industry to consider the sustainability credentials of packaging formats. At present, commercially viable packaging can only address a portion of the 2025 National Packaging Targets. Innovation in packaging is likely to increase the availability and commercial viability of sustainable formats in the longer term.

2023 Short-term packaging considerations

Several alternative packaging formats comply with retailers and regulatory targets

Findings from the global scan indicate that there is a substantial number of alternatives to plastic (PET) punnet trays that comply with current targets set by regulators (2025 National Packaging Targets) and major retailers.

Evidence suggests rPET is the most suitable packaging solution

Alternative packaging formats identified in the global scan were observed to have varied commercial suitability for the Australian mushroom industry.

A high-level costs benefit analysis and stakeholder input indicated that recycled plastic (rPET) punnet trays demonstrate the highest level of commercial suitability out of the options assessed due to their comparative affordability and preferred material characteristics.

Findings indicate that alternatives to PVC wrap are not commercially viable

The global scan and additional stakeholder consultation indicated that alternatives to PVC wraps are not commercially viable for the mushroom industry due to high cost and lack of available supply. PVC film is identified as a problematic material by the 2025 National Packaging Targets.

2030 Long-term packaging considerations

Increased availability and number of sustainable packaging formats

The transition towards a circular economy is likely to attract increased investment and resources. It can therefore be expected that the waste and packaging industries will be better equipped to manufacture, distribute and process sustainable packaging formats.

This includes the development of the supply chains capabilities, infrastructure and intellectual capital that will enable the production of sustainable packaging solutions that have a lower environmental footprint, are of acceptable cost to mushroom growers, and maintain/improve the product quality attributes of mushrooms.

As a result, sustainable packaging formats may become more widely available and commercially viable for mushroom industry participants in the medium to long-term.

Continued evolution of packaging targets

The transition towards a circular and more resource efficient economy will also include increasingly ambitious target setting by regulators and retailers.

By 2030, the 2025 National Packaging Targets will have elapsed. Revised targets will exceed current standards for recyclability and problematic packaging. Retailers are likely to adopt new targets as they are set.

Potential next steps for Hort Innovation are to support the development, commercialisation and credibility of alternative sustainable packaging

To ensure that Hort Innovation supports industry with embedding sustainable packaging options, key focus areas involve running effective packaging trials and gathering relevant data to substantiate the packaging's efficacy as a sustainable and fit for purpose option.

	1 Insights	2 Recommendations
	There has been significant growth and development in the innovative sustainable packaging industry, though a significant number of these companies are in their infancy and are not yet commercially viable to fulfil the demands of the Australian mushroom industry, particularly including the alternative lid/wrapping alternatives.	It is recommended that an updated review takes place in 12-24 months' time and then on an ongoing basis, with a 5-10 year longer term perspective, to re-evaluate the sustainable packaging landscape to lead business insights for the sector. Noteworthy innovations include compostable stretch wrapping, and integrated punnet and lid solutions.
	As competition increases in the packaging industry, so does the need to market sustainability measures. The ACCC[1] is doing a widespread investigation into greenwashing. For example, ensuring the recycled rates stipulates the different consumer recycled material.	It is recommended that Hort Innovation supports the industry to gather sustainability data on packaging solutions in a consistent and targeted manner. For example, simplified life cycle analysis covering sourcing, manufacturing and recommended end-of-life processes.
	The end-of-life outcomes for fresh food packaging are dependent on the behaviours of the consumer. If a product is designed to be recycled or composted, that outcome is reliant on the consumer actively processing that unit of waste into the correct stream.	It is recommended that Hort Innovation takes a leading role in consumer behaviour/marketing and supports a whole of industry approach to contribute to the consumer knowledge uplift in packaging disposal. This may include supporting packaging suppliers to add clear disposal information to packaging at the manufacturing stage.
	Assessment of the quantitative and qualitative results of the high-level cost benefit analysis indicate that the rPET punnet tray solution is the lowest cost option that presents the greatest level of benefit for growers whilst meeting emerging packaging targets set by APCO.	It is recommended that Hort Innovation lead the transition by trialling and supporting the implementation of rPET packaging solutions for the Australian mushroom sector.

1. ACCC – Australian Competition and Consumer Commission

7

Appendices

APPENDIX 1: GLOBAL SCAN INSIGHTS

APPENDIX 1.1: Evaluation criteria for global scan

Five evaluation criteria areas were confirmed following consultation with the Project Advisory Group (PAG)

Criteria were selected to be applied to the identified long-list of packaging solutions, to facilitate an evaluation of each option for its suitability as an alternative to existing plastic packaging. Criteria was developed in close consultation with PAG stakeholders and interviews with key members of the supply chain.

DESIRABLE CRITERIA	DESIRABLE CRITERIA DETAILS	Rationale for selection
Cost	The packaging solution is cost effective. Hence, it costs the same per unit as a comparable plastic packaging solution or less than a comparable plastic packaging solution (for procurement of the unit itself, not including logistics costs etc.). For the purposes of this analysis, the average cost used for comparison is $0.15.	Packaging costs need to be commercially viable for the producer/retailer to ensure that it does not, as far as possible, create added cost burden for either the business or the consumer. This criteria is also considered to ensure the selected solution is commercially viable for industry.
Sustainability	The packaging solution contributes to sustainability goals and targets considering whether: • The solution can be disposed of by the consumer sustainably in a consumer-friendly manner (i.e. recyclable and or compostable). • The origin of the solution material is sustainable and/or circular in nature, and thus is likely to contribute less carbon to the system.	The packaging solution needs to align to the National Packaging Targets[1] of 100% reusable, recyclable, or compostable packaging by 2025 and strive to align with a circular economy, ensuring: • Reduced burden on the recycling system • Reduced waste in the supply chain (including microplastics) • Reduced waste to landfill
Product quality and safety parameters	The packaging solution has features that ensure shelf-life maintenance/extension and spoilage mitigation, to target atmospheric, temperature, and humidity regulation. This also supports food safety standards compliance.	A controlled atmosphere can reduce the respiration rate/metabolic activity of mushrooms[2] and reduce excess moisture and humidity from within the packaging resulting in: • Extended/maintained shelf-life of the product • Maintained product quality • Improved consumer acceptability of the product • Reduced potential for food waste from spoilage • Enhanced food safety and ability to limit pest/biosecurity issues

1. Australia's 2025 national packaging targets - APCO. (2018). Retrieved February 6, 2023, from https://apco.org.au/national-packaging-targets
2. Ares, G., Lareo, C., & Lema, P. (2007). Modified atmosphere packaging for postharvest storage of mushrooms. A review. *Fresh Produce*, *1*(1), 32-40.

Criteria aimed to cover commercial, operational, and product-specific factors to ensure relevance to the mushroom industry

DESIRABLE CRITERIA	DESIRABLE CRITERIA DETAILS	Rationale for selection
Meets logistics requirements	The packaging solution meets the logistic requirements of the entire mushroom value chain (including on-farm production, cold chain logistics, etc.) to allow for: • Durability/structural integrity. • Ease of handling and storage. • Solution being scaled to meet industry demand.	Durability refers to the ability of a packaging option to protect mushrooms from physical damage, which in turn reduces food waste, maintains product quality, and improves customer acceptability of the product. It is also able to withstand logistic processes whilst limiting damage to the product. Ease of handling refers to the packaging option being operationally viable for handling along the entire supply chain, with storage also being important both for logistics efficiency and on-site storage. The packaging solution identified will be required to meet the industry's demand in order to roll out a systematic change to the industry, if desired.
Consumer acceptability	The packaging solution doe not impede the consumer's ability to: • View the product. • Access product information. • Conveniently choose and take the product home (including disposal). • Purchase either sliced mushrooms or whole mushrooms using the same packaging type. Given the ability to shape consumer acceptance through other means, this criteria was seen as slightly less influential than the other four. Therefore, if there are any split-decisions on ratings, this will be taken into account based upon where those solutions rate strongly or poorly.	Consumers of fresh produce rely heavily on the appearance of the product to make final purchasing decisions. Therefore, it is imperative that the product can be visualised by the consumer. Secondly, the packaging alternative should not impede the consumer's ability to access product information and should not impede the ability to adhere labelling information to the pack. Finally, the packaging solution should not impede the convenience of the consumer who wishes to purchase pre-packaged mushrooms. These factors should also not differ regardless of whether the mushrooms are in a sliced or whole format.

Each criteria had related scoring parameters to guide the assessment, which were also validated by the Project Advisory Group

The following scoring system was applied to generate an overall rating of each alternative packaging option under consideration.

DESIRABLE CRITERIA	DESCRIPTION	STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIABLE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0
Cost	The packaging solution is cost effective. That is, it costs the same per unit as a comparable plastic packaging solution or less than a comparable plastic packaging solution (for procurement of the unit itself, not including logistics costs etc.). For the purposes of this analysis, the average cost used for comparison is $0.15.	Cost per unit of packaging (procurement only – not currently including logistics or CAPEX/OPEX costs) is the same or lower than a comparable plastic packaging solution.	The cost per unit of packaging (procurement only – not currently including logistics or CAPEX/OPEX costs) is up to 10% higher than a comparable plastic packaging solution.	The cost per unit of packaging (procurement only – not currently including logistics or CAPEX/OPEX costs) is more than 10% higher than a comparable plastic packaging solution.
Sustainability	The packaging solution contributes to sustainability goals and targets considering whether: • The solution can be disposed of by the consumer sustainably in a consumer-friendly manner (i.e. recyclable and or compostable). • The origin of the solution material is sustainable and/or circular in nature, and thus is likely to contribute less carbon to the system.	Solution contributes to sustainability goals and a circular economy by both allowing for: • Sustainable consumer-friendly disposal of the packaging • Sustainable sourcing of packing materials	The packaging solution meets only one of the following criteria: • Sustainable consumer-friendly disposal of the packaging • Sustainable sourcing of packing materials	The packaging solution does not meet any of the following criteria: • Sustainable consumer-friendly disposal of the packaging • Sustainable sourcing of packing materials
Product quality and safety parameters	The packaging solution has features that ensure shelf-life maintenance/extension and spoilage mitigation, to target atmospheric, temperature, and humidity regulation. This also supports food safety standards compliance.	The packaging solution meets all three of the following criteria: • Maintain optimal breathability • Maintain optimal humidity • Maintain adequate temperature control	The packaging solution meets two of the following criteria: • Maintain optimal breathability • Maintain optimal humidity • Maintain adequate temperature control	The packaging solution meets one or less of the following criteria: • Maintain optimal breathability • Maintain optimal humidity • Maintain adequate temperature control

These parameters were then used in the multi-criteria assessment to rank the long-list of options

DESIRABLE CRITERIA	DESCRIPTION	STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIABLE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0
Meets logistics requirements	The packaging solution meets the logistic requirements of the entire mushroom value chain (including on-farm production, cold chain logistics, etc.) to allow for: • Durability/structural integrity *Durability means the packaging solution can withstand the manufacturing process, protect the product from damage and the packaging integrity is not lost* • Ease of handling *Defined by the ability for the solution can be moved, stacked or stored easily* • Solution can be scaled to meet the whole industry's demand. *Refers to the capacity of the provider to fulfill the necessary production scale as well as allow for the standard footprint of conventional punnets to be replicated.*	The packaging meets all three of the following criteria: • Durability/structural integrity • Ease of handling and storage • Ability to be scaled to meet industry demand	The packaging meets two of the following criteria: • Durability/structural integrity • Ease of handling and storage • Ability to be scaled to meet industry demand	The packaging solution meets one or less of the flowing criteria: • Durability/structural integrity • Ease of handling • Ability to be scaled to meet industry demand
Consumer acceptability	The packaging solution does not impede the consumer's ability to: • View the product. • Access product information. • Conveniently choose and take the product home (including disposal). • Purchase either sliced mushrooms or whole mushrooms using the same packaging type. Given the ability to shape consumer acceptance through other means, this criteria was seen as slightly less influential than the other four. Therefore, if there are any split-decisions on ratings, this will be taken into account based upon where those solutions rate strongly or poorly.	The packaging solution does not impede the consumer's ability to: • View the product • Access product information • Conveniently choose and take the product home (including disposal)	The packaging solution only allows for the product to complete only 2 of the three of the below criteria: • View the product • Access product information • Conveniently choose and take the product home (including disposal)	The packaging solution only allows for the product to complete 1 or less of the three of the below criteria: • View the product • Access product information • Conveniently choose and take the product home (including disposal)

Additional assessment factors were identified and were included in the profiling of two priority options and high-level cost benefit analysis

There are a number of criteria that were not conducive for inclusion in the initial evaluation of the long-listed solutions given data availability, though were required to be considered further in the process. The below considerations are included during the profiling and high-level cost-benefit analysis of the two prioritised solutions taken forward from the multi-criteria assessment.

Criteria	Description	Consideration in high-level cost benefit analysis
Suitability	Suitability of implantation for both large-scale and small-scale producers.	A scenario analysis was conducted to understand the influence of production scale on adoption costs and benefits.
Logistics Costs	Cost of logistics for transportation of packaging, including consideration of sourcing locations for the new solution and impact on lead tie for procurement of packaging.	The transportation costs of production were considered for each packaging format.
Implementation Cost	Cost of implementing including: • New Machinery CAPEX costs (if to be operated directly by industry) • High-level variable OPEX costs (if applicable) • Additional labour costs (if applicable) • Additional costs including change of labelling etc (if required)	The analysis considered the packhouse operational and process changes required to adopt a new packaging solution. The cost and/or benefits of any operational changes were considered in the development and execution of the analysis.
Embodied Carbon	Embodied carbon/life cycle assessment of materials – to validate sustainability analysis.	Embodied carbon/life cycle assessment of materials were included as a cost in the analysis.
Operational Validation	Validation of on-farm logistics/operational suitability.	Ongoing operational expenditures associated with packaging are included in the analysis.

APPENDIX 1.2: Evaluation of global scan to establish top-ranking solutions

Solutions identified included both combined punnet and lid as well as stand-alone punnet solutions.

Australian companies are producing solutions in line with 2025 targets

The Australian 2025 National Packaging Targets encourage packaging companies to collaborate with the government's Australian Packaging Covenant Organisation (APCO) in developing innovative recyclable, reusable, and compostable packaging alternatives. Eco-friendly packaging solution providers are taking a lead role in this effort. While the disposal of compostable packaging presents challenges, the focus is now shifting to circular recycled plastic solutions.

Solution number	Format	Primary Material	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
1	Punnet + Lid Full Solution	Plastic Base Plastic Resealable Lidding	NA	1	2	2	1
2	Punnet Only	Kraft Paper Base Punnets PLA Coating	N/A	1	2	1	2
3	Punnet Only	Cane Pulp - Bagasse	2	2	2	2	2
4	Punnet + Lid Full Solution	Bamboo Fibre – Bagasse	0	2	2	1	2
5	Punnet Only	Corrugated Fluted Board (Cardboard)	1	2	2	1	2
6	Punnet Only	Cane Pulp - Bagasse	1	1	2	2	2
7	Foil	Potato Cellulous Bioplastic	0	1	1	1	2
8	Punnet Only	Cane Pulp - Bagasse	1	1	2	1	1
9	Punnet Only	rPET (recycled PET)	N/A	1	2	2	2
10	Multiple	Polyhydroxyalkanoates (PHA)	N/A	1	0	0	0
11	Punnet Only	Cane Pulp - Bagasse Composty™	NA	1	2	1	1

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section
**Including in the lidding shortlist*

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

India is a significant producer of plastic waste and requires solutions

India has a dependence on single-use packaging to accomplish critical objectives like preserving freshness and maintaining affordability. In response to this issue, the use of innovative materials such as bamboo and areca palm leaf, along with a focus on cost-effectiveness, is driving sustainable packaging initiatives.

Company	Format	Primary Material	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
12	Multiple	Vegetable Composite Bioplastic	N/A	1	1	1	0
13	Punnet Only	Pressed Banana Leaf	N/A	1	2	1	1
14	Punnet Only	Bamboo Fibre Punnet	N/A	1	2	1	2
15	Punnet Only	Areca Palm Leaf	N/A	1	1	1	2
16	Punnet Only	Sugarcane Bagasse Base	2	1	2	2	2
17	Punnet Only	Areca Palm Leaf	0	1	1	1	2
18	Punnet + Lid (Transparent)	Paper Based Punnet PLA Transparent Lid	1	2	2	1	2
19	Punnet + Lid	Plastic	N/A	0	2	1	1
20	Punnet Only	Areca Leaf Base	N/A	1	1	2	2
21	Punnet + Lid	Paper Based	0	1	1	2	0

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

Europe has been a long-term market leader in packaging innovation

With clear targets, such as achieving 100% recycled packaging by 2023, incumbent European plastic and paper packaging companies are producing eco-friendly materials as an alternative to petroleum based packaging solutions.

Solution provider	Format	Primary Material	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
22	Punnet + Lid Full Solution	Areca Palm Leaf	N/A	2	2	1	1
23	Punnet Only	Sugarcane Bagasse Base	1	1	2	2	2
24	Punnet + Lid Full Solution	Plastic Punnet Optional Papper Based Lid	N/A	1	1	1	1
25	Punnet + Lid Full Solution	Cardboard - CartonShell® PLA Cellulosic Lid	N/A	1	2	1	2
26	Seal Lid	PET – COEXSHIELD Antibacterial Monomaterial	N/A	1	2	1	2
27	Punnet + Lid Full Solution	Corrugated Fluted Cardboard Plastic or PLA Seal Lid	N/A	1	2	1	2
28	Multiple	PLA FUTERRO RENEW®	N/A	1	2	1	2
29	Punnet Only	Bamboo Paper Based	0	1	2	1	2
30	Multiple	Starches, Cellulous, Veg Oil Matter-Bi	N/A	2	2	0	2
31	Foil	PLA	N/A	1	2	1	2
32	Punnet + Lid Full Solution	Paper Based Punnet Glassine Paper or PLA Lid	N/A	1	2	2	2
33	Punnet Only	Pulp Fibre Based Punnet	1	2	2	2	2
34	Punnet Only	Pulp Fibre Based Punnet	1	2	2	2	2
35	Seal Lid	PLA - Luminy®	N/A	1	2	1	2

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section
Including in the lidding shortlist

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

Consumer concerns, government policy and innovation drives eco-friendly packaging innovations in the US

The drive towards environmental consciousness and the use of alternative materials as the basis for packaging, such as mycelium, is set to advance further throughout North America. Notably, American firms are making significant strides in the development and commercialisation of materials.

Company	Format	Primary Material	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
36	Punnet Only	Non-tree plant base pulp	N/A	1	2	1	2
37	Punnet Only	Formed Mycelium MycoComposite™	0	1	2	0	1
38	Punnet Only	PLA Punnet	0	1	2	1	2
39	Punnet + Lid Full Solution	Fibre Paper Board Option PLA seal lid	N/A	1	2	2	2
40	Multiple	Original PLA material	1	1	2	2	2
41	Multiple	Polyhydroxyalkanoates(PHA)	N/A	1	2	1	1
42	Punnet Only	Polystyrene foam AZURA®	N/A	0	2	1	1
43	Punnet + Lid Full Solution	Paper Board Punnet PLA window - ReadyCycle®	N/A	1	2	1	2
44	Seal Lid	Plastic	N/A	1	2	0	2
45	Seal Lid / Bag	Bio & Fossil Fuel based polymers	N/A	1	2	0	2
46	Punnet Only	Plant fiber and biomass	N/A	1	2	1	2

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

Supermarkets are demanding eco-friendly alternatives in the UK

Similarly to Europe, the United Kingdom's plastic elimination targets have incentivised major UK supermarkets to look for alternatives. The UK is also developing innovative alternatives using other input materials making the market important to review.

Company	Format	Primary Material	Cost	Sustainability	Product Quality & Safety Parameters	Suits Logistics Requirements	Consumer Acceptability
47	Punnet + Lid Full Solution	Paper Based Punnet Plastic/PLA Lid Option	N/A	1	2	1	2
48	Punnet Only	Paper Based PET/PLA Coating	1	1	1	1	2
49	Seal Lid	Plastic – RPET Seal	N/A	1	2	1	2
50	Punnet Only	Formed Mycelium MycoComposite™	N/A	1	2	0	1
51	Punnet + Lid Full Solution	Formed Pulp Fibre Punnet	N/A	0	2	1	2
52	Seal Lid	Plastic	N/A	1	2	1	2
53	Punnet Only	Formed Mycelium MycoComposite™	N/A	2	2	0	2
54	Punnet + Lid Full Solution	Plastic	N/A	1	2	1	2
55	Punnet + Lid Full Solution (Hinge)	Seaweed Based Punnet	1	1	1	1	1
56	Punnet + Lid Full Solution	PLA Punnet	1	1	2	0	2
57	Punnet + Lid Full Solution	Corrugated Paper Punnet	N/A	1	2	1	2

Outlined solutions scored highly in the multi-criteria assessment and were included in the short-list of options presented in the following section

DESIRABLE CRITERIA DESCRIPTION		
STRONG COMPLIANCE WITH DESIRABLE CRITERIA = 2	MODERATE OR PARTIAL COMPLAINCE WITH DESRIALE CRITERIA = 1	WEAK OR NO COMPLIANCE WITH DESRIABLE CRTIERIA = 0

APPENDIX 1.3: Shortlist of packaging solutions (punnet only)

Solution 3

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Company is a provider of sustainable packaging solutions for the food and beverage industry[1].
- Company's product lines include food containers, cups, cutlery, napkins, bags and other food services-related accessories made from renewable and compostable materials such as sugarcane pulp, plant-based bioplastics, and paper. They strive to create a circular economy by promoting responsible sourcing, reducing waste, and encouraging the use of renewable materials.
- Works to promote environmental awareness and sustainability in the food service industry through education and advocacy in partnership with larger food conglomerates[2].
- B Corp certified. A third-party certification that recognises for-profit companies that meet rigorous standards of social and environmental performance, accountability, and transparency.

Packaging solutions – Biocane

- Tray is made of sugarcane bagasse as a reclaimed by-product of sugar cane production.
- Product is manufactured in China.
- Product is home compostable and commercially compostable (certified AS5810-2010)[3].
- Custom solutions are available.

Solutions available

500 g Biocane Produce Tray
- 40X37.5X29cm
- 15.8g

1kg BioCane Punnet
- 500X390X300mm
- 22g

1kg BioCane Produce Tray
- 550X400X360mm
- 30.5g

Relevance for Australia Mushroom Growers

1. **Able to be purchased locally.**
2. **Options to offset production emissions.**
3. **Punnet options for fresh Australian mushrooms.**
4. **Punnet is able to be implemented into current production processes.**

Assessment against core criteria

Cost	2	Whole sale quote of $0.12 cents a punnet.
Sustainability	2	Sourced from renewable raw materials that are both home and industrially compostable.
Product quality and safety parameters	2	The product is currently in the market. Complements shrink or stretch wrapping.
Meets logistic requirements	2	Durable, scalable and easy handling.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website
2. Analysis of packaging solution provider, via publicly available website
3. ABA – Who is Certified in AUS & NZ | Retrieved March 14, 2023, from https://bioplastics.org.au/certification/who-is-certified-in-aus-nz/#toggle-id-2

Solution 16

Punnet | India | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Creates sustainable alternatives to single-use plastics by converting crop waste into biodegradable and compostable food packaging and tableware[1].
- The company operates under the principles of a circular economy, deriving 100% of its revenue from sustainable practices.
- Company has 12 global sales partners, 23 distributors in India, and over 500 point-of-sales shops.
- It has 19 sustainability certifications, highlighting the company's commitment to promoting sustainability and reducing plastic waste.
- Company currently sells its products in India, the United States of America, parts of Asia, and Europe.

Packaging solutions

- All products are biodegradable and compostable food packaging and tableware made from natural and renewable resources.
- Raw materials are sourced from the likes of sugarcane bagasse, wheat straw, and bamboo.
- Products are certified as safe and compostable by international standards organisations like BPI, and EN 13432[2].
- Company supplies Subway with a variety of eco-friendly packaging materials[3]. Company partnered with Etihad Airways to cater an eco-flight in the United Arab Emirates[4].

Solutions available

Deep Tray

- 22X17.5X2.6cm

600ml Bowl

- Diameter – 140mm
- Height 56mm

Relevance for Australia Mushroom Growers

1. **Punnet option for fresh Australian mushrooms.**
2. **Compostable solutions. No Plastic inputs.**

Assessment against core criteria

Cost	2	Cost per units is $0.10 cents.
Sustainability	1	Sources from renewable materials that are compostable and biodegradable.
Product quality and safety parameters	2	The product is currently in the market. Complements shrink or stretch wrapping.
Meets logistic requirements	2	Durable, scalable and does not impede ease of handling.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website
2. Analysis of packaging solution provider, via publicly available website
3. Analysis of packaging solution provider, via publicly available website
4. Analysis of packaging solution provider, via publicly available website

Solution 33

Punnet | European Union | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- A global producer of paper-board and paper. The headquartered company is listed with global revenues of over XX.
- A feature of the organisation is its substantial forestry assets, valued at $8 billion. Coupled with the utilisation of recycled materials, this guarantees that all primary resources are sourced from a verified renewable origin.
- The company has been one of the world's largest producers of liquid packaging board. The company cites that the renewable packaging market is growing faster than plastic-based alternatives. This is driving a growth strategy aimed at their food packaging line[2].

Packaging solutions A

- The wood-pulp-based packaging is recycled and compostable.
- Products can be customised to include more advanced food packaging needs, such as extended shelf-life modification.
- Product line A achieves a 75% lower CO2 footprint and is Per- or poly-fluorinated alkyl substances (PFAS) free.

Packaging solutions

- Product is a tray or punnet made from a paper base material as an alternative to plastic and aluminium.
- Contains Bio plastic film covering that provides heat resistance and protection against humidity, oxygen (outside atmosphere) and grease
- Both solutions are certified to industry composting standards (EN13432)[2].

Solutions available

Rectangular food tray

- 178X205X41mm

Relevance for Australia Mushroom Growers

1. **Punnet option for fresh Australian mushrooms. It is expected that the material will ensure freshness and quality of the mushroom are not compromised.**
2. **Product is easily integrated into current industry operation. Product has similar size and shape options packaging currently used in the Australian industry.**
3. **Recyclable and biodegradable solutions.**

Assessment against core criteria

Cost	1	Punnet unit costs $0.27cents. Cost varies with distributors.
Sustainability	2	Renewable source and materials are fully biodegradable and recyclable.
Product quality and safety parameters	2	The product is suitable for fresh produce. Complimented by heat or wrap seal.
Meets logistic requirements	2	Structural integrity in line with the current packaging used in the mushroom industry.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website
2. Analysis of packaging solution provider, via publicly available website

Solution 6

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Online retailer and wholesaler of compostable and biodegradable packaging[1].
- Vision of becoming the largest supplier in Australia of compostable, recyclable, and biodegradable packaging.

Packaging solutions – Sugarcane Bagasse

- Material derived from crushed sugarcane stalks after the juice has been extracted.
- Sugarcane pulp is a compostable and biodegradable resource, that biodegrades in 30-90 days without toxic residues.
- Material can be recycled if not contaminated (stained) by food products.

Solutions available

Fruit Produce Tray

- 155X145X35mm

1kg Produce Tray

- 268X173X46mm

500g Produce Tray

- 182X134X41mm

Relevance for Australia Mushroom Growers

1. **Able to be purchased locally**
2. **Punnet option for fresh Australian mushrooms.**
3. **Product is easily integrated into current industry operation with minimal disruptions.**
4. **Recyclable and compostable solutions with no plastic inputs.**

Assessment against core criteria

Cost	1	Cost per units is $0.16 cents.
Sustainability	1	Sources from renewable materials and is compostable and biodegradable.
Product quality and safety parameters	2	The product is currently in the market. Complements shrink or stretch wrapping.
Meets logistic requirements	2	Durable, scalable, and does not impede ease of handling.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website

Solution 23

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Company is a distributor of compostable tableware and packaging products. The company was founded in the Netherlands in 2011 and has expanded its operations through Europe with orders shipped to Belgium, Denmark, Germany, France and Austria.
- Distributes to a wide range of industries demanding sustainable products including food packaging, takeaway containers, cups, cutlery, and bags, as well as other custom-made products.
- Provides consultation services to clients on optimal practices for the disposition of their products.

Packaging solutions

- Solution composed of formed fibre
- Sustainable product lines distributed by the company are composed of materials that can be composted and recycled after use in accordance with EN-13432 certification[1].
- Solution identified for assessment is a sugarcane-based or bagasse pulp tray. The tray comes in a variety of sizes and is able to be lidded by a heat-sealed plastic sleeve.
- The kraft box is currently utilised for pre-prepared meals and food service.

Solutions available

Sugarcane Box 1050ml

- 228X166X58mm

Sugarcane Box 1350ml

- 220X160X80mm

Relevance for Australia Mushroom Growers

1. **Punnet option for fresh Australian mushrooms.**
2. **Product is easily integrated into current industry operation with minimal disruptions.**
3. **Recyclable and compostable solutions with no plastic inputs.**

Assessment against core criteria

Cost	1	Punnet unit costs $0.24cents (cost varies with distributors).
Sustainability	2	Renewable source. Raw materials are fully compostable & recyclable.
Product quality and safety parameters	2	The product is currently in the market. Complemented by shrink or stretch wrapping.
Meets logistic requirements	2	Acceptable structural integrity through there is a high chance for the structure to be compromised due to the potential of moisture exposure along the supply chain.
Consumer acceptability	2	Open tray. Dependent on an additional sealing component.

1. Analysis of packaging solution provider, via publicly available website

Solution 40

Punnet Material	Australia	Recyclable	Compostable	5 Core Criteria	Cost
					$$$

Company background

- A leading supplier of biopolymers. Started as a research initiative investigating alternative materials to make plastics. The research focused on using carbohydrates from organic material to produce bioplastic.
- Headquartered out of XX, company has manufacturing facilities in XX and XX and offices in North America, Europe and the Asia Pacific. In the second half of 2024, a fully integrated biopolymer facility in South East Asia is set to start operation.
- Company was the first company to successfully commercialise a viable polylactic acid in 2002, starting the PLA or bioplastic industry as a more environmentally friendly alternative to large-scale petrochemical-based plastics. The facility will have a capacity of 75,000 tonnes per year, supporting the increasing demand for solution in new markets.

Packaging solutions

- Solution is produced by fermenting sugar in plant material to make lactic acid. Raw organic materials like corn, cassava, sugar cane or beets are can be utilised in this process to extract starch or glucose to be fermented into lactic acid.
- Company leverages its proprietary technology to transform lactic acid into lactides, which through polymerisation forms polylactides, the finished product.
- Company manufactures the raw material. Bioplastic is used by a range of manufacturers in Australia.
- Solution is certified compostable in commercial facilities (EU EN 13432).

Relevance for Australia Mushroom Growers

1. **Multiple application of materials.**
2. **Available in variety of standardisations and is able to be customised into required dimensions. Can be integrated into current process with minimal disruptions.**

Assessment against core criteria

Cost	1	Distributor prices punnet at $0.27 cent.
Sustainability	1	Renewable source. The raw material is certified compostable.
Product quality and safety parameters	2	The product is suitable for fresh produce.
Meets logistic requirements	2	Material can be manufactured to meet logistic requirements.
Consumer acceptability	2	When thermoformed, the punnet is transparent.

1. Analysis of packaging solution provider, via publicly available website

Solution 4

Punnet | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Is an Australian packaging company that specialises in manufacturing sustainable and resealable packaging solutions for fresh and perishable products[1].
- Melbourne-based company offers a range of packaging products, including paperboard trays, plastic containers and foil containers, as well as a range of lids, seals and film.
- Along with sustainability, the company is focused on reducing food waste through the use of high-barrier packaging.

Packaging solutions

- The product is a punnet tray made from bamboo fibres, which is an environmentally sustainable material. The tray can be further enhanced with either a PVC stretch wrap or sealed film.
- The tray is both recyclable and home compostable, thereby promoting eco-friendly practices. Compostable certification aligned to EU industrial standards (EU EN13432).
- The tray's design can be customised with new tooling requirements to meet unique specifications, adding to its versatility. The product is already available in the market, signifying its successful implementation and appeal to consumers.

Relevance for Australia Mushroom Growers

1. **Punnet and lid solution for fresh Australian mushrooms. The material will ensure freshness and quality of the mushroom are not compromised.**
2. **Punnet can be integrated into the existing packaging process.**
3. **Recyclable and compostable solutions.**

Assessment against core criteria

Cost	0	A punnet unit costs $0.40 cents.
Sustainability	2	Renewable source. The raw material is certified compostable. Recyclable in domestic paper bin[1].
Product quality and safety parameters	2	The product is suitable for fresh produce.
Meets logistic requirements	1	Material can be manufactured to meet logistic requirements.
Consumer acceptability	2	Punnet is open top and allows for a transparent lidding or seal.

1. Analysis of packaging solution provider, via publicly available website

Solution 32

Punnet | European Union | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Company is an Irish-based manufacturer of paper-based packaging, which has merged American container organisation, resulting in a fully integrated production system. This integration has empowered the company with complete transparency over the sourcing of raw materials and the capacity to recycle and reuse materials to manufacture fibre-based products[1].
- The company has grown to 48,000 employees in 35 countries with 355 production sites. The product offerings of the organisation are comprised of four lines that work to promote a sustainable circular product life cycle.
- The company's production capabilities include the manufacturing of virgin paper and cardboard materials, which serve as the foundation for its packaging product line. These raw materials are sourced through a combination of recycling processes and forestry operations. Chain or custody certified to FSC® and/or PEFC™[1].

Packaging solutions – Formed Fibre

- Boasts a fully renewable, recyclable, and biodegradable construction.
- Prior to the launch, the company conducted extensive research, which demonstrated a strong consumer preference for products that offer both transparency and sustainability.
- The company plans to capitalise on the success of the existing campaign by furthering its research and development efforts towards creating durable, hygienic, and highly visible fresh produce packaging options that align with the company's commitment to sustainability and provide consumers with an environmentally conscious choice.

Relevance for Australia Mushroom Growers

1. **Punnet and lid solution for fresh Australian mushrooms.**
2. **Punnet can be integrated into the existing packaging process.**
3. **Recyclable and compostable solutions.**

Assessment against core criteria

Cost	N/A	Cost are quoted on an orders or contract basis. Similar product are priced at $0.27 per unit
Sustainability	1	Renewable source. Recyclable in domestic paper bin[1].
Product quality and safety parameters	2	The product is suitable for fresh produce.
Meets logistic requirements	2	Material can be manufactured to meet logistic requirements
Consumer acceptability	2	Punnet is open top and allows for a transparent lidding or seal

1. Analysis of packaging solution provider, via publicly available website

APPENDIX 1.4: Short-list of packaging solutions (punnet and lid)

Solution 18

Punnet/Lid | India | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Based out of India, the company is a sustainable packaging organisation that is dedicated to environmentally responsible manufacturing[1].
- The company has developed a unique system for producing their material that utilises a patented system that results in significant CO2 reduction and a sustainable raw material supply.
- The manufacturing process requires no heat input, which reduces CO_2 emissions by up to 95% compared to the manufacture of similar materials.
- Commenced manufacturing in India following the Indian government's decision to ban single-use plastics and has been in operation for 15 years.
- Company currently produces products for India and the United Kingdom.

Packaging solutions

- Solution is fully compostable, provides a water-tight barrier and is FDA approved as of March 3, 2023.
- Packaging solution features a V-shaped fluted structure known as V-Strong Flute that is integrated into their material. This fluted structure provides increased strength and rigidity to packaging and built-in hygiene advantages that can reduce the risk of person-to-person transmission.
- Provides fresh fruit boxes which include boxes for mushrooms to a large supermarket in Bangalore India.

Solutions available

Offering 1

- 160X160X75mm

Offering 2

- 180X140X45mm

Relevance for Australia Mushroom Growers

1. **Punnet and lid solution for fresh Australian mushrooms.**
2. **Product will require a new product packaging process as the current shrink wrap is not required**
3. **Recyclable and compostable solutions, with a PLA transparent viewing window. Product has no transferable certifications if introduced to the Australian market.**

Assessment against core criteria

Cost	1	A solution unit costs $ 0.27 cents.
Sustainability	2	Renewable source, and raw materials are fully compostable, biodegradable & recyclable.
Product quality and safety parameters	2	The product is suitable for fresh produce. The product is resealable and breathable.
Meets logistic requirements	1	May not be suitable for mushroom transport as the solution does not allow for a secure pack, compared to the current solution.
Consumer acceptability	2	A transparent window on the lid allows the product to be viewed.

1. Analysis of packaging solution provider, via publicly available website

Solution 39

Punnet/Lid | Australia | Recyclable | Compostable | 5 Core Criteria | Cost

Company background

- Listed on the NYSE and headquartered in America, Company is a global leader in fibre-based solutions for a wide variety of packaging needs.
- The company prioritises the cultivation of raw materials with a continuous replanting strategy that emphasises end-of-life outcomes in the production process.
- The core strategy of the company entails the development of alternative materials that best align with their product model, particularly with regards to reducing the use of plastic.

Packaging solutions – Formed Fibre

- The company has recently launched a cutting-edge fresh food packaging option which comprises a fibre-based punnet tray. The product is a fiber-based punnet tray.
- If a PLA or bioplastic lid is applied, the product is completely recyclable.
- Currently partnered with a UK mushroom producer.
- Supply custom packaging solutions.

Relevance for Australia Mushroom Growers

1. **Have an existing mushroom-specific packaging solution.**
2. **Utilises a top heat seal foil to secure the produce in the punnet shortening required packaging time.**
3. **Whole cartons can be printed on allowing for a large proportion of product marketing.**

Assessment against core criteria

Cost	NA	Cost are quoted on an orders or contract basis. Similar product are priced at $0.27 per unit.
Sustainability	1	Sourced form renewable tree fibres or recycled fibres that can all be recycled at end of life.
Product quality and safety parameters	2	The product is suitable for fresh produce. Complimented by flexible seal.
Meets logistic requirements	2	Durable, scalable and does not impede ease of handling. Implementation would require process alterations.
Consumer acceptability	2	Open tray. Dependent on heat seal option.

1. Analysis of packaging solution provider, via publicly available website

APPENDIX 2: HIGH-LEVEL COST BENEFIT ANALAYSIS

APPENDIX 2.1: METHODOLOGY AND APPROACH

Detailed methodology and approach

High-level cost benefit analysis: overview of approach and objectives

A high-level cost benefit analysis was conducted to understand the suitability of alternative packaging formats for the Australian mushroom industry and its participants. To do so, the two prioritised packaging solutions identified through the global scan were compared with an industry reference standard. Additional analysis was conducted to understand the influence of scale and closure method on the costs of adoption.

High-level approach

1. **Determine scope, parameters and assumptions**
2. **Identify relevant cost and benefit buckets**
3. **Collate data points to measure costs, benefits and considerations for growers**
4. **Determine the variability of costs, benefits to growers at different scales (small, medium, large) and with alternative seal solutions**

Objectives and scope

Objective:

- To identify the relevant costs, benefits and considerations of adopting alternative packaging solutions in the mushroom industry.
- The analysis compares the costs and benefits of alternative packaging solutions to an industry reference standard..

Scope:

- Conduct a high-level cost benefit analysis to understand the **suitability of alternative packaging formats for the Australian mushroom industry** and its participants
- To do so, **two prioritised packaging solutions** will be compared with an industry reference standard.
- Further analysis will also seek to understand the cost impact of adopting alternatives to PVC wrap and seal solutions.

Reference standard – PET	**Option 1** – rPET (70%)	**Option 2** – Corrugated cardboard

Identification of cost and benefit categories: cost identification

A range of cost and benefit categories were identified to ensure the high-level cost benefit analysis is relevant growers and considers a breadth of operations, implementation, commercial and strategic considerations of adopting alternative packaging solutions. A summary of these cost categories is provided below.

Description of cost categories included in the high-level cost benefit analysis

Business impact	Category	Category Description	Consideration	Data type	Data points
Cost	Implementation Costs (Capital expenditure)	Upfront costs of adjusting processes and systems to transition to new packaging solutions	Cost of new machinery of equipment for packaging produce	Quantitative (monetisable)	Market price for required machinery and/or equipment
			Cost required to customise packaging solutions. For instance, the cost of a unit design tool for plastic manufacturing.	Quantitative (monetisable)	Cost to customise packaging solution
			The cost of training of change management required to transition to a new packaging format	Qualitative	Description of training required to prepare packhouse staff for change in packaging solution
	Operational costs (Operational expenditure)	Ongoing costs of adjusting to alternative packaging formats	Cost of packaging solution	Quantitative (monetisable)	Cost per unit of 500 gram punnet
			Additional operations or processes associated with alternative packaging solution	Quantitative (non-monetisable)	Additional time required for altered packhouse operations and processes
	Environmental costs	Costs associated with environmental impact of packaging solution	Cost associated with carbon emissions attributed to packaging solution throughout its lifecycle	Quantitative (monetisable)	Carbon emissions (CO_2 equivalents) multiplied by price of Australian carbon credit units (ACCUs)

Identification of cost and benefit categories: benefit identification

A range of cost and benefit categories were identified to ensure the high-level cost benefit analysis is relevant growers and considers a breadth of operations, implementation, commercial and strategic considerations of adopting alternative packaging solutions. A summary of these benefit categories is provided below.

Description of benefit categories included in the high-level cost benefit analysis

Business impact	Category	Category Description	Consideration	Data type	Data points
Benefit	Shelf-life and quality of the product	The contribution of packaging solution to quality attributes of mushrooms, such as colour, texture and smell	Additional days of shelf life	Quantitative (non-monetisable)	Number of days increase/decrease product stays within acceptable quality parameters
			Contribution to the colour, texture and smell of product	Qualitative	Description of mushroom product qualities
			Ability to maintain ventilation, temperature and moisture of packaging environment	Qualitative	Description of material qualities of punnet solution
	Robustness	Robustness of packaging solution in the supply chain	Failure rate of packaging solution	Quantitative (non-monetisable)	Number of punnet trays expected to lose integrity throughout mushroom supply chain
			Structural integrity of packaging solution	Qualitative	Description of material strength throughout mushroom supply chain
	Consumer preference	The preference for packaging by end consumer	Consumer preference for packaging solution	Quantitative (non-monetisable)	Consumer preference or willingness to pay for identified packaging solution

Identification of cost and benefit categories: benefit identification (cont.)

A range of cost and benefit categories were identified to ensure the high-level cost benefit analysis is relevant growers and considers a breadth of operations, implementation, commercial and strategic considerations of adopting alternative packaging solutions. A summary of these benefit categories is provided below.

Description of benefit categories included in the high-level cost benefit analysis

Business impact	Category	Category Description	Consideration	Data type	Data points
Benefit	Sustainability credentials	Assessment of packaging sustainability	Assessment against 2025 National Packaging Targets	Qualitative	Ability to comply with 2025 National Packaging Targets
			Qualitative description of sustainability credentials (i.e., environmental impacts)	Qualitative	Description of environmental footprint

High-level cost benefit analysis: collation of data points

A series of data was gathered through desktop analysis and stakeholder consultation to inform the high-level cost benefit analysis. The data sources used as inputs in the analysis are described below.

Data points utilised as inputs to the high-level cost benefit analysis

Model component	Consideration	Description	Data source	Rationale (if required)
Option 1	Weight PET of punnet tray	The estimated weight of packaging solution is 27.6g.	Information shared by packaging solution provider.	The weight of the PET punnet tray was used to estimate lifecycle carbon emissions.
	Solution price	Cost of packaging solution per unit (500g punnet tray). Price identified as $0.1 per punnet tray.	Information shared by packaging solution provider.	
	Embodied carbon of packaging solution	The estimated lifecycle carbon emissions per weight of material for packaging solution. Estimated to be 2.23 kg of CO_2 per kg of material.	Please see reference list below; number 1.	
Option 2	Weight of rPET punnet tray	The estimated weight of packaging solution is 31.0g.	Information shared by packaging solution provider.	The weight of the rPET punnet tray was used to estimate lifecycle carbon emissions.
	Solution price	Cost of packaging solution per unit (500g punnet tray). Price identified as $0.15 per punnet tray.	Information shared by packaging solution provider.	
	Embodied carbon of packaging solution	The estimated lifecycle carbon emissions per weight of material for packaging solution. Estimated to be 2.23 kg of CO_2 per kg of material.	Please see reference list below; number 2.	

1. Packaging and recycling. University of Cambridge (n.d.). Retrieved March 27, 2023, from http://www-materials.eng.cam.ac.uk/energyforschools/downloads/D-PackagingRecycling.pdf.
2. Virgin vs. Recycled Plastic Life Cycle Assessment, The Association of Plastic Recyclers. (2020). Retrieved March 27, 2023, from https://plasticsrecycling.org/images/library/APR-Recycled-vs-Virgin-May2020.pdf

High-level cost benefit analysis: collation of data points (cont.)

A series of data was gathered through desktop analysis and stakeholder consultation to inform the high-level cost benefit analysis. The data sources used as inputs in the analysis are described below.

Data points utilised as inputs to the high-level cost benefit analysis

Model component	Consideration	Description	Data source	Rationale (if required)
Option 3	Weight PET of punnet tray	The estimated weight of packaging solution is 24g.	Information shared by packaging solution provider.	The weight of the PET punnet tray was used to estimate lifecycle carbon emissions.[1]
	Solution price	Cost of packaging solution per unit (500g punnet tray). Price identified as $0.21 per punnet tray.	Information shared by packaging solution provider.	
	Embodied carbon of packaging solution	The estimated lifecycle carbon emissions per weight of material for packaging solution. Estimated to be 1.14 kg of CO_2 per kg of material.	Please see reference list below; number 1.	
Assumptions	Cost of Australian Carbon Credit Units (ACCUs)	The price of ACCUs as at 27 March 2023 ($36.5 per tonne).	Please see reference list below; number 3.	The price of AACUs was used to estimate the cost associated to the emissions created by a packaging solution throughout its lifecycle.[2]
	Size of punnet tray	The size of punnet tray assumed for the base case and both prioritised options was 500 grams.	PAG input.	
	Mushroom variety	The variety of mushroom assumed for analysis was whole white button mushrooms (Agaricus bisporous).	PAG input.	
	Grower production volumes	Grower production volumes were used in a scenario analysis to identify if any variability of cost exists between production sizes. Production volumes identified for the analysis were 20 tonnes per week for a small producer, 50 tonne p/w for medium and 120 tonnes p/w for large.	PAG input.	

1. Carbon footprint of cardboard. Consumer Ecology (n.d.). Retrieved March 27, 2023, from https://consumerecology.com/carbon-footprint-of-a-cardboard-box/#:~:text=A%20common%20e%2Dcommerce%20box,the%20walls%20of%20the%20box.
2. The estimated cost of emissions was calculated by multiplying the weight of the packaging solution by the embodied carbon score. This represents the estimated emissions (CO2 equivalents) over the lifecycle of the product. The estimated emissions were then multiplied by the price of an Australian Carbon Credit Unit (ACCU) as at 27 March 2023 ($36.50) to represent for the cost of carbon emissions related to the packaging solution.
3. Australian energy and environmental market update March 2023, Core Markets. (2023). Retrieved 27 March, 2023, from https://coremarkets.co/insights/australian-energy-environmental-market-update-march-2023.

APPENDIX 2.2: COST BENEFIT ANALAYSIS

Results and findings

Cost summary: Base Case – PET punnet tray

Estimated costs incurred by growers for the adoption and implementation of PET punnet trays.

Cost bucket	Modelled scenarios		
	1 – Large producer	2 – Medium producer	3 – Small producer
Cost of packaging format – PET punnet tray	$6,240,000	$2,600,000	$260,000
Cost of estimated lifecycle carbon emissions from packaging solution	$140,182	$58,409	$5,841
Capital expenditure associated with new machinery or equipment for packhouse operations[1]	$0	$0	$0
Operational expenditure associated with adjusted or additional operations and processes[1]	$0	$0	$0
Total costs	**$6,380,182**	**$2,658,409**	**$265,841**

Other costs and benefits identified but not modelled for PET punnet trays

Category	Description	Source
Adherence to APCO targets	Under current targets it is expected that packaging solutions are required to have an average of 50% recycled content. PET has the potential to be recycled to rPET. PET packaging solutions with less than 50% recycled materials are non-compliant with the 2025 National Packaging Targets.	2
Quality and shelf life	PET trays are known to preserve the shelf life of mushrooms for 5-7 days post-picking. PET packaging solutions demonstrate low levels of moisture absorption and therefore do not create substantial moisture build up in the packaging environment and create adverse changes in the colour, texture and smell attributes of mushrooms.	3-4
Robustness of packaging	PET is a high strength material with high levels of rigidity and hardness. These product qualities mean that punnet designs maintain structural integrity throughout the product lifecycle, including stretch wrap processes. As PET demonstrates low moisture absorption it is a suitable material for the high moisture environment of mushroom packhouses and retail fresh produce sections.	4-5
Consumer preference	Transparency of punnet tray and cling film combination allows consumers to assess quality of the product. Consumers may demonstrate less preference for packaging format due to perceptions of environmental impacts of plastics.	6

1. Capital and operational expenditure will not apply to the base case (PET) as it is assumed growers are currently using this packaging format. Costs associated with changing processes and operations will therefore not apply.
2. National Packaging Targets 2025, Australian Packaging Covenant Organisation. (2023). Retrieved March 27, 2023, from https://apco.org.au/national-packaging-targets
3. Stakeholder consultation findings.
4. PET, Ensinger Plastics. (2023). Retrieved March 27, 2023, from https://www.ensingerplastics.com/en/shapes/engineering-plastics/pet-polyester
5. Stakeholder consultation findings.
6. Consumers prefer paper packaging to plastic, Environmental Leader. (2021). Retrieved March 27, 2023, from https://www.environmentalleader.com/2021/01/survey-finds-consumers-show-strong-preference-for-paper-packaging-over-plastic/.

Result summary: Option 1 – rPET punnet tray

Estimated costs incurred by growers for the adoption and implementation of rPET punnet trays.

Cost bucket	Modelled scenarios		
	1 – Large producer	2 – Medium producer	3 – Small producer
Cost of packaging format – PET punnet tray	$9,360,000	$3,900,000	$390,000
Cost of estimated lifecycle carbon emissions from packaging solution	$48,012	$20,005	$2,000
Capital expenditure associated with new machinery or equipment for packhouse operations[1]	$0	$0	$0
Operational expenditure associated with adjusted or additional operations and processes[1]	$0	$0	$0
Total costs	**$9,408,012**	**$3,920,005**	**$392,000**

Other costs and benefits identified but not modelled for rPET punnet trays

Category	Description	Source
Adherence to APCO targets	Under current targets it is expected that packaging solutions are required to have an average of 50% recycled content. rPET punnet trays are compliant with the 2025 National Packaging Targets assuming the packaging solution obtains 50% or more of recycled PET materials.	2
Quality and shelf life	rPET trays will obtain the same material qualities as PET. As a result, the quality and shelf life attributes of rPET punnets are expected to preserve the shelf life of mushrooms for 5-7 days and not excessively contribute to adverse quality outcomes of the product.	3-4
Robustness of packaging	Like PET, rPET is a high strength material with high levels of rigidity and hardness. rPET will also maintain structural integrity throughout the supply chain and demonstrates suitable qualities for mushrooms, such as low moisture absorption.	4-5
Consumer preference	Transparency of punnet tray and cling film combination allows consumers to assess quality of the product. Additionally, consumers demonstrate increased preference for recycled packaging solutions.	6

1. Desktop analysis and stakeholder consultation identified that transitioning to a rPET punnet tray will result in no changes to packhouse operations and processes. Please refer to slide 98 for more information.
2. National Packaging Targets 2025, Australian Packaging Covenant Organisation. (2023). Retrieved March 27, 2023, from https://apco.org.au/national-packaging-targets
3. Stakeholder consultation findings.
4. PET, Ensinger Plastics. (2023). Retrieved March 27, 2023, from https://www.ensingerplastics.com/en/shapes/engineering-plastics/pet-polyester
5. Stakeholder consultation findings.
6. Consumer preference for recycled plastic, Ruokamo, Raisanen and Kauppi. (2022). Retrieved March 27, 2023, from https://www.sciencedirect.com/science/article/pii/S0959652622042925#:~:text=The%20results%20reveal%20that%2093,decisions%20of%2086%25%20of%20consumers.

Result summary: Option 2 – Corrugated Cardboard

Estimated costs incurred by growers for the adoption and implementation of corrugated cardboard punnet trays.

Cost bucket	Modelled scenarios		
	1 – Large producer	2 – Medium producer	3 – Small producer
Cost of packaging format – PET punnet tray	$13,104,000	$5,460,000	$546,000
Cost of estimated lifecycle carbon emissions from packaging solution	$62,315	$25,965	$2,596
Capital expenditure associated with new machinery or equipment for packhouse operations[1]	$0	$0	$0
Operational expenditure associated with adjusted or additional operations and processes[1]	$0	$0	$0
Total costs	**$13,166,315**	**$5,485,965**	**$548,596**

Other costs and benefits identified but not modelled for corrugated cardboard punnet trays

Category	Description	Source
Adherence to APCO targets	Under the 2025 National Packaging Targets it is expected that 100% of packaging materials are reusable, recyclable or compostable. Corrugated cardboard is readily recyclable or compostable and recyclable.	2
Quality and shelf life	Corrugated cardboard packaging demonstrates moderate to high moisture absorption. This removes moisture content from the mushroom product, leading to increased sliminess and blemishing.	3-4
Robustness of packaging	Corrugated cardboard packaging demonstrates moderate strength, rigidity and ability to maintain product shape and format. However, when compared to PET and rPET, corrugated cardboard is less strong and rigid. Corrugated cardboard also demonstrates higher moisture absorption, with moisture compromising the integrity of the packaging material. This leads to a lower suitability for the high moisture environment of a mushroom supply chain.	3
Consumer preference	The combination of cardboard punnet tray and cling film impedes the visual appearance of the product to the consumer. The consumer will not be able to assess the visual quality of the product prior to purchasing. Consumers do however demonstrate a preference for cardboard due to its perceived sustainability credentials.	5

1. Desktop analysis and stakeholder consultation identified that transitioning to a corrugated cardboard punnet tray will result in no changes to packhouse operations and processes. Please refer to slide 98 for more information.
2. National Packaging Targets 2025, Australian Packaging Covenant Organisation. (2023). Retrieved March 27, 2023, from https://apco.org.au/national-packaging-targets
3. Cardboard: an overview, Science Direct. (n.d.). Retrieved March 27, 2023, from https://www.sciencedirect.com/topics/engineering/cardboard.
4. Stakeholder consultation findings.
5. Stakeholder consultation findings.

Several cost and benefit categories were identified but not reviewed quantitatively

A range of cost and benefit categories that are relevant in the packaging of mushrooms were identified during the initial scoping of the high-level cost benefit analysis. Several of these cost and benefit categories were not modelled in the quantitative analysis. A summary of these cost and benefit are summarised below.

Cost and benefit categories not modelled in the high-level analysis

Category	Description	Rationale for excluding from model
Implementation costs (capital expenditure)	The upfront costs of adjusting processes and systems to transition to new packaging solutions. This includes the cost of new machinery of equipment for packaging produce and any costs associated with training or change management.	Desktop analysis and stakeholder consultation identified that transition to either rPET or corrugated cardboard does not result in substantial changes to packhouse operations or processes. The same picking and packing processes will remain the same across the Base Case, Option 1 and Option 2. As a result, there is no capital expenditure required to upgrade equipment or machinery, or invest in training of staff, to facilitate a transition to these alternative packaging types.
	Costs required to customise packaging solution.	The customisation costs of the prioritised packaging solutions (rPET and corrugated cardboard) were identified as commercially sensitive information. The packaging solution providers were unable to share detailed pricing schedules for customisation as this information is regarded as private and confidence. Consultation with the packaging solutions providers of the two prioritised options did indicate that pricing for customisation is highly variable and influenced by the size and frequency of order. Stakeholder consultation also indicated that pricing for customisation of rPET packaging is likely to be high, this is attributed to the design costs of injection moulds used during plastic manufacturing.
Operational costs (operational expenditure)	Ongoing costs of adjusting to alternative packaging formats. This includes the cost of additional operations or processes associated with alternative packaging solutions.	As outlined above, it is expected that there is no substantial change in packhouse operations across the three proposed options (Base Case, Option 1 and Option 2). As a result, there are no applicable ongoing costs of adjusting alternative packaging formats.

Several cost and benefit categories were identified but not reviewed quantitatively

A range of cost and benefit categories that are relevant in the packaging of mushrooms were identified during the initial scoping of the high-level cost benefit analysis. Several of these cost and benefit categories were not modelled in the quantitative analysis. A summary of these cost and benefit are summarised below.

Cost and benefit categories not modelled in the high-level analysis

Category	Description	Rationale for excluding from model
Operational costs (operational expenditure)	Transportation costs. These are the costs associated with the transport of packaging materials from manufacturer to grower.	Consultation with packaging solution providers indicated that transport costs are highly variable and depend on factors such as order size and the distance between manufacturer and grower. Industry stakeholders and packaging manufacturers suggested scale is preferential, with larger order sizes moving through the supply chain more efficiently and cost effectively. Consultations indicated that transport costs for alternative packaging solutions, such as rPET and cardboard, are likely to be higher as there are fewer suppliers and distributors resulting in greater distances between suppliers and buyers. Precise transport costs were identified as commercial in confidence. These findings suggest that transportation is likely to disproportionately affect small to moderate growers as they do not have the ability to leverage scale to reduce the cost associated with logistics and transportation.

A supplementary analysis demonstrated that PO bioplastics present significant increases to grower operational costs

A supplementary analysis was performed to understand the cost impact of adopting alternative closure solutions. To do so, the cost of a PVC film was compared with a PO film. Results demonstrated that the adoption of PO bioplastics will result in 200 percent increase in expenditure on wrap and seal solutions for growers at current market prices for PO cling films.

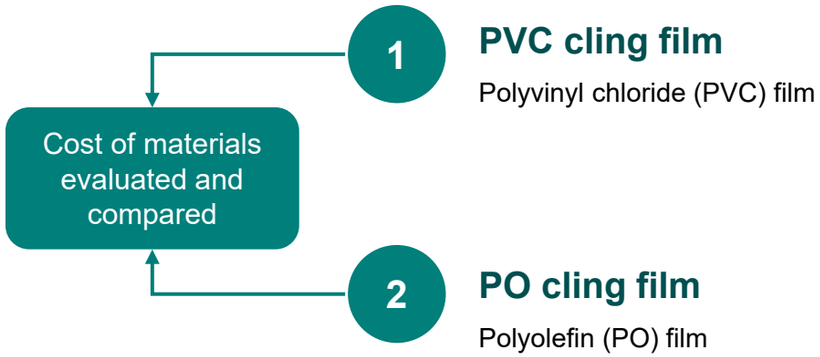
Approach and methodology

Objective:

- A supplementary analysis was performed to understand the cost considerations of adopting alternative packaging seal solutions to PVC cling film.

Scope:

- Conduct a high-level cost analysis to identify the difference of cost between traditional PVC cling film and PO cling film.
- The analysis was structured to highlight the difference in cost between each option across a small (20 tonne per week), medium (50 tonne per week) and large (120 tonne per week) grower.



Assumptions and data points

Assumptions and data points:

- Costs were modelled assuming a growers consumption of film wrap across a single year.
- The consumption of cling film per punnet was assumed as 30cm^2.[1]
- The cost of PVC wrap was estimated to be $0.05 per m^2 of film. This was taken as an average market price of PVC wrap.[1]
- The cost of PO wrap was estimated to be $0.15 per m^2. This was taken as the market price of PO wrap.[2]

Results

Packaging solution	Large producer	Medium producer	Small producer
PVC film	$187,200	$78,000	$7,800
PO film	$561,600	$234,000	$23,400

1. Validated through stakeholder consultation.
2. Analysis of PVC wrap solution provider, via publicly available website.
3. Analysis of PO wrap solution provider, via publicly available website.

APPENDIX 3: STAKEHOLDER ENGAGEMENT APPROACH AND FINDINGS

Stakeholders from all stages of the Mushroom and Packaging industry supply chain were consulted for insights and validation

To ensure the relevance of research, insights, and recommendations for stakeholders in mushroom packaging, industry stakeholders from all stages of the supply chain were engaged for their insights and to validate research methodology and outcomes. Excluded from this list are the phone calls made during the global market scan to obtain pricing and product specification information.

Industry representation	Consultation Date	Topic of Focus
Manufacturer	16/02/2023	- Gaps and problem areas with the adoption on new packaging technology
Mushroom Producer	28/02/2023	- Contribution to the development of criteria for the Global Scan of packaging option - Including pricing, process validation, best practice and gaps insight
Industry	06/03/2023	- Treatment of waste packaging material by consumer. Packaging option end-of-life
Manufacturer and Distributor	14/03/2023	- Focus on option under review. - Insight on fibre based bagasse option. Cited a prior case study on mushrooms
Manufacturer and Distributor	08/03/2023	- Focus on option under review - Insight on requirement on moisture management related to mushrooms
Manufacturer and Distributor	23/03/2023	- Focus on option under review - Insight on rPET and process of adoption of new packaging
Distributor	06/03/2023	- Provided insight on cane bagasse moisture management
Industry	21/03/2023	- Focus on fit for purpose packaging - Insights on the food waste contributor to GHG and benefit of packaging
Manufacturer	23/03/2023	- Focus on PET and rPET product current in use with mushroom industry - Understanding specification requirement in the industry
Mushroom Retailer	29/03/2023	- Provided insight into retailer perspectives on alternative packaging solutions in the mushroom industry
Mushroom Producer	27/02/2023	- Provided validation to the area packaging is required to perform throughout the production process

The project received input and challenge from a project advisory group comprised of industry representatives, retailers and packaging providers

The Project Advisory Group participated in a series of three workshops aimed at evaluating sustainable packaging options. The initial workshop involved the validation of assessment criteria used to assess options from a global scan. The second workshop focused on the testing of sustainable packaging options identified from the global scan, with the aim of providing guidance on which option to subject to further analysis. The third workshop tested the approach and methodology used to conduct a high-level cost benefit analysis of the two priority options.

Organisation	Industry	Workshop 1 06/03/2023	Workshop 09/03/2023	Workshop 3 27/03/2023
White Prince Mushrooms	Grower	✔	✔	✔
AMGA	Industry Body	✔	✔	
Bulla Farms	Grower			✔
Costa Group	Grower	✔	✔	✔
AIP	Packaging Industry Association	✔	✔	✔
Coles	Retailer		✔	✔
Harris Farm	Retailer	✔	✔	
ALDI	Retailer	✔	✔	

Stakeholder engagement was utilised to validate research findings and provide insight to sustainable alternatives to existing packaging solutions

Packaging producers highlighted the need to reach the Australian Packaging Covenant 2025 targets and the process involved while highlighting barriers to adoption with respective packaging options and for mushrooms specifically. Industry bodies shared insights into broader problems of compromising product shelf life in the effort to increase sustainable packaging.

Broader Industry

- A packaging manufacturer stated, in regards to recyclability and sustainability, 'take dependence away from the customer'. Ensure that whichever way the packaging is disposed of, in which every bin, its end-of-life process is either circular or decomposed.
- A large mushroom producer provided validation during the development of the criteria used to assess suitable packaging options. Insight included the procurement, pricing structure and key attributes required for mushroom packaging.
- An independent research institution stated that packaging of fresh produce should be fit for purpose at its core. Food waste is a major contributing factor to unsustainable environmental practices regarding waste/disposal of carbon rich materials.

Sustainability and End of Life

- Biodegradability and composability are completely dependent on consumer behaviour. Households without composability options are unable to provide end-of-life product sustainability assurance.
- Life-cycle assessments are a useful insight into the transparency of sustainability. More need to be done to ensure the legitimacy and objectivity of the assessment.

Cane Pulp (bagasse) and fibre based products

- Broad explanation of different studies and case studies for the mismanagement of moisture, specific to mushrooms.
- Retailers of bagasse punnet stressed that bagasse absorbed moisture from the mushroom. A manufacturer cited prior case studies completed in the industry

PET and rPET

- Enhanced transparency is imperative regarding each stage of the rPET life cycle. A comprehensive life cycle assessment should be conducted to holistically evaluate the environmental impact of individual businesses (plastic manufacturers) production and disposal processes.
- The process for the transition or adoption of a new packaging punnet requires additional costs. These include negotiating ordering logistics and amounts, and tool cost for the new thermomoulding process. These are actioned on a per producer or customer level with the plastic punnet manufacturing.
- Plastic packaging, both PET and rPET, provided insights of levels or recycled inputs within their material and stressed the importance of credible transparency. This was further reiterated with the numerous mentioning of ACCC's focused efforts tackling greenwashing[1].
- There is a limited regulatory stipulation on the definition of recycling within the rPET. Further information is required on the amount of post consumer recycled plastic input to the manufacturing rPET.

1. ACCC blasts worst greenwashing sectors, with cosmetics, clothing, and food and drink sectors having the highest proportion of companies making "concerning" statements about their green credentials (afr.com)

MU22008: Review and evaluation of mushroom packaging options

May 2023

Hort Innovation
Strategic levy investment

MUSHROOM FUND