

Final Report

Review and evaluation of nashi packaging

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Public summary

The global movement toward sustainable packaging has been identified as a significant challenge and opportunity for the Australian Nashi industry. Consumers, retailers, and regulatory bodies are increasingly demanding environmentally friendly packaging solutions that reduce waste, minimise carbon footprint, and enhance product quality and safety. To remain competitive, maintain key market access and meet evolving customer expectations, it is crucial for the Nashi industry to embrace sustainable packaging practices.

In Australia, there is an increasing number of actions and public commitments to achieve sustainability goals and solve packaging challenges. The evidence is seen via the 2025 National Packaging Targets managed by the Australian Packaging Covenant Organisation (APCO).

The objective of this short project was to identify and evaluate alternative sustainable product packaging options for the Australian Nashi industry to support long term market access, meeting the 2025 National Packaging Targets, alongside the requirements of the main domestic retailers, and focusing mainly on the identification of substitutes to the plastic sock (sleeve) currently in use to protect Nashi in their transit to the consumers.

We followed a systematic methodology to gather insights from desktop research, international networks, and stakeholder feedback. This allowed us to understand the sustainable packaging products and practices for produce globally in use, and determine which could be a solution for achieving a solid protection of a very sensitive fruit (Nashi), as well as meeting the sustainable credentials for compliance within Australia.

The identified options were shared and discussed with the Nashi industry through a draft report, presentation, and a virtual session to select the two that would best meet their strategic goals. The chosen two were the compostable sock as a direct swap with the existing one, and a box with a moulded press paper tray that could potentially protect the fruit whilst eliminating the use of the sock. The first one fits into the compostable targets and the second one is a fully recyclable solution that is collected and processed through existing paper and cardboard streams.

These two options were assessed in costs and benefits and compared to the reference packaging used today. The results show that, although both represent a slightly or significant saving in costs, the difference in benefits favour the adoption of a compostable sock for the current time, until a proper performance test can be done to the paper tray solution to determine its ability to preserve Nashi quality and integrity.

These alternatives can be easily adopted by industry, representing advantages in sustainability credentials and meeting compliance requirements. The challenges remain within the remit of Australian readiness in collection schemes and processing of compostable materials, as well as the potential of new paper formats (such as moulded pressed trays) to perform effectively in protecting such a sensitive fruit as is Nashi.

Regardless of the final decision industry takes, this review has provided knowledge and tools that will continue to evolve in time and balance the costs and benefits to allow them to become part of the circular economy solution, and to achieve their strategic priorities.

Keywords

Nashi, packaging, sustainable, circular economy, plastics, cardboard, National Packaging Targets, APCO

Introduction

The global movement toward sustainable packaging has been identified as a significant challenge and opportunity for the Australian Nashi industry. Consumers, retailers, and regulatory bodies are increasingly demanding environmentally friendly packaging solutions that reduce waste, minimise carbon footprint, and enhance product quality and safety. To remain competitive, maintain key market access and meet evolving customer expectations, it is crucial for the Nashi industry to embrace sustainable packaging practices.

As outlined in the Nashi strategic priorities, one of their key objectives is to improve supply, productivity, and sustainability by identifying better and more sustainable packaging options. This will allow industry to maintain or improve their profitability and the quality of their products.

Nashi are sensitive fruits, requiring very careful handling and transport to avoid damage (scuffing and bruising) which creates a cost as well as a sustainability threat due to the 'sock' used to protect it, currently made of expanded polyethylene (EPE). This material offers exceptional cushioning and smooth appearance at a low cost, but unfortunately, it is not recyclable in Australia at the present date*. Therefore, one of the key issues to overcome is to find an alternative to the use of plastic socks that can provide protection as well as meeting the compliance and environmental demands by customers and consumers alike.

The recommendations in this report take into consideration the Australian Packaging Covenant Organisation (APCO) guidelines for recyclability and targets for 2025 as well as the specific sustainability requirements set by major retailers Coles and Woolworths.

APCO has set ambitious targets for the Australian packaging industry to achieve by 2025. These targets include a 20% reduction in packaging waste going to landfill, a 25% increase in the average recycled content of packaging, and a 70% increase in the use of reusable or recyclable packaging. Compliance with these targets is an essential step toward building a sustainable and resilient industry.

Major retailers Coles and Woolworths have recognised the importance of sustainability and have set their own targets for packaging sustainability. These retailers are actively seeking suppliers who align with their sustainability goals, which often involve reducing plastic packaging, increasing the use of recyclable materials, and adopting innovative packaging solutions that minimise environmental impact. Nashi growers must consider these retailer requirements to secure long-term partnerships and maintain their market presence.

The elimination of plastics and the adoption of sustainable packaging options pose both challenges and opportunities for the Nashi industry. While transitioning away from traditional packaging materials may involve higher upfront costs and process adjustments, embracing sustainable packaging can yield numerous benefits. Sustainable packaging solutions can enhance product shelf appeal, extend shelf life, reduce food waste, and contribute to a positive brand image. By addressing the industry's challenges proactively, Nashi growers can position themselves as leaders in sustainability and gain a competitive advantage in the market.

This report will provide an overview of the current state of packaging practices in the Nashi industry, highlight the global challenges and trends in sustainable packaging, and present a range of sustainable packaging options suitable for the industry's specific requirements. The report will also address strategies to optimise packaging efficiency, enhance fruit quality, and navigate the compliance requirements of APCO and major retailers.

By implementing sustainable packaging solutions that align with APCO targets and retailer requirements, the Nashi industry can foster profitability, improve productivity, and contribute to a more sustainable future.

() It complies with the APCO guidelines: Designing for Recyclability – Household Consumer Soft Plastics. With the demise of the RedCycle soft plastics collection scheme there is now no national scheme for soft plastics collection in Australia. Although in theory the "socks" are recyclable, in reality most will not get recycled until a national soft plastics collection scheme is established. It is not recyclable or compostable in Australia at the present date.*

Methodology

Local and global scan:

- 1) **Desktop research:** strategic review of websites, online reports, published Hort Innovation reports, news articles, videos of global produce suppliers of Nashi, Asian pears and other soft fruit produce, retailers or wholesaler distributors, packaging manufacturers, online shops, or marketplaces. We identified existing practices and different types of packaging solutions available or commonly used for Nashi or similar sensitive produce.
- 2) **Interviews and conversations:** We engaged directly with Nashi growers, national retailers, domestic independent grocers, international retailers and wholesalers, local and international packaging experts and manufacturers, quality assessors of produce, APCO and AIP. We gathered the knowledge and understanding of the supply chain, the problem to solve and challenges of Nashi packaging, as well as the requirements and targets for sustainable packaging alternatives, existing options and their benefits and risks.
- 3) **Visits:** We visited two growers: Seeka (Bunbartha, Victoria) and Magarey Orchard (Adelaide Hills, South Australia). We also interacted with various growers of fresh produce at the Hort Connections event.
- 4) **Global store audits/checks:** In-store research performed in Australia, the UK, Singapore, France, the US, and the UAE. Using our international resources, we visited leading retailers with strong reputations in fresh produce to see how their sensitive produce is handled through to end consumers. Additionally, by analysing how fresh produce is retail packed in different markets, we highlighted alternative packaging technologies and solutions.

For added context, various packaging firms were approached for interviews or via email for questions regarding materials, characteristics, and availability, in addition to our team attending key trade shows during the timeframe of the project (Hort Connections, Adelaide & Food Pro, Melbourne).

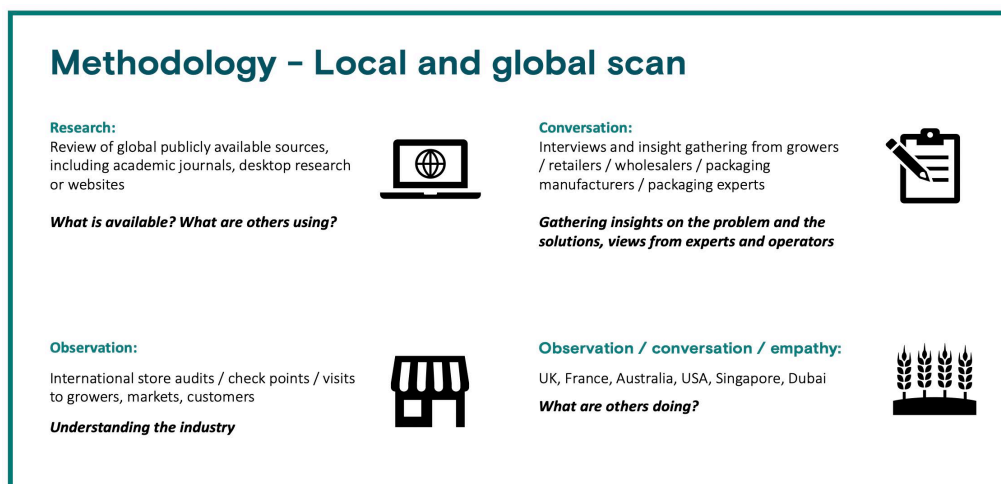


Figure 1 - Mix of methods used in the review.

The suitability of the proposed packaging options were assessed using the following criteria:

- **VIABILITY:** Based on the availability of commercial options and potential suppliers
- **APCO GUIDELINES:** Meeting APCO requirements
- **NATIONAL COLLECTION AND RECYCLING:** Existing ability to deliver on sustainability credentials, based on current schemes in Australia (Australia “readiness” for the option to be adopted)
- **INDICATIVE COST:** Based on known cost data, where available
- **ABILITY TO PROTECT FRUIT:** Qualitative perceived ability to maintain product quality and integrity based on material characteristics
- **ADOPTION COMPLEXITY:** Based on changes needed from existing formats currently in use for packaging
- **CUSTOMISATION FOR NASHI:** How many additional, bespoke developments needed for this package to be fully adopted

From this evaluation, a visual scorecard was provided to key stakeholders and a voting selection process was undertaken through a virtual session, to choose the preferred two that would undergo a further, high-level cost benefit analysis.

High-level cost benefit analysis:

The analysis was conducted to compare the two options to the existing packaging solution in use. Our baseline (reference benchmark) was taken from the current packaging architecture, which uses a cardboard box, a plastic tray, EPE socks for every fruit, and a bubble wrap sheet for some types of boxes. We chose to base our analysis on two highly used packaging structures: 6Kg class 1 and 4 Kg class 2 boxes, with ranging fruit counts of 18 to 35.

Main costs, benefits and other considerations were then identified for each option, in a way that could help industry make an informed decision about their potential adoption.

Costs used were the sum of all packaging components needed for adoption, and a qualitative assessment of the speed of packaging for every option. Key benefits were weighted for their criticality for industry and how they impacted the success factors in review (achieving sustainability whilst protecting fruit quality and integrity). Details are provided in the results section of the report.

Results and discussion

This review identified solutions to current Nashi packaging that fit with the National Packaging Targets for Australia in 2025, some of which would represent additional costs and adoption complexities, but the preferred ones maintain a viable and simplified adoption alternative, as well as potentially decreasing costs slightly or significantly. Further testing and validations are required to confirm these findings, but they offer a roadmap to achieving the strategic priorities related to sustainable packaging.

Given the review took insights from a global market scan and many valuable conversations with key stakeholders, we were also able to further understand the current and changing landscape for Nashi and other produce packaging and displays, as well as capturing some relevant issues from retailers and packaging suppliers.

Relevant key project findings:

- **Netting of Nashi is inconsistent through retailers and geographies:** In Australia, most imported Nashi are displayed with the sock/mesh, commonly from China or South Korea. Their types and formats vary in colour, shape (petal or loose nets) and may also have additional packaging elements such as a strip or a sticker. All are made from EPE or LDPE. Major local retailers expressed that their internal policy was to remove the socks for display, but we saw inconsistencies in the adherence to this policy throughout different stores. International scans, in stores or online, showed marked differences. Some countries showcased excessive use of packaging like Indonesia where they use the socks on every fruit plus an additional plastic wrap on top.
- **Sustainable packaging of produce globally is adapting to new regulations and trends and these are visible in stores:** Countries such as France** had the highest use of reusable crates in store - some made of rigid plastic, some of wood, and a few of cardboard - evidently showing a big emphasis on circularity and reusability. This differs from Australian practices, even within more progressive retailers. The most common solutions to sustainable packaging found in advanced markets (UK, France, and Germany) were various types of moulded fibre and paper-based solutions. The type and combination of packaging and the way fruit is handled varies between retailers. The type of packaging impacts the handling in-store and vice versa. This also has an effect on the fruit and its potential for overhandling and bruising.

***France has new laws on food waste and single-use plastic packaging which has impacted the way fruit is packaged, shipped, and sold. Circularity is increasingly evident. Another important observation is the very limited-to-non-existing use of EPE netting apart from two niche supermarkets and on imported fruit – mangoes.*

- **Packaging suppliers and experts see a growing need for fit for purpose and fit for country solutions:** Consistent views on the need to improve the specialist skills and knowledge in packaging for fresh produce, so that adequate solutions are developed and properly fit for every industry. Another relevant opinion was related to the high disparity in the global regulations that add more complexity, making it challenging to identify the right strategies and materials. Experts are excited about the innovations under development and their promise to deliver cost-effective alternatives in the medium term. Many traditional suppliers are becoming more innovative and active into finding these solutions as new incumbents also bring new materials and options to life. Paper and cardboard-based solutions are in high demand, plant and nature-based materials are becoming more important as a raw material source, which is a growing area of innovative solutions such as seaweed or mushroom roots (mycelium).
- **Retailers have a strong commitment to circularity and national targets but are challenged by Australia's readiness for collection and processing:** Such as the soft plastic schemes and the disparity of available processing solutions for industrial composting across the country. Cross contamination of materials or migration of components into food are also a big risk they face.

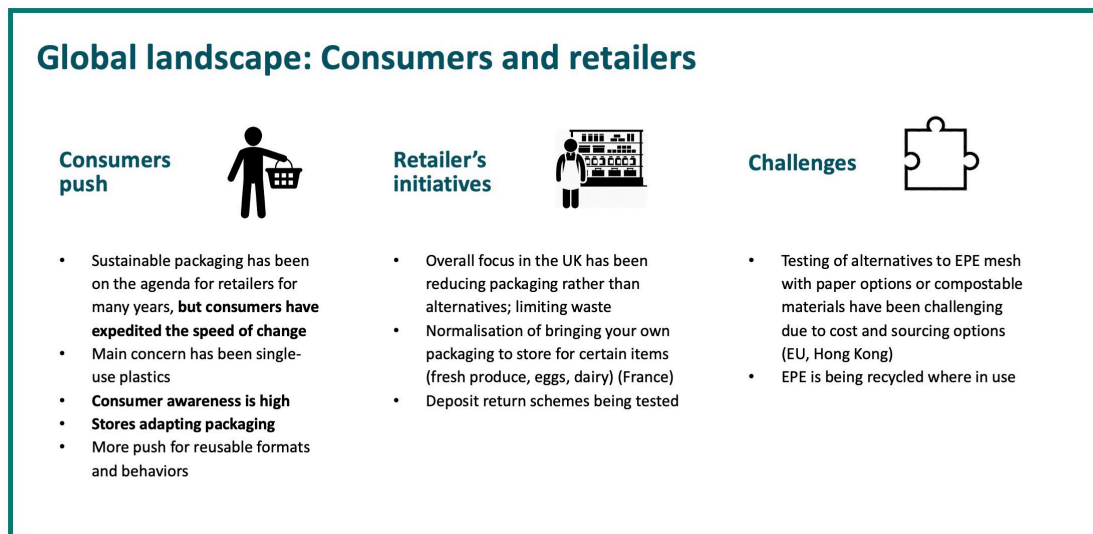


Figure 2 - Summary of key highlights found in the global landscape scan

A detailed summary into the global insights from regulations, is provided in **Appendix 2**

Identification of sustainable packaging alternatives for Nashis:

The starting point or baseline utilised was the existing packaging solution which consists of an expanded (foamed) polyethylene (EPE) sock which is applied to the fruit and conforms tightly to it, isolating and protecting Nashis from the surrounding environment and other fruits. It is of low complexity, commonly used globally and requires manual application. At a low cost it is estimated at 4c per fruit and provides excellent protection and performance for the fruits in transit.

Currently not a suitable sustainable option due to the non-recyclability of soft plastics in Australia. In theory it is recyclable with other polyethylene soft plastics. It conforms to the European CEFLEX – Designing for a Circular Economy Guideline. Used by some growers in Australia, widely used globally and for export/imports.


There are three key stages where solutions can be applied, single fruit, multi-packs or within the bulk case, potentially a combination of each or all, to deliver the desired outcome. We have broken our observations into each area of application for ease.


Identification of options

Single fruit solutions (direct swap): substitute from the existing, single fruit net protection (EPE mesh) for a sustainable version.

Bulk/retail display (non-mesh solutions): Recyclable or compostable trays or box arrangements to fit and potentially protect or cushion the fruits, without the specific netting. Various combinations of materials and packaging architectures are provided.

Multi-pack arrangements made of sustainable materials.








Figure 3 - The three categories of packaging options considered for the current review.

A total of nine solutions were shortlisted as potential feasible and viable alternatives for Nashi packaging. Multipack arrangements were researched and described, but not considered in the final shortlist for analysis. Each of these were assessed by the criteria discussed in the methodology and their characteristics, materials, fit for purpose and considerations were detailed and described for the industry and other key stakeholders. The key criteria used is described in the methodology and considers the commercial viability of the packaging material(s), the fit into APCO guidelines and existing national collection and recycling schemes, their indicative cost, ability to protect the fruit, its adoption complexity or need for customisation. The summary of these options and their ratings can be visualised in Table 1.

		Viability	APCO Guidelines	National Collection & Recycling	Indicative cost	Ability to protect fruit	Adoption complexity	Customisation for Nashi required
	SINGLE FRUIT OPTIONS							
BASELINE	Existing mesh EPE							
	DIRECT SWAP							
OPTION 1	A Paper Version of the Sock							
OPTION 2	Current Sock made from a Compostable Material							
	BULK/DISPLAY OPTIONS							
	NON-SLEEVE SOLUTIONS							
OPTION 3	Box with Internal Grid							
OPTION 4	Box with Internal Grid & Cushioning							
	Cushioning							
OPTION 5	Box with Internal Foam Insert							
	Compostable Foam Insert							
OPTION 6	Box with Internal Corrugated Board Insert							
OPTION 7	Box with Internal Soft Moulded Fibre Insert							
OPTION 8	Box with Internal Bagasse Moulded Insert							
OPTION 9	Box with Internal Moulded Paper Insert							

Table 1- Shortlisted packaging options assessment based on the criteria described in the methodology.

Legend:

HIGH, EXCELLENT, FIT
MEDIUM, MAY REQUIRE STRETCH
CLOSE TO LOW, DISTANCE FROM IDEAL BECOMES BIGGER
LOW, BIG CHALLENGE

These solutions were discussed and shared in detail with industry and key supply chain stakeholders (retailers). They selected two options to analyse further, which were the compostable sock and the cardboard tray with an internal moulded pressed paper insert, as per the table below.





Summary of shortlisted alternatives preferred ones	
DIRECT SWAP	
Option 1	Paper based sock
Option 2 ✓	Compostable sock  
NON-MESH SOLUTIONS	
Option 3	Box with grid (Cardboard)
Option 4	Option 3 with added cushioning
Option 5	Box (Cardboard) with foam insert (compostable or recyclable)
Option 6	Box with corrugated paper insert
Option 7	Box with soft mould insert
Option 8	Box with bagasse insert
Option 9 ✓	Box with pressed moulded paper insert  

Table 2 - Summary of packaging options evaluated and chosen for further analysis.

High-level cost benefit analysis:

The selected options were taken as preferred and with a priority interest. Some baseline assumptions and considerations were taken for the analysis.

Our baseline (reference benchmark) was taken from the current packaging architecture, which uses a cardboard box, a plastic tray, EPE socks for the individual fruit, and a bubble wrap sheet for some types of boxes. We chose to base our analysis on two highly used packaging structures provided by industry: 6Kg Class 1 and 4 Kg class 2 boxes, as these represent the most complex, challenging, and expensive formats, used to preserve the quality of the Nashi in long transits and the ones with high volume customer acceptance. Fruit counts in these formats range from 18 to 35 (for 6 kg boxes) and from 12 to 25 (for 4 Kg boxes)

Main costs, benefits and other considerations were then identified for each option, in a way that could help industry make an informed decision about their potential adoption. Recognising that there are additional costs specific to growers, packers, and retailers across the supply chain, in many cases unique to each business using a direct comparison focused on packaging solutions, enabled us to produce more meaningful data to support the industry.

A few considerations were taken based on conversations with industry throughout the project:

1. **COSTS:**

- The main costs of the packaging solution(s) are the costs of packaging components and the speed of labour.
- **Figure 4 (below)** helps understand the packaging components that add to the packaging cost in every option. The speed of labour would be reflected in the complexity and number of the various components. Therefore, it is assumed that simpler solutions (less layers of packaging would be faster, and similar to identical solutions (direct swap of one sock to another) would lead to similar productivity in the pack room.

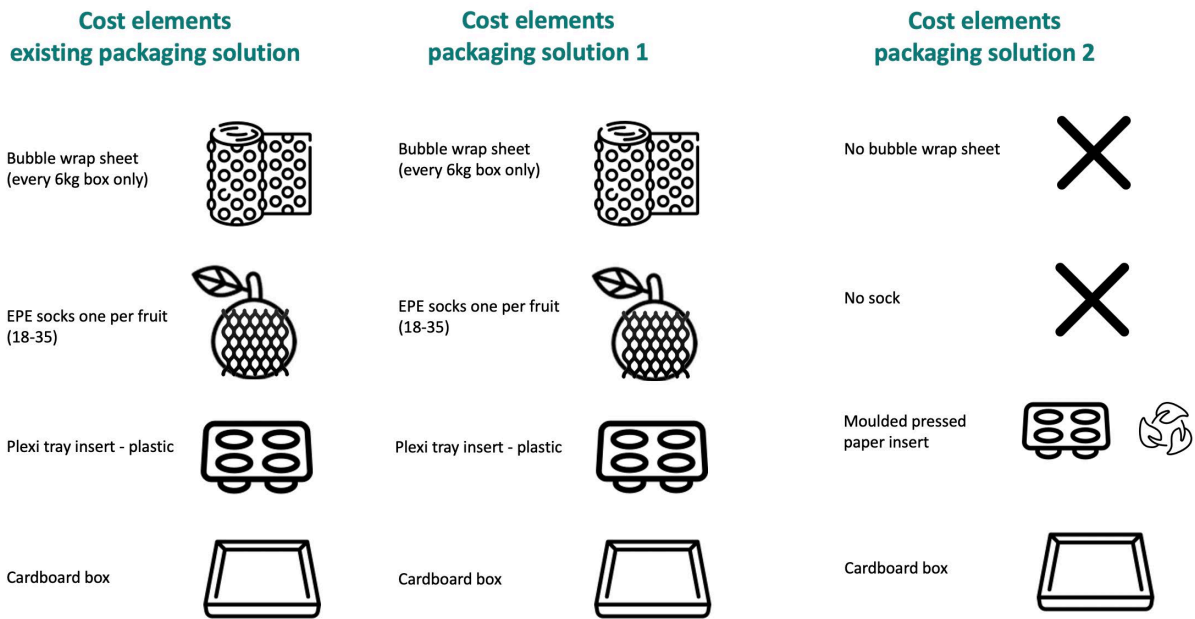


Figure 4 - Visual comparison of the existing costs of the packaging solution elements with the proposed alternatives.

2. **BENEFITS:**

The benefits have been considered under the following categories, as these would be the ones that have the biggest impact in the potential for adoption or decision - making process.

BENEFIT CATEGORY	DESCRIPTION	IMPORTANCE/WEIGHT FOR ANALYSIS
QUALITY OF NASHI	Refers to the solution’s ability to protect the quality and integrity of the fruit (in transit and beyond). Avoids scuffing and bruising. Avoids rejection from customers.	Critical
SUSTAINABILITY CREDENTIALS	The packaging would meet all sustainable targets and requirements: APCO, national targets, customers’ initiatives.	Critical
PACKHOUSE OPERATIONAL FIT	The proposed solution is simple to adapt or integrate to current operational packhouse practices without causing significant operational process changes or capex investment.	Important
CUSTOMER ACCEPTANCE	The solution helps industry retain market access and continue to sell or potentially grow. Nashi volume. All major retailers welcome the solution for compliance and responsible, sustainable practices.	Critical
AUSTRALIAN READINESS	Refers to existing capabilities to collect and or process effectively the packaging materials.	Desired
IMPACT TO WASTE	Refers to a larger or smaller waste footprint, according to the amount of packaging the solution requires. More or less than the baseline.	Desired

Table 3 - Categories and weighting applied for the benefit assessment.

The results of the analysis are summarised in the tables below. **Table 4** provides the total packaging cost for 6Kg class 1 boxes which contain a low count (18) to high fruit count (35). The pressed paper insert cost indicative is based on an average/mid ground number of fruits (23). As described, it includes each of the materials pictured in **Figure 4**. The ratings are on a scale of 100% with intervals of 25%.

The reference solution has a complex and multi component packaging structure, making it quite inefficient and labour intensive, but it provides a high level of protection to Nashis and has therefore becomes preferred by industry when fruits need to travel long distances to reach its customers. Therefore, its costs and challenges have become the benchmark or norm. It is unlikely that it would have been revisited in the absence of the new sustainability targets and APCO requirements due to its perceived functionality. There are certain exceptions for growers who manage to deliver Nashis without socks when other conditions are met, such as shorter travel times and special transport characteristics.

The compostable sock is almost identical, but rates higher in both costs and benefits given that the sock is slightly less expensive, meets sustainability requirements, customer acceptance with comparable packhouse fitness. The differences are that the -prototype- sock that was tested is tighter, and this can translate ‘potentially’ as a slower packaging speed. *Further testing and adapting of the material and size will need to be done with suppliers to obtain an optimal result.* The additional difference in benefits relates to the fact that current industrial composting capabilities in Australia are limited, and this could become an issue for retailers or for consumers, depending on who is dealing with the sock as waste.

The box with a moulded pressed paper insert is the least expensive packaging solution, as it removes many layers of packaging materials (socks and bubble wrap sheets). It should also be the most efficient packaging solution, as the fruits would be placed directly into the trays with no further time to wrap them in a sleeve. The limitations may come from the pre-established number of “holes” or areas to place the Nashis, or the need for a bespoke solution development to adapt the current “of the shelf” solution for avocados to be specifically for Nashis. Its recyclable credentials are extremely high, and it reduces the total amount of packaging. But its biggest challenge, that brings down all other benefits, is its uncertain ability to protect the fruit’s quality and integrity. This option will require significant testing to explore the performance in transportation and the level of acceptance by customers.

Table 4 - Cost benefit analysis results for 6 kg, class 1 boxes of Nashi. Costs are compounded and rated for total packaging materials used for a low and high count (*), benefits are described for every option and rated in combination (**). The overall assessment column describes final output.

	FRUIT COUNT	PACK COSTS/ BOX	COST ANALYSIS*	R	BENEFITS**	R	OVERALL ASSESSMENT	CBA
BL	Low (18)	2.422	Current solution is made of four components: box, tray, socks per fruit and a top protective bubble wrap sheet, making in expensive and labour intensive. It has been the benchmark for the industry for many years because no other solution has proven effective in the protection of the fruit, becoming the standard for growers that need to send Nashi between states or large distances. This is the baseline or reference for the study.		High ability to protect the quality and integrity of fruits, no adjustments required for adoption and packing fit-out. Solution is non-compliant to National targets and APCO requirements, currently non existing recycling capabilities in Australia.		Existing solution is very effective in protecting the fruit and reasonable in cost but does not have the ability to comply with sustainable packaging targets, becoming a risk for market access and continuity. If the soft plastic scheme resumes and is effective, this can be a suitable option.	
	HIGH (35)	3.187						
CS	LOW (18)	2.116	The compostable sock is slightly less expensive but can stand the test of quality and integrity protection. Labour wise, it may require some minor adapting to be equivalent to the existing one, as the initial prototype is a bit tighter and bigger. But for the purpose of this analysis, we are assuming they can perform identically once changes are made. We have rated it slightly better than baseline.		High ability to protect the quality and integrity of the fruits, no adjustments required for adoption and packing fit-out. Solution is compliant to National targets and APCO requirements, limited but existing composting capabilities in Australia.		PREFERRED (1) Proposed option has a slightly lower cost than baseline, and provides many benefits at a higher level, in particular the preservation of the fruit's quality and integrity. Nevertheless, it continues to be a packaging "heavy" solution, with multiple components and labour intensity. It also poses some questions on the existing capabilities in industrial composting schemes in Australia.	
	HIGH (35)	2.592						
MP	MID + BW	1.614	The box with a moulded paper insert ranks as the most cost effective, because two of the packaging components are eliminated reducing the actual cost of package, but also significantly able to reduce the speed and productivity in the pack room, saving labour costs and time. This is the lowest cost option.		Unknown ability to protect the quality and integrity of the fruits in transit (potentially medium). Solution is 100% compliant and with existing recycling capabilities in Australia and reduces total packaging footprint. It could also have an additional benefit in packaging efficiency and speed, given the removal of the need to individually wrap every fruit in a sock.		SECOND CHOICE: Best cost ratio, both for packaging materials and labour, high level of benefits in sustainability, customer acceptance, waste credentials and fit for packhouse performance. But at this point, the high uncertainty in its ability to protect the fruit without additional cushioning or preservation layer (Critical to sustain market access) makes this option a second choice. Worth testing and exploring further, as it is fully sustainable and compliant ready in Australia.	
	MID (23)	1.447						

BL= Baseline (EPE sock), **CS**=Compostable sock, **MP**=Moulded pressed paper insert, **R**= ratings score, **CBA**=Cost benefit analysis. **MID**=Medium count (23), **BW**= with bubble wrap sheet added. (*) Costs are a compounded figure that includes cardboard box (85mm), Plexi tray (to fit low -18 count- to high -35 count), bubble wrap protecting sheet (used in every box), and socks (EPE or compostable) where used. In the case of the moulded paper insert cost includes cardboard box and paper insert for low count or high count. Based on data provided by industry. (**) Benefits criteria used are detailed in report. Categories of benefits used are: Quality (fruit protection), sustainability credentials (meeting of APCO and national targets), Operational and packhouse "fitness". Retailer acceptance, Australian readiness for solution and waste credentials (level of packaging).

Table 5 is a very similar assessment and result for 4 Kg class 2 boxes. The main difference is the specific costs reflected for a different cost of tray, less fruit counts (12 to 25) and the fact that these boxes do not use a bubble wrap sheet on top. This, although a simpler packaging solution and less expensive than the class 1 boxes, does not result in a different overall result.

Table 5 - Cost benefit analysis results for 4 kg, class 2 boxes of Nashi. Costs are compounded and rated for total packaging materials used for a low and high count (*), benefits are described for every option and rated in combination (**). The overall assessment column describes final output.

	FRUIT COUNT	PACK COSTS/ BOX	COST ANALYSIS*	R	BENEFITS**	R	OVERALL ASSESSMENT	CBA
BL	Low (18)	2.422	Current solution is made of four components: box, tray, socks per fruit and a top protective bubble wrap sheet. It has been the benchmark for the industry for many years because no other solution has proven effective in the protection of the fruit, becoming the standard for growers that need to send Nashi between states or large distances. This is the baseline or reference for the study.		High ability to protect the quality and integrity of fruits, no adjustments required for adoption and packing fit-out. Solution is non-compliant to National targets and APCO requirements, currently non existing recycling capabilities in Australia.		Existing solution is very effective in protecting the fruit and reasonable in cost but does not have the ability to comply with sustainable packaging targets, becoming a risk for market access and continuity. If the soft plastic scheme resumes and is effective, this can be a suitable option.	
	HIGH (35)	3.187						
CS	LOW (12)	2.116	The compostable sock is slightly less expensive but can stand the test of quality and integrity protection. Labour wise, it may require some minor adapting to be equivalent to the existing one, as the initial prototype is a bit tighter and bigger. But for the purpose of this analysis, we are assuming they can perform identically once changes are made. We have rated it slightly better than baseline.		High ability to protect the quality and integrity of the fruits, no adjustments required for adoption and packing fit-out. Solution is compliant to National targets and APCO requirements, limited but existing composting capabilities in Australia.		PREFERRED (1) Proposed option has a slightly lower cost than baseline, and provides many benefits at a higher level, in particular the preservation of the fruit's quality and integrity. Nevertheless, it continues to be a packaging "heavy" solution, with multiple components and labour intensity. It also poses some questions on the existing capabilities in industrial composting schemes in Australia.	
	HIGH (25)	2.592						
MP	MID + BW	1.435	The box with a moulded paper insert ranks as the most cost effective, because two of the packaging components are eliminated reducing the actual cost of package, but also significantly able to reduce the speed and productivity in the pack room, saving labour costs and time. This is the lowest cost option.		Unknown ability to protect the quality and integrity of the fruits in transit (potentially medium). Solution is 100% compliant and with existing recycling capabilities in Australia and reduces total packaging footprint. It could also have an additional benefit in packaging efficiency and speed, given the removal of the need to individually wrap every fruit in a sock.		SECOND CHOICE: Best cost ratio, both for packaging materials and labour, high level of benefits in sustainability, customer acceptance, waste credentials and fit for packhouse: performance. But at this point, the high uncertainty in its ability to protect the fruit without additional cushioning or preservation layer (Critical to sustain market access) makes this option a second choice. Worth testing and exploring further, as it is fully sustainable and compliant ready in Australia.	
	MID (23)	1.268						

BL= Baseline (EPE sock), CS=Compostable sock, MP=Moulded pressed paper insert, R= ratings score, CBA=Cost benefit analysis. MID=Medium count (23), BW= with bubble wrap sheet added. (*) Costs are a compounded figure that includes cardboard box (90mm), Plexi tray (to fit low -12 count- to high -55 count), bubble wrap protecting sheet (used in every box), and socks (EPE or compostable) where used. In the case of the moulded paper insert cost includes cardboard box and paper insert for low count or high count. Based on data provided by industry. () Benefits criteria used are detailed in report. Categories of benefits used are: Quality (fruit protection), sustainability credentials (meeting of APCO and national targets), Operational and packhouse "fitness". Retailer acceptance, Australian readiness for solution and waste credentials (level of packaging)**

The high-level cost benefit analysis identifies a solution with ease of adoption and potential cost savings for industry, which is the compostable sock. It meets the APCO and national target requirements and aligns with customer expectations for sustainable packaging solutions. The biggest challenge it has is related to the Australian readiness for compostable packaging collection and processing which is uneven between states, making it difficult to perform at its highest sustainable credentials. The solution also provides a high-quality standard and effective protection for the fruit, which is a key element of maintaining market acceptance or allowing industry to grow.

The second option would be very cost effective, well acquainted to existing paper recycling schemes and reduces the overall packaging and waste footprint, but it still requires proper testing and evaluation to rate adequately and fully understand its ability to preserve Nashi quality. This is also a very new packaging material, which may evolve further and become more widely used and more flexible to cushioning specifications and requirements. It should be explored further to determine if it becomes option one and simplifies cost and complexity for Nashi.

Once the soft plastics recycling resumes in Australia, the existing EPE mesh should also raise its current sustainability handicap and become a proper solution.

Outputs

The most relevant output of this project was to provide an identification and detailed review of sustainable packaging alternatives for Nashi. This is intended to inform and guide Nashi growers with a comprehensive set of existing packaging solutions for fresh produce that could support the adoption of sustainable packaging practices and allow its members to remain competitive, meeting the National Packaging Targets and in alignment with their customers' expectations.

This document provides:

1. A global scan of sustainable packaging practices and solutions currently applied for different produce.
2. A curated selection of options that can adapt to the Nashi operational challenge of protecting the sensitive fruit in transit, and moving towards sustainable options that will meet the APCO targets.
3. A review of additional materials that could become a solution for the future.
4. A high-level set of criteria and ranking to guide the selection of the most feasible and potentially successful options.
5. A high-level summary of global insights regarding regulations, retailers, and consumer views.
6. A high-level cost benefit analysis between the two preferred options selected by a broad Nashi stakeholder group, providing valuable guidance to industry for potential adoption of alternative solutions.

This knowledge was achieved by the following activities:

- >25 Interviews and engagement with key stakeholders to understand the supply chain, existing practices, existing and potential options, suppliers.
- A global market audit of visits and online reviews of retailers and distributors across Australia, the US, the EU (UK, France, and Germany), Singapore, and UAE.
- Desktop research of available solutions, materials, and suppliers.
- A description and rating of existing available options for industry to consider.
- A set of engaging conversations with Nashi stakeholders and supply chain key players.
- A virtual workshop to support the understanding of available options and to allow stakeholders to vote on their preferred solutions.
- A desktop high-level cost benefit analysis of 2 packaging alternatives.

Outcomes

The review and evaluation of Nashi packaging aligns with the first strategic industry outcome (SIP) that focuses on industry supply productivity and sustainability, impacting more specifically the ability to maintain local supply, of consistently high-quality products that also meet the National Packaging Targets and customers' expectations.

Achieving the outcome will involve: Identifying better and more sustainable packaging options to increase sustainability, maintain local competitiveness and viability of supply, whilst consistently supplying a high quality and compliant product to market.

Nashi is a niche, unique product that could be at risk of being deleted from the major retailers as it is important but low demand in proportion to some other fresh produce lines should it be unable to meet sustainability commitments, so finding its own solutions to become fully compliant with National Packaging Targets and keeping its high-quality credentials is essential for market access and productivity. A solution to the currently non-recyclable plastic sleeve will be necessary to stay present in the range.

Through this research, we have provided effective options for the Nashi industry, which can result in cost savings, as well as meeting the sustainable requirements and national goals. Some options, although still needing to undergo testing for quality protection, may also represent a potential opportunity to reduce the complexity and labour-intensive manual packaging structure that has been in place for a long period of time.

These solutions provide industry with more options, awareness of new packaging materials and alternatives, that can result in a better consumer or customer acceptance and will certainly allow Nashi to remain in market as a delicious, high-quality option for Australians and beyond.

Monitoring and evaluation

- **To what extent has the project contributed to improve industry sustainability as per SIP(s) outcome 1?**

The new knowledge in packaging alternatives for Nashis, existing or under development for the near future will certainly contribute to improving their commitments with responsible and compliant sourcing, as well as aligning with sustainable alternatives. This project has upskilled the key stakeholders through domestic and global insights.

It also may provide a slight cost benefit as both options explored in more depth can result in cost savings for the industry, whilst maintaining the highest quality and raising their sustainability credentials.

- **To what extent has the project contributed the Nashi industry achieving compliance and alignment with National Packaging Targets (plus customers' requirements)?**

It will allow industry to meet requirements, once commercially trialled, and adopted. Depending on the options chosen and how they are adopted, it may still pose some challenges due to the collecting and processing capabilities in Australia (I.e. industrial or at home composting, soft plastics)

- **To what extent has the project contributed to finding packaging options that maintain or enhance the product's quality in transport?**

Our activities have all been focused on realising potential solutions that can improve the industry's sustainability by introducing sustainable, compliant materials and solutions that meet the National Packaging Targets, but also mindful that if these options do not preserve the fruit's quality and integrity, they cannot be used. We have provided one option that meets both requirements (quality and protection), and one that needs to be further explored (unknown at the moment)

- **To what extent has the project met the needs of industry levy payers?**

It provides a cost-effective solution, easy to adopt to meet National Targets and Packaging requirements of major customers.

- **To what extent were the target engagement levels of industry levy payers achieved?**

We visited two growers and included others in our engagement activities, as per the recommended contacts given by our PRG. We believe we have represented their interests well and have had good engagement with them.

- **Have regular project updates been provided via the PRG and other activities?**

Yes, very regular activities and conversations in between meetings.

- **How effective were the knowledge sharing activities? Did the project engage with industry levy payers through their preferred learning style?**

Currently our engagement has been positive and through the PRG group. We had a very good workshop session virtually with an excellent engagement and valuable feedback from the levy payers and extended stakeholder group.

We were able to reach a good consensus of the preferred options to assess with our cost benefit analysis.

We used simple engaging methods such as slido in the workshop to gather more direct feedback from all participants as well as making it very easy to engage and vote.

- **What efforts did the project make to improve efficiency?**

We had frequent contacts with the PRG individually and collectively, always advised when certain things did not meet the expected pace or followed up for data and feedback. We used many visual representations of alternatives, of global scanning results, minutes and summaries of meetings, and simple engaging methods such as slido. This allowed for higher efficiency and better use of everyone's time.

Recommendations

- Further R&D activity is recommended to validate the alternative packaging options reflected in the high-level cost benefit analysis and trialling a controlled commercial environment from an operational perspective (efficiency vs quality) across the supply chain and through to the instore or customer experience. Collecting consumer acceptance of the new material should be a critical consideration to maintain brand awareness and consumer satisfaction measures.
- From a customer perspective the changing in material for the sock could easily go unnoticed as such the Nashi industry should look at how it communicates to consumers the positive outcome and investment in sustainable packaging to build consumer awareness and extend credibility. This will also contribute to informing consumers and helping them dispose of the new material in the correct waste stream (at home composting). Education is an essential element of success. If this packaging material is considered a secondary packaging at the customer level, then the education must be tailored to them, as the socks will be handled in a different collection and disposing stream (industrial composting)
- Direct engagement with the packaging suppliers that have demonstrated access and capability to suitable alternatives as a build on this work should lead to a cost reduction in sock unit price and the ability to fine tune any design requirements utilising the material.
- As seen with this project, it is essential to realise that the sustainability of each material will differ by country and their collection facilities, therefore consideration should be given to local requirements in key export markets to maintain the positive outcome.
- Regulations and packaging materials are evolving very quickly in the sustainability space. We recommend monitoring and keeping current with the changing landscape as it brings to life new opportunities and challenges.

References

<https://www.thegrocer.co.uk/sustainability-and-environment/is-paper-packaging-really-more-sustainable-than-plastic/680773.article>

<https://www.mla.com.au/globalassets/mla-corporate/research-and-development/final-reports/v.rmh0127.redmeatpackaging-006.pdf>

ALDI (n.d.), Plastics and Packaging [Accessed 18 Nov 2021] [online] Available at: <https://corporate.aldi.com.au/en/corporate-responsibility/environment/plastics-packaging/>

Coles (n.d.), Together to Zero Waste [Accessed 18 Nov 2021] [online] Available at: <https://www.coles.com.au/about-coles/sustainability/environment/together-to-zero-waste>

Woolworths (n.d.), Reducing and recycling plastic [Accessed 18 Nov 2021] [online] Available at: <https://www.woolworths.com.au/shop/discover/sustainability/recycling>

Triguero, A., et al. (2019). Environmental and health impacts of using food waste as animal feed: A comparative analysis with energy recovery. *Journal of Cleaner Production*, 219, 270-280. doi:10.1016/j.jclepro.2019.02.030

Geyer, R., et al. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), e1700782. doi:10.1126/sciadv.1700782

Gonzalez-Torre, P., et al. (2021). Influence of packaging on consumer perceptions and purchasing behavior for fresh produce: A review. *Postharvest Biology and Technology*, 171, 111331. doi:10.1016/j.postharvbio.2021.111331

Soni, P., et al. (2020). Sustainable packaging alternatives for the food industry: A review. *Journal of Cleaner Production*, 263, 121460. doi:10.1016/j.jclepro.2020.121460

Oloyede OO, Lignou S. Sustainable Paper-Based Packaging: A Consumer's Perspective. *Foods*. 2021 May 10;10(5):1035. doi: 10.3390/foods10051035. PMID: 34068639; PMCID: PMC8151435.

Sustainable Packaging Coalition. (2019). Guidance for Optimal Fiber Recovery in Packaging. https://sustainablepackaging.org/wp-content/uploads/2019/11/Fiber_Recovery_Guidance.pdf

Ellen MacArthur Foundation. (2017). The New Plastics Economy - Rethinking the future of plastics. https://www.ellenmacarthurfoundation.org/assets/downloads/New-Plastics-Economy_Jan-2017.pdf

https://emf.thirdlight.com/file/24/kLSzgpKl.2CJxQkLb3XkLQIS7_/Case%20Studies%20-%20French%20Anti%20Waste%20Law.pdf

Sustainability Victoria. (2021). Packaging Sustainability Framework. <https://www.sustainability.vic.gov.au/-/media/resources/documents/packaging-and-education/packaging-sustainability-framework.pdf>

<https://documents.packagingcovenant.org.au/public-documents/Quickstart%20Guide%20-%20Design%20for%20Recovery;%20Reuse,%20Recycling%20or%20Composting>

Zhou, Ran & Su, Shuqiang & li, Yunfei. (2008). Effects of cushioning materials on the firmness of Huanghua Pears (*Pyrus pyrifolia* Nakai cv. Huanghua) during distribution and storage. *Packaging Technology and Science*. 21. 1 - 11. doi:10.1002/pts.769.

<https://documents.packagingcovenant.org.au/public-documents/Quickstart%20Guide%20-%20Design%20for%20Recovery;%20Reuse,%20Recycling%20or%20Composting>

Dhall RK. Advances in edible coatings for fresh fruits and vegetables: a review. *Crit Rev Food Sci Nutr*. 2013;53(5):435-50. doi: 10.1080/10408398.2010.541568. PMID: 23391012.

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Seeka	Grower
Magarey Orchard	Grower
Coles	Retailer
Aldi China	Retailer China
APCO	Packaging Covenant
Rudge produce systems	Produce quality auditor
COPAR	Packaging supplier Australia
OPAL	Packaging supplier
YUTO	Packaging supplier
DETPAK	Packaging supplier
Huhtamaki	Packaging supplier
OJI Fibre	Packaging supplier
Polycell	Packaging supplier
VISY	Packaging supplier
Greencell foam	Packaging supplier US
Flexihex	Packaging supplier UK
R3 pak	Packaging supplier NZ
BioFab and Grown Bio	Mycelium packaging suppliers: NL, Australia/NZ
Apeel	Edible coating supplier, US
Bio-Pak	Packaging supplier
Tipa-Corp	Packaging supplier

Appendices

Appendix 1 - Summary of chosen options

Compostable version of sock

The same format of sock but using a material that is compostable. The sock would function in the same way as the existing sock.

Assessment of this packaging option is as follows:

VIABILITY	Commercially available, multiple suppliers	
APCO Guidelines	Compostable	
National Collection & Recycling	Compostable, may have limitations in different states (industrial compostability)	
INDICATIVE COST	Slightly less expensive than current EPE sleeve	
ABILITY TO PROTECT FRUIT	Potentially high	
ADOPTION COMPLEXITY	Low	
CUSTOMISATION FOR NASHI	Only sizing, simple execution	

Three supplier solutions were found to be available and in market. They use different biopolymers, with combinations of plant starch and other components, all certified as a raw material and certifiable for home or industrial composting standards, in EU and Australia (standards A5810, AS5810, AS4736).

Please note: The raw materials used for manufacture are certified compostable, but the finished product should also be tested to the required standards to confirm compost ability. It is a simple solution and easy to adopt, as it is expected that the material can come in a sized, ready to use format, that can be a direct swap to the existing plastic version of the sock. From the sustainability credentials point of view, compostable materials are aligned with APCO targets, but the disposing streams are not available or efficient in all states. The home composting approach is an option to consider.

Suppliers: BioPak, Biotec and Tipa-Corp

Box with internal moulded paper insert

The use of the existing cardboard box with an insert made of a moulded paper. The process to make moulded paper consists of pliable multiple layers of paper thermoformed into the desired shape. Currently used in mangoes and avocados in various geographies. The level of cushioning needs to be tested for Nashi. 100% sustainable if paper is sustainably sourced and disposed of.

The assessment of this packaging option is as follows:

VIABILITY	Commercially available	
APCO Guidelines	Meets APCO Design Guidelines for Fibre-based Packaging	
National Collection & Recycling	Recyclable through current Paper Streams	
INDICATIVE COST	Removes plex insert (-0.195\$), adds moulded paper insert	
ABILITY TO PROTECT FRUIT	Medium to low, requires testing	
ADOPTION COMPLEXITY	Low	
CUSTOMISATION FOR NASHI	Potentially	

Appendix 2 - Summary of regulatory global insights

Table 3: Global Scan Insights: Regulations. Based on existing knowledge, conversations, observations, and interviews

<p>Regulatory Drivers (non-comprehensive)</p>	<p>FR</p>	<ul style="list-style-type: none"> Waste and circular economy law 2020 – France is said to be leading this approach according to Ellen McArthur Foundation: https://emf.thirdlight.com/file/24/kLSzgopkL.2CjxQkLb3XkLQIS7_/Case%20Studies%20-%20French%20Anti%20Waste%20Law.pdf What the law means in practice for F&V – according to the the French Ministry of ecological transition: https://www.ecologie.gouv.fr/sites/default/files/en_DP%20PJL.pdf Plastic around F&V is banned since 2022. It is taking time to be completely implemented but there are very few examples where there is single use plastic packaging – for example, I just saw the EPE nets in two niche stores on mangoes. In one national supermarket (LeClerc) a floor employee confirmed that the molded fibre tray inserts are sorted back of house and sent for recycling.
	<p>EU</p>	<ul style="list-style-type: none"> The European Commission proposed a revision of the Packaging and Packaging Waste Directive in November 2022. This will support the delivery of the European Green Deal which includes the new circular economy action plan and packaging is part of that. All packaging on the EU market will need to be reusable or recyclable in an economically viable way by 2030. The New Circular Economy Action Plan makes way for the EU’s objectives regarding plastic for example, transforming the way plastic products are designed, produced, used and recycled in the EU and creating new opportunities for innovation. There are other aspects as well and there are specific policies covering bio based, biodegradable and compostable plastics (European Commission, n.d.)
	<p>EU</p>	<ul style="list-style-type: none"> EU Plastic Pact. This isn’t a regulation but includes over 80 signatories from governments, companies, non-governmental organisations, and industry associations. They are aiming for better design, responsible use, recycling capacity and use of recycled content to reduce the environmental impact of plastics and plastic packaging. <p>Some of the targets are interesting and reflect what is happening with APCO: Target 1- Design all plastic packaging and single-use plastic products placed on the market to be reusable where possible and recyclable by 2025; - Target 2 - Reduce virgin plastic products and packaging by at least 20% (by weight) by 2025, with half of this reduction coming from an absolute reduction in plastics; - Target 3 - Increase the collection, sorting and recycling capacity by at least 25 percentage points by 2025 and reach a level that corresponds to market demand for recycled plastics; - Target 4 - Increase the use of recycled plastics in new products and packaging by 2025, with plastics user companies achieving an average of at least 30% recycled plastics (by weight) in their product and packaging range. (WRAP, 2022) and (European Plastics Pact, n.d.)</p> <p>(Signatories of note: Auchan Retail, Carrefour, Hilton Food Group, Nestle)</p>
	<p>GM</p>	<ul style="list-style-type: none"> The German Packaging Act: As of July 2022, packaged goods in Germany cannot be distributed unless the manufacturer is registered on the LUCID Register. This is an extension of the existing Packaging act. Similarly stringent measures have also been established for downstream distributors, online marketplaces and fulfilment service providers who are now required to monitor compliance under the Packaging Act. (GVW, 2022). This is interesting with respect to transport packaging that isn’t sold e.g., molded trays for bulk produce sales.
	<p>EU</p>	<ul style="list-style-type: none"> We might see changes in future coming from France and Germany, maybe EU overall, regarding the recycled content of food contact plastic - there may be an expectation to increase the amount of plastic for food contact that contains recycled plastic from food contact. Therefore, being fully circular, rather than “just” recycling virgin plastic into non-food packaging.
	<p>UN</p>	<ul style="list-style-type: none"> The UN Plastic Treaty will speed up awareness and action from Governments around the world. As the negotiations were in June, we don’t know all the details yet.
<p>Legend</p>		<p>UK, United Kingdom. FR: France, EU: European Union, UN: United Nations, SK: South Korea, GM Germany</p>

Appendix 3 - Summary of Innovations on packaging materials to monitor

Many new materials and solutions are currently being developed, some with existing commercial applications, and some in an earlier phase. All of them promise an inspiration of what is possible, and a solution to some of the existing materials' challenge. Some examples are provided, non-comprehensively, but as an illustration of the evolving landscape:

- 1) **Seaweed-based packaging:** Seaweed-based packaging is gaining traction due to its abundance, biodegradability, and renewability. Alginate, a natural polymer derived from seaweed, is widely used to create flexible, biodegradable films and coatings. Seaweed-based packaging helps reduce plastic waste and can even enhance the shelf-life of certain perishable foods due to its moisture-retaining properties. Example: Notpla, a London-based start-up, has developed Ooho, an edible water bubble made from seaweed extract. These bubbles can potentially replace single-use plastic bottles for beverages and other liquid food products.

Pros: Renewable and biodegradable, reduced environmental impact compared to traditional plastics, offers excellent barrier properties against moisture and gases.

Risks: Limited scalability in large-scale production, shelf-life limitations for some products, sourcing, and traceability challenges for seaweed materials.

- 2) **Mushroom mycelium packaging:** Mushroom mycelium, the root structure of fungi, can be used to create a sustainable alternative to traditional foam packaging. It is a biodegradable material that can be moulded into various shapes and sizes, providing excellent cushioning and protection for fragile food items. Examples: Growbio (UK) and BioFab (NZ, Australia).

Pros: Biodegradable and compostable, lightweight, and strong. Could develop into different levels of cushioning, suitable for custom designs and shapes. It is also a very sustainable solution as its source raw materials are from agricultural food and fibre waste.

Risks: Longer production time compared to traditional foam, mycelium growth variability might affect consistency, substrates can vary, relatively higher costs for certain applications.

- 3) **Sugarcane-based packaging:** Sugarcane-based packaging utilises bagasse, a fibrous residue left after sugarcane juice extraction. Bagasse is a renewable resource and can be moulded into containers and trays suitable for food packaging. It offers a viable alternative to polystyrene foam trays and containers. Example: PULP Packaging uses sugarcane bagasse to create sustainable food trays, reducing the reliance on single-use plastic trays in the food industry.

Pros: Made from agricultural waste, biodegradable and compostable, excellent thermal insulation.

Risks: Availability of bagasse might vary seasonally, energy-intensive production processes, limited shelf life for some food products.

- 4) **Cellulose Moulds and Foam:** Cellulose moulds and foam are derived from renewable plant-based sources like wood pulp. They are suitable for packaging applications that require cushioning and protection for delicate food items. Example: Protectiflex utilises cellulose foam for packaging fresh produce, providing an eco-friendly alternative to petroleum-based foams.

Benefits: Biodegradable and compostable, versatile, and customisable, good thermal insulation properties.

Risks: Production can require substantial water and energy, may not be suitable for all types of food products, competes with traditional paper industries for raw materials.

- 5) **Paper-based Foam:** Paper-based foam is an innovative alternative to plastic foam packaging, created by combining paper fibres with other natural binders. It offers excellent protection for food items and can replace polystyrene foam for certain applications. Example: Green Cell Foam produces a packaging material made

from renewable plant-based materials that are fully compostable and water-soluble.

Pros: Renewable and compostable, customisable, and lightweight, reduces reliance on traditional plastic foams.

Risks: Energy - intensive production processes, limited moisture resistance compared to plastic-based foams, may not provide adequate protection for all food products.

The materials mentioned above demonstrate the potential of sustainable alternatives in food packaging. Each material offers unique benefits and challenges, and their suitability depends on specific packaging requirements and the commitment of the food industry to embrace innovative solutions. By adopting these sustainable materials, the food industry can reduce its environmental footprint and contribute to a more circular and eco-friendly packaging ecosystem.

Edible coatings:

A different approach that was reviewed was the use of edible coatings. The rationale was that maybe, an extra layer of natural components could strengthen the exterior of the Nashis, therefore, protecting them from the bruising and scuffing they suffer today. We reached out to Apeel to understand if they had any experience with Nashis or other Asian pears. They did not at current date, but they offered data from other fruits experiences in which the extension of shelf life and fruit stability were proven.

Other advances in edible coatings' applications for fresh fruits and vegetables have been documented, such as their potential to improve safety, nutritional and sensory attributes. But, the implications, costs, regulatory impact of any of these applications need to be considered on a one-by-one basis. For the purposes of the current review, these are not recommended as an option, but could be a solution in the future if developed with the focus of the protection of the fruit's skin.

Innovative Suppliers links:

Notpla - <https://www.notpla.com/>

Ecovative Design - <https://ecovatedesign.com/>

PULP Packaging - <https://www.pulppackaging.com/>

Protectiflex - <http://www.protectiflex.com/>

Green Cell Foam - <https://www.greencellfoam.com/>

Sealed Air: [SEE \(Sealed Air\)](#).

Paper Foam: [Paper Foam](#)

FlexiHex: <https://www.flexihex.com/environment/>

R3pack: <https://www.r3pack.co.nz/sustainability/>

Verite: [Verite](#)

Pregis: [Pregis](#)

BiopaK: [BioPak](#)

COPAR Smart Packaging: <https://www.linkedin.com/company/copar-smart-packaging/?originalSubdomain=au>

Smurfit Kappa: <https://www.smurfitkappa.com/innovation/success-stories/mcgarlet-success-story>

GrowBio: <https://grow.bio/>

BioFab: <https://www.biofab.bio/>

Naturalvi: [NaturAlvi](#)

JCF France: [JCF France](#)

TPF: [TPF Tour Pour Le Fruit](#)

Storaenzo: [Storaenzo](#)

Happy Eggs: [Happy Eggs](#)

ESP Pulp: [ESPulp](#)

Evesham specialist packaging: [Evesham Specialist Packaging](#)