

FINAL REPORT:

The role of packaging in minimising food waste in the supply chain of the future

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CHEP Australia

Philip Austin, Renee Holbrook, Dzintra Horder and Connie Sellaro

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Authors:

Dr Karli Verghese

Dr Helen Lewis

Simon Lockrey

Dr Helen Williams

CONTACT

Centre for Design
School of Architecture and Design
RMIT University
GPO Box 2476
Melbourne VIC 3001
Tel: + 61 (03) 9925 3484
Fax: + 61 (03) 9639 3412

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Research Partners

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Executive Summary

Food security is an emerging challenge for policy makers and companies in the food supply chain. The global population is expected to grow to 9 billion and demand for food by 77% by 2050. Over the same period food production will be under threat from climate change, competing land uses, erosion and diminishing supplies of clean water. One of the solutions to this dilemma is increased efficiency and waste reduction in the food supply chain.

This report focuses on packaging opportunities that may help to reduce or recover food waste. Packaging has a vital role to play in containing and protecting food as it moves through the supply chain to the consumer. It already reduces food waste in transport and storage, and innovations in packaging materials, design and labelling provide new opportunities to improve efficiencies. Product protection needs to be the primary goal for packaging sustainability, and sometimes this requires trade-offs between packaging and food waste.

The report draws on an international literature review and interviews with representatives from 15 organisations in the Australian food and packaging supply chain. It considers food waste along the entire food supply chain, but with a particular emphasis on food waste that occurs prior to consumption, i.e. during agriculture production, post-harvest handling and storage of raw materials, and in the commercial and industrial (C&I) sector consisting of food manufacturing, wholesale trade, food retail and distribution and food services. Food rescue through charities is also a focus of the report.

Over 4.2 million tonnes of food waste is disposed to landfill in Australia each year. Around 1.5 million tonnes of this is from the commercial and industrial sector (the focus of this report), costing around \$10.5 billion in waste disposal charges and lost product. The largest single contributor in the commercial and industrial sector is food service activities (e.g., cafes, restaurants, fast food outlets), which generate 661,000 tonnes of food waste per year, followed by food manufacturing (312,000 tonnes) and food retail (179,000 tonnes). Most waste in food manufacturing is unavoidable, and almost 90% is already recovered as animal feed, compost or energy.

The reasons for food loss and waste at each stage of the supply chain include:

- **Agricultural production:** damage from pests and disease; unpredictable weather conditions; not meeting quality specifications
- **Post-harvest handling and storage:** not meeting specifications for quality and/or appearance; pest damage; spillage and degradation
- **Processing and packaging:** trimmings and other food preparation waste; production line start up; batch mistakes; inadequate remaining shelf life
- **Distribution (wholesale and retail):** damage in transit/storage due to packaging failures; product spoilage; fresh produce not meeting specifications or damaged during handling; inadequate remaining shelf life due to poor stock rotation or low sales
- **Food service:** trimmings and other food preparation waste; poor inventory management (e.g. over-ordering); improper food handling; confusion over use-by and best-before dates; plate leftovers
- **At home:** trimmings and other food preparation waste; food spoilage; preparing too much food; past use-by or best-before dates; plate leftovers.

A number of opportunities to reduce food waste through packaging improvements were identified, including:

- 1) Distribution packaging that provides **better protection and shelf life for fresh produce** as it moves from the farm to the processor, wholesaler or retailer. This may require the development of tailored solutions for individual products.
- 2) Distribution packaging that supports **recovery of surplus and unsaleable fresh produce** from farms and redirects it to food rescue organisations.
- 3) Improved design of secondary packaging to ensure that it is **fit-for-purpose**, i.e. that it adequately protects food products as they move through the supply chain. Packaging

developers need to understand the distribution process and where and why waste occurs.

- 4) A continuing shift to **pre-packed and processed foods** to extend the shelf life of food products and reduce waste in distribution and at the point of consumption (the home or food services provider). The packaging itself also needs to be recoverable to minimise overall environmental impacts.
- 5) Adoption of **new packaging materials and technologies**, such as modified atmosphere packaging and oxygen scavengers, to extend the shelf life of foods.
- 6) Education of manufacturers, retailers and consumers about the meaning of **use-by and best-before date marks** on primary packaging to ensure that these are used appropriately. Confusion about date marking results in food being thrown away when it is still safe to eat.
- 7) Product and packaging development to cater for **changing consumption patterns and smaller households**. Single and smaller serve products will reduce waste by meeting the needs of single and two person households.
- 8) Collaboration between manufacturers and retailers to **improve the industry's understanding of food waste** in the supply chain. Greater attention to be given to where and why this occurs, tracking over time, will reduce the costs and environmental impacts of waste.
- 9) More synchronised supply chains that use **intelligent packaging and data sharing** to reduce excess or out-of-date stock.
- 10) Increased use of **retail ready packaging** to reduce double handling and damage and improve stock turnover, while ensuring that it is designed for effective product protection and recoverability (reuse or recycling) at end of life.

The implementation of these initiatives could be supported by further research and communication activities to highlight the critical links and trade-offs between packaging, product protection and food waste. Study recommendations include:

- Detailed analysis of food waste using direct observations and sampling at key aggregation points, such as post-harvest grading, sorting and packing. The reasons for waste would be documented and analysed to identify opportunities for improvement.
- Collaborative research into the potential for packaging systems to be improved to reduce food waste in specific food supply chains. Agricultural products and processed food items could be selected based on their contribution to the economy, unit sales value, environmental impact, or waste volumes in the supply chain.
- Analysis of food waste in different food service premises (e.g., hotel, café, restaurant, take away) to identify opportunities for packaging innovation and increased food recovery.
- Life cycle assessment of primary packaging formats (e.g., modified atmosphere packaging) that extend shelf life to better understand the trade-offs between packaging use and food waste generation.
- Life cycle assessment of packaging formats (e.g., single serves, bulk packaging) to understand their impact on product protection and food waste.
- Education and communication to raise awareness and educate stakeholders in the food and packaging supply chain on opportunities to further reduce food waste through packaging innovation.
- Education and communication to improve consumer understanding of the role that packaging can play in keeping a product safe and fresh.

1 Introduction – the significance of food waste and the role of packaging

Food security is an emerging challenge for policy makers and companies in the food supply chain. The global population is expected to increase by another 2 billion people by 2050, putting more pressure on resources. In Australia, food production is under threat from climate change, competing land uses, erosion and diminishing supplies of clean water.

When food is lost or wasted, all of the natural resources that were expended in the supply chain are also lost, including the use of land, nutrients, synthetic fertilisers, water and energy. As every new step in the value chain adds resources and emissions, the waste of cooked food at the consumer or food service level has the highest environmental impact.

One of the solutions to this dilemma is increased efficiency and waste reduction in the food supply chain. Around 40% of all food intended for human consumption in developed countries ends up as waste. In Australia 4.2 million tonnes of food ends up in landfill each year—2.7 million tonnes from households and 1.5 million tonnes from the commercial and industrial sector [1]. Some of this is unavoidable waste from processing and preparation, but much of it is avoidable.

Food manufacturers generate a significant amount of organic waste but recover almost 90%, primarily as animal feed or compost. The biggest opportunities for waste reduction and recovery are therefore in other parts of the supply chain, particularly in distribution, food service and in the home.

Packaging has a vital role to play in containing and protecting food as it moves through the supply chain to the consumer. It already reduces food waste in transport and storage, and innovations in packaging materials, design and labelling provide new opportunities to improve efficiencies.

This report explores some of the opportunities to reduce or recover food waste through further improvements in packaging. Product protection is the primary goal for packaging sustainability, and sometimes this requires trade-offs between packaging and food waste.

1.1 Research aims and approach

The aims of this research were to:

- examine industry, resource and lifestyle trends most likely to impact food waste in urban and regional Australia to 2030
- identify primary, secondary and tertiary packaging insights to help minimise food waste across the Australian supply chain.

Previous studies into food security and food waste, e.g., [2-7], have helped to focus attention on the significant proportion of food that is wasted in the supply chain, and its implications for policy, infrastructure and behaviour. *This* research makes a unique contribution by focusing on packaging insights that may help to reduce food waste. There has been very little research into the role of packaging in protecting fresh and processed foods at every stage of the supply chain, and in extending product shelf life. These important functions are often overlooked in debates about food security and waste.

While *this* research considers food waste along the entire food supply chain, it has a particular focus on food waste that occurs prior to consumption, i.e. during post-harvest handling and storage of raw materials, during manufacturing of packaged food products and in the distribution and retail chain. There are other studies and programs, such as the NSW Government's Love Food Hate Waste program, that focus on household food waste and consumer behaviour.

1.2 Research method

The need for further research on interactions between packaging and food waste was originally identified in the Australian Food and Grocery Council's (AFGC) *Future of Packaging White Paper* [8]. The research draws on an international literature review and interviews with representatives from 15 organisations across the Australian food and packaging supply chain.

Definitions

There are two terms often used to describe food that is produced for human consumption but does not end up being consumed. This is described as **food loss** when it occurs during agricultural production, post-harvest handling or processing of products, and as **food waste** when it occurs at the end of the food chain (during distribution, retail sale and final consumption) [9]. Food losses include crops destroyed by drought or pests, and wastes from food processing such as fruit and vegetable peel. This is largely unavoidable. In contrast, food waste is linked to human action and could potentially be avoided through improved efficiency and planning [10].

For the purpose of this report packaging is divided into:

- **Primary packaging:** the retail or consumer pack that contains the sales unit (e.g. a plastic bag, glass jar or steel can, or a plastic crate for loose fresh produce).
- **Secondary/tertiary packaging:** additional layers to protect and contain the primary packs during distribution (e.g. a corrugated box, plastic or timber pallet, plastic crate for processed foods, or stretch wrap).

1.3 Food security and waste

The global population is expected to increase from 6.9 billion to around 8 billion by 2030, and 9 billion by 2050 [11]. As a result world demand for food is expected to be 77% higher in 2050 compared to 2007 [6, p 4], mostly in developing and emerging economies in Asia. Combined with changing food preferences, this will provide new export opportunities for the Australian food industry.

To take advantage of the increasing demand for food products, farmers, fishers and food processors will have to be more productive, but with less water and a lower carbon footprint [12]. There will be less land available for agriculture in the future due to a range of factors, including environmental degradation, stresses linked to climate change, and competition from other land use demands such as urban development and transport [13].

The United Nations Food and Agricultural Organisation (FAO) estimates that approximately one billion people around the world are already under-nourished [14]. With climate change and population growth expected to increase food insecurity in the future, finding ways to reduce avoidable food waste will become even more critical.

"In the world today, we produce enough food to feed everybody, but at the same time 1 in 7 people in the world are literally starving, that's 1 billion people. One in every 3 kilograms of food produced for human consumption (according to the international research) is wasted. So everybody is asking how are we going to feed 9 billion people by 2050? They are asking the wrong question. It's not about more food today, although we will need more food, it's about the allocation or reallocation of food. If we can't address that, then producing more food is not going to solve the problem by 2050."

1.4 Actions to address food waste

Many governments around the world, including in Australia, have policies to reduce and recover food waste. This is driven by concerns about food security, the environmental impacts of food production and consumption, and the contribution of greenhouse gas emissions (such as methane from degrading organic matter) to climate change [12]. FAO is working in partnership with public and private sector organisations to raise awareness about food waste and to find solutions¹.

In Australia, the *National Waste Policy* provides a framework for coordinated action by the federal government and all state and territory governments to ‘*enhance biodegradable (organic) resource recovery and reduce greenhouse gas emissions from landfill*’ [1, p 13]. A number of state governments have policies and programs to reduce household food waste and in some cases food waste generated by businesses.

Options available to recover food waste for beneficial use range from donations to charities through to recovery as compost or energy (**Figure 1**). New markets for recovered food are being driven by a range of factors, including:

- the rising costs of landfill
- government policies and programs to reduce waste
- investments by the waste industry in alternative waste facilities
- the proactive efforts of retailers, manufacturers and food service providers to divert their food waste from landfill
- growth in the number of businesses that recover food for distribution by charities.

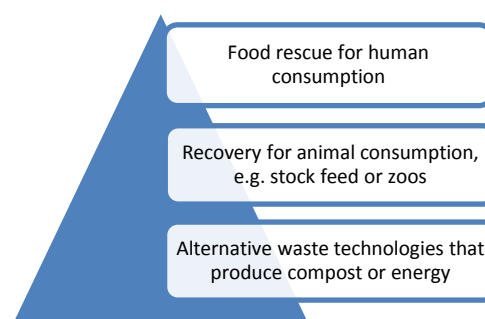


Figure 1 Hierarchy of recovery options for surplus food

There are three key organisations in Australia that collect surplus or unsalable products for redistribution to charities providing emergency food relief to the homeless or disadvantaged. The types of foods that are recovered include packaged foods that are close to their use-by or best-before dates; products with no labels or incorrectly labelled; and surplus prepared foods from cafes and restaurants. Foodbank is the largest rescue organisation, operating nationally to redistribute shelf stable, chilled and frozen foods (see *Case study 1: Foodbank (food rescue)* on page 42). OzHarvest collects fresh produce and foods ready for human consumption, such as prepared meals that are excess to requirements, while SecondBite has a focus on fresh produce.

Food waste that is no longer suitable for human consumption (e.g. through food rescue organisations) or for animal feed, can be diverted to an ‘alternative waste facility’. This is an umbrella term for a wide range of different technologies including in-vessel composting, windrow (open) composting, vermiculture, anaerobic digestion and bioreactor landfills.

¹ Food and Agriculture Organization, www.fao.org/save-food/savefood/en/

1.5 The role of packaging in food protection

Consumers now demand fresh and processed foods all year round, often sourced globally, in a form that is safe and convenient. A combination of different materials are used in primary and secondary/tertiary packaging to contain, protect, preserve, distribute and sell each food item.

The important role that packaging plays in the global food supply chain is often underestimated, but includes *'to **protect** the product; **promote** the product; provide **information** on product usage, health and safety, disposal etc.; enable the **convenient** transportation and usage of the product; allow **utilisation** of the product through the supply chain; and support efficient **handling** of the product, again, throughout the supply chain'* [15, p 7]. These roles are acknowledged in the first principle of the Sustainable Packaging Guidelines in the Australian Packaging Covenant—that packaging must be 'fit for purpose' [16].

Packaging that is designed to effectively contain and protect food across the supply chain will minimise waste of both food and packaging. **Figure 2** illustrates the average energy inputs for one person's weekly consumption of food, at each stage of the food supply chain. On average packaging accounts for only 10% of total energy but it plays a critical role in ensuring that the other 90% is not wasted.

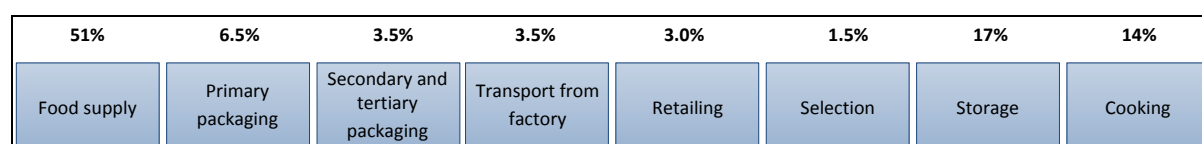


Figure 2 Energy for one person's weekly consumption of food MJ/person/week

Source: Adapted from [8, 17].

It is therefore critical to recognise and investigate the potential trade-offs between packaging consumption and food waste that may be required to produce the best environmental outcome (**Figure 3**). For example, the shift to single serve formats in some food categories may result in more packaging per serve but the potential for food waste is reduced [18, 19].

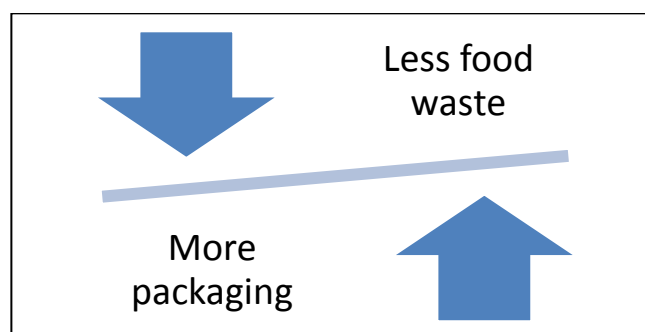


Figure 3 Trade-offs between food waste and packaging

In addition to product protection, the decision to use a particular type of packaging is a complex one driven by demands at numerous points along the supply chain (**Table 1**). The increasing focus on food waste adds another dimension to the decision-making process. Understanding where and why this occurs (section 2) will support the development of improved packaging systems.

Packaging considerations for fresh and processed foods			
Material selection	Material weights	Package design, dimension and shape (ergonomics)	Interaction between packaging levels
Mechanical and chemical characteristics	Packing line efficiency	Filling / packing line speed	Handling efficiencies
Cube utilisation	Stackability	Easy to open, dispense and close	Stability and robustness through supply chain
Warehousing, stocking and stacking	Inventory control	Filling , order picking, sorting and packing	End of life waste management options
Transport mode and lengths	Infrastructure conditions	Loading / unloading operations	Change of transport modalities
Product containment	Product protection and preservation	Product convenience	Temperature and humidity control
Product quality	Product shelf life	Product safety and hygiene	Product communication
Packaging material costs	Equipment costs	Waste management costs	Marketing costs
Source: Adapted from [20-23]			

Table 1 Examples of packaging decisions for fresh and processed foods

1.6 Outline of the report

Section 2 of the report provides an overview of food waste in Australia, including the estimated quantities lost at each stage of the supply chain; why this occurs; and how waste is influenced by demographic, industry and lifestyle trends. Opportunities to reduce food loss and waste through improvements in packaging are then explored in Section 3.

2 Where and why food waste is generated

2.1 Overview

Efforts to measure and understand the reasons for food waste have gained momentum in recent years. A report for the FAO estimated that around one-third of the edible parts of food produced for human consumption is lost or wasted globally; equivalent to 1.3 billion ton each year [3, p. 4]. In the United States, the figure is likely to be closer to 40% ([24] cited in [2]).

There is no publicly available data on the percentage of food that is grown or sold in Australia for human consumption that eventually becomes waste. However, the per capita food loss for North America and Oceania combined (including Australia) is estimated to be around 280-300 kg per year, which is equivalent to around 6.5 million tonnes of food waste in Australia² [25]. The average household in New South Wales (NSW) throws out \$1,036 of food each year [26]. If this figure is extrapolated to all households in Australia, the total figure is close to \$8 billion³.

Around 4.2 million tonnes of food waste are disposed to landfill in Australia each year, with almost half of the commercial and industrial (C&I) waste coming from the food services sector [27, p. 140] (Figure 4).

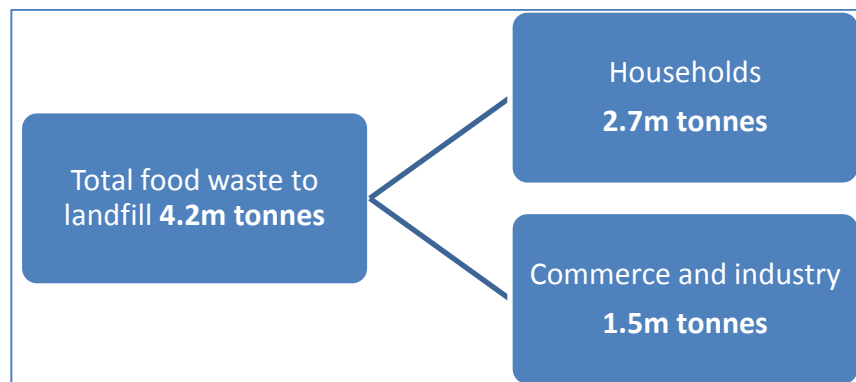


Figure 4: Sources of food waste in Australia

Source: Estimates from the National Waste Report [1] and Encycle and SRU [31]. Note: These figures exclude food that doesn't reach its intended market and is either donated to charity, sold at a lower market value (e.g., as stock feed) or recycled.

Figure 5 provides a simplified model of Australia's food supply chain illustrating the key food loss and waste flows and end of life waste management treatment options. Food becomes waste for a variety of reasons depending on the food type and business sector, but some general observations can be made for each stage in the supply chain. These are discussed in sections 2.2 to 2.6.

² Based on a population of 22,893,354.

³ Based on ABS figure of 7,760,320 occupied dwellings from the 2011 census.
http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/0

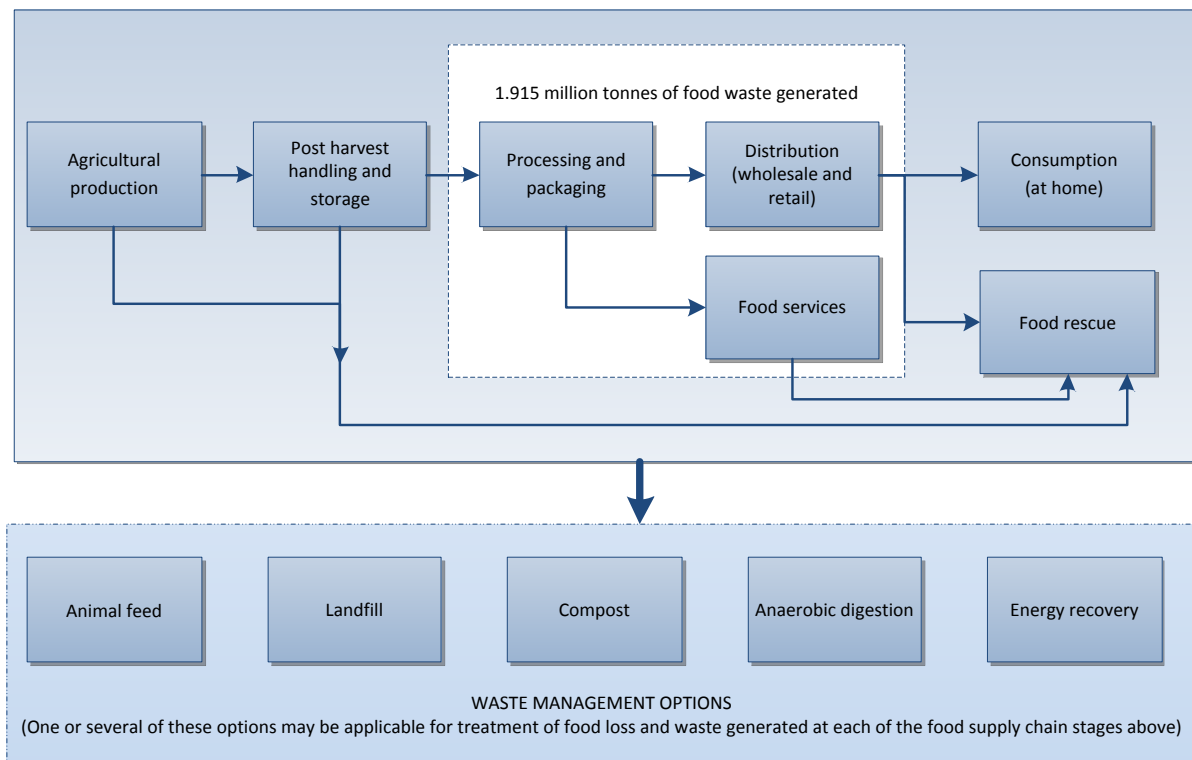


Figure 5 The food supply and recovery chain in Australia

Source: Adapted from National Food Plan green paper [12, p. 26] and Viridis [28, p. 9]. Waste values for processing, distribution and food services from [29].

In less developed economies food tends to be lost at the agricultural and post-harvest stages [30] due to inefficient harvesting, storage, transport and processing. Waste tends to move up the distribution chain to the retail and consumer levels as the standard of development improves [13, 30]. This is where food is much more likely to be thrown away when it is still edible [3].

Australian data on how much and why food is lost and wasted at each stage of the supply chain (i.e. pre-purchase) is relatively limited [31]. Two recent studies for the National Waste Policy Implementation Program have started to address this gap [28, 29], with the exception of agricultural production and post-harvest handling and storage.

A report to the Australian Government on commercial and industrial (C&I) waste [29] included some important findings relating to food waste⁴ (**Figure 6**):

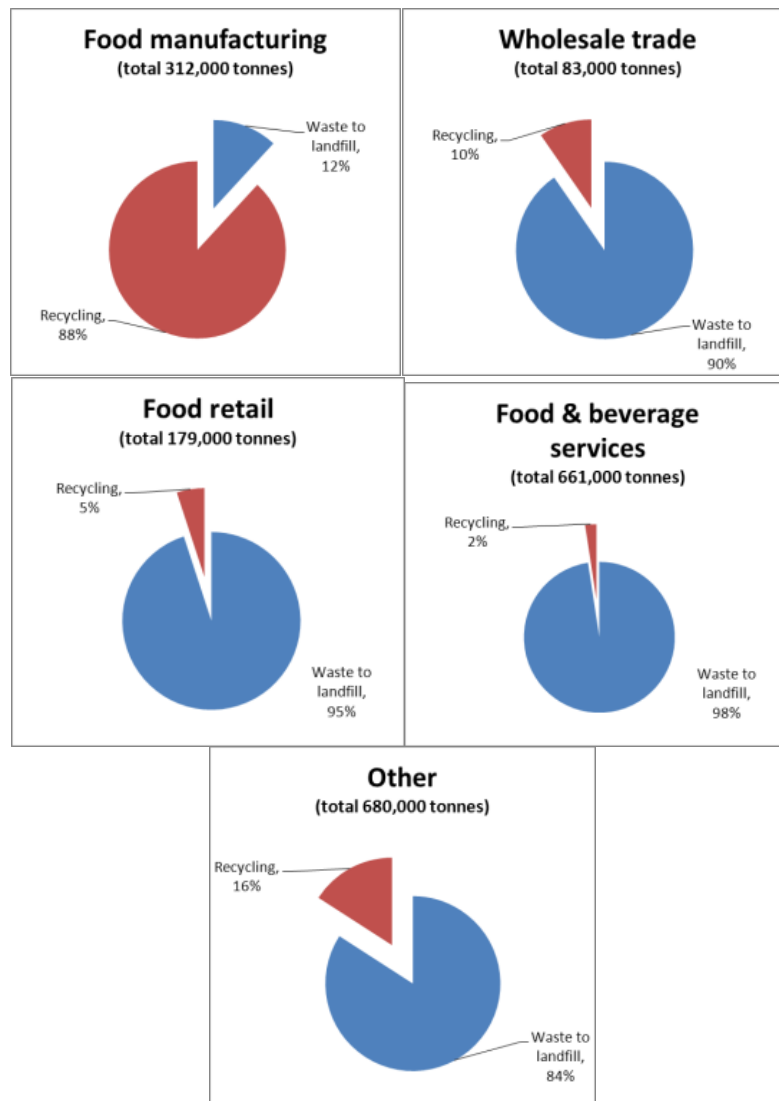
- The largest single contributor to food waste in Australia is the food services sector (food and beverage services) (refer Section 2.6), which includes businesses such as hotels, pubs, restaurants, cafes and commercial caterers. This sector recycles only 2% of the food waste they generate and send approximately 645,000 tonnes to landfill each year.
- The second largest contributor is the food retail sector (refer Section 2.5), which also recycles very little (5%) and sends around 170,000 tonnes to landfill each year. The areas of high loss are perishable products such as fruit, vegetables, meat, bread and cut flowers. Another 75,000 tonnes is sent to landfill from the wholesale trade sector.
- The food manufacturing sector (refer Section 2.4) generates a significant amount of food waste but with a recycling rate of around 88% sends very little to landfill. A large proportion of this waste is unavoidable, for example skins, seeds, bones and other inedible food components. One of the reasons for the high recovery rate for food waste is that

⁴ The research involved a meta-analysis of existing waste audits and reports, supplemented by interviews and site visits. Various assumptions were used to extrapolate the data nationally and to break it down into the sub-sectors.

manufacturers produce relatively consistent and uncontaminated wastes that can be used for animal feed or as feedstock for composting.

- The remaining food waste is generated in manufacturing and service organisations that are largely outside the food supply chain. Most of this waste is related to employee consumption, i.e. generated in canteens and kitchens.

Figure 6 Food waste generated in the C&I sector in Australia 2012 and sent for recycling and landfill*



Source: Based on unpublished data from Encycle Consulting and Sustainable Resource Use [29]

* The 'other' category includes over 20 other sectors that include all other manufacturing (mainly plate waste from canteens and kitchens), other retail, accommodation, finance and other service sectors.

Low recovery rates for C&I food waste (with the exception of the food manufacturing sector) can be attributed to inadequate infrastructure for recovery; difficulties in on-site handling, storage and collection; and the low value of this material compared to other recyclables [29]. This waste represents a significant cost to business. In addition to the costs of waste disposal and recycling, the value of food inputs that are ultimately thrown away or recycled by the C&I sector in Australia is estimated to be around \$10.5 billion [29, p. 104].

The amount of food wasted at each point in the supply chain varies significantly between food types. Specific data for Australia is not available, but **Figure 7** shows the percentage of the *edible* components of food that is wasted at each stage of the supply chain in North America and Oceania (including Australia). For example, wastage rates for fruit and vegetables in the supply chain are 4% in post-harvest handling and storage, 2% in processing and packaging, and 12% in distribution including retail. Overall wastage rates are highest in consumption, followed by agricultural production. The reasons for food loss and waste at each stage of the supply chain are discussed further below.

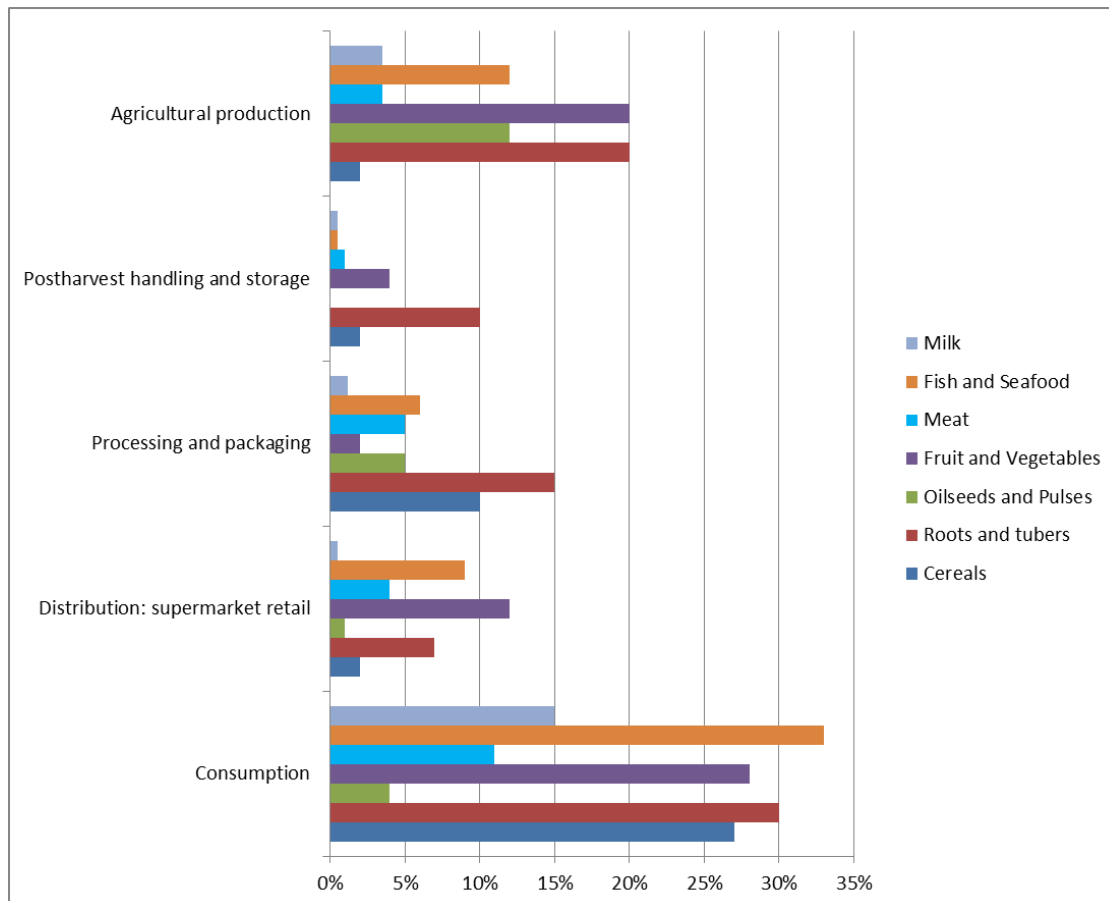


Figure 7 The estimated waste for each commodity group in each step of the food supply chain for North America and Oceania (as a percentage of what enters each step)

Source: Gustavsson *et al* [3, p. 26]

2.2 Agricultural production

There are many factors that contribute to food loss as farmers try to grow the required quantities to match demand [2]. These include:

- crop variability or abandonment due to damage from pests and disease and the unpredictability of extreme weather conditions (e.g., drought, floods, and cyclones) [2, cited in 10, 32] and
- quality control measures to meet contractual obligations to customers (processors, wholesalers and retailers) [2, 3, cited in 10, 32, 33].

While some surplus produce is sold to food processors or farmers, often at a financial loss, alternative avenues are opening up for 'out of spec'/unsaleable food. In Australia, Foodbank (see *Case study 1: Foodbank (food rescue) on page 42*) recently started collecting surplus produce from farmers to supply charities. In California, Arizona, Oregon and Colorado, growers receive a tax credit for donating excess produce to state food banks [2].

The high Australian dollar is contributing to an increase in imports by making imported raw materials and packaged food items cheaper and more competitive. The value of total industry imports in 2009 was \$25 billion, equivalent to almost 23% of domestic industry turnover, compared to 17% in 2002 [34, p 24]. The value of food imports has doubled over the past 10 years (**Figure 8**).

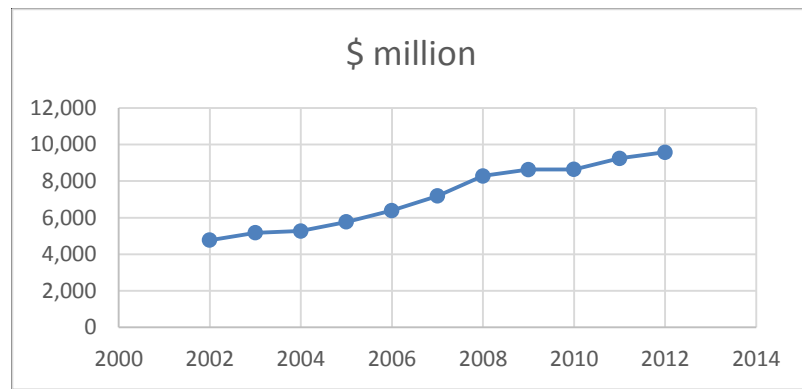


Figure 8 Food imports, Australia, 2002 – 2012

Source: Based on [35, Table 13a]

Imports are likely to continue increasing as a percentage of the market due to the high exchange rate, a contracting local manufacturing sector and the impacts of climate change on agricultural production. Food processors will need to diversify their sources of raw materials to guarantee supply in a more uncertain climate:

“A few years ago we had to source some of our raw materials from overseas because of the drought. We had to go through a long process with the supplier to get the quality right. We’ve experienced more waste from imports due to water or vibration damage, or sometimes it’s just the quality of the grain or the milling process.” Interviewee (brand owner)

The longer and more complex supply chains associated with imports have a number of implications for food waste (**Figure 9**). There are increased risks of product damage, so packaging is even more critical, but importers may have less control over packaging than they would if they were buying locally.

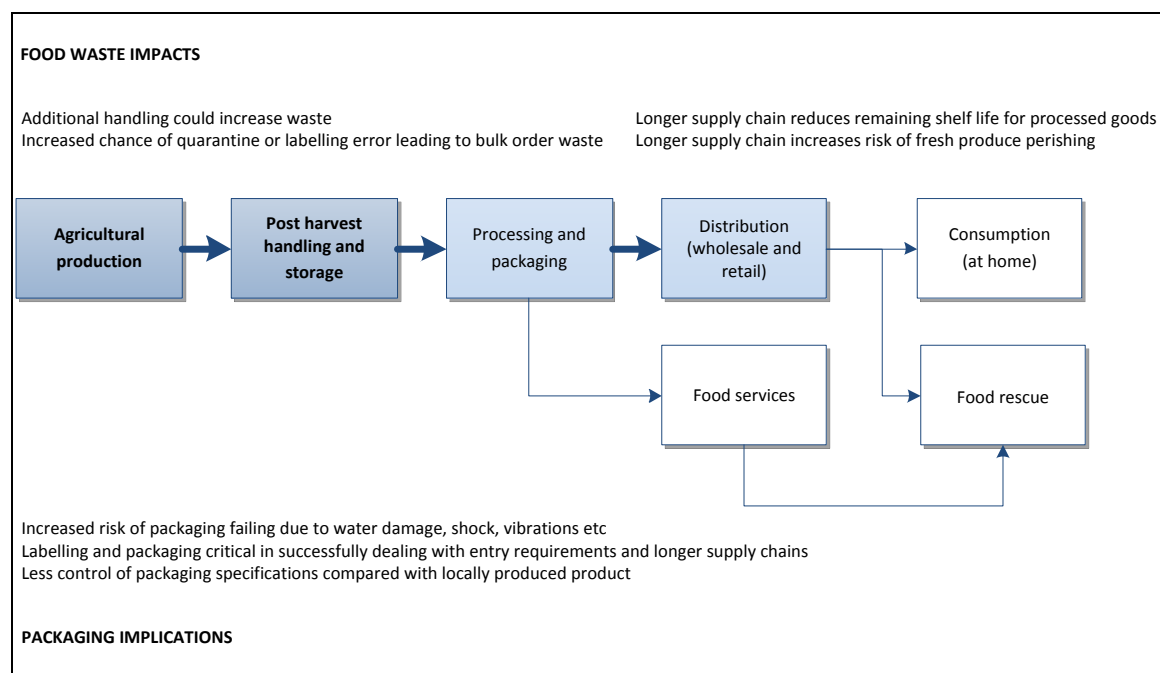


Figure 9 Food imports – possible impacts on food and packaging waste

2.3 Post-harvest handling and storage

In the fresh produce sector, loss occurs during grading and trimming to meet quality and/or appearance standards [2, 33], pest damage [31, 32], as well as spillage and degradation during handling, storage and transportation:

"Most waste is generated at the packing sheds. This varies a lot depending on the product and the season; from around 2% up to 20%."

Interviewee (grower/wholesaler).

"We have waste from trimmings, quality assurance (if something doesn't meet the quality standard) or damage. If a product spends time outside its required temperature range it also needs to be thrown away....so waste is due to either quality or food safety."

Interviewee (grower/wholesaler).

Product that doesn't meet retailer specifications is often sold to food processors (e.g. for juice or canned produce), smaller retailers or through farmers markets. One of the growers interviewed for this study estimated that around 5-8% of their produce is sold through secondary markets and around 2% on average is thrown away.

Trimming and unsaleable product are often recovered for stock feed or compost. At Sydney Markets, for example, fruit and vegetable waste is recycled through an alternative waste facility that generates energy and fertiliser.

In the meat, dairy and seafood industries, other sources of loss include [3, p 2]:

- animal deaths during transport and condemnation at the slaughterhouse
- fish spillage and degradation during icing, packaging, storage and transportation after landing
- milk spillage and degradation during transportation between farm and distribution.

2.4 Processing and packaging

Losses during food processing include trimmings of both the edible (e.g., fat, skins, peels, end pieces, crusts) and inedible (e.g., pits and bones) portions of the fresh produce [2]. In the meat industry lack of demand for many animal parts (e.g., offal) is also a contributor [33].

Sources of waste identified by interviewees for this study include:

- product waste during start up, for example while waiting for an oven to reach the required temperature
- batches that don't work out the way they should, for example due to variability in natural raw materials
- rejects due to quality control, for example, if a metal detector identifies something in the product
- spillage on conveyor belts and at transfer points
- regular, planned shutdowns for cleaning
- dust extraction to maintain a safe working environment, which generates a large quantity of particle fines
- equipment failures resulting in an unplanned stoppage.

One of the food manufacturers interviewed for this research mentioned that the bill of materials for most products makes an allowance for waste, often in the order of 5-10%. While some of this is inevitable, the interviewee observed that *'there is also a cultural issue that a certain amount of waste is acceptable and normal.'*

Manufacturers aim to maintain a minimum 'safety stock level' for finished products to make sure that they can meet their contractual obligations to customers. If stock turnover is too slow, a batch may become unsaleable because its shelf life falls below the retailer's 'minimum remaining shelf life'. This is generally expressed as either a percentage of the remaining shelf life or a minimum time period, depending on the product.

Some interviewees noted that over-production losses are falling due to improved forecasting and information sharing in the supply chain:

“Occasionally we have stock rotation issues, but this isn’t a big problem for us because our products have a long shelf life. We have a finely tuned supply chain to avoid this problem. There would be less than 1% wasted due to product being out of shelf life or returned due to the end of a promotion.”

Interviewee (food brand owner)

When there is excess stock there are options to either sell it through staff shops or secondary markets (discount retail stores or as animal feed); or to donate it to charity (**Figure 10**).

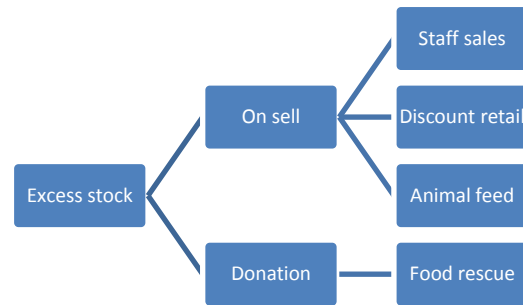


Figure 10 Routes for excess stock

Manufacturers are continually looking for opportunities to reduce waste. This is driven by environmental policies and targets, business improvement programs and rising costs associated with disposal. Most food manufacturers have programs in place to recover food waste, and are working together to achieve this through the AFGC’s *Sustainability Commitment*, which includes a target of reducing waste to landfill by 40% by 2020 [36, p. 15]. For food waste this will be achieved through a combination of process improvements (waste reduction), recovery of edible food for consumption through other channels, and recovery of any remaining wastes for animal feed, compost or energy recovery.

2.5 Distribution (wholesale and retail)

There are many reasons why food is wasted during distribution, including damage in transport, handling and storage. As supply chains increase in length there is an increasing possibility that food could be spoilt or damaged [37], particularly if inadequate packaging is used. This can result in high costs to business.

Loss at the retail distribution centre (DC) can result for a range of reasons, for example:

- if fresh produce doesn’t meet specifications for shape, size and freshness
- if there are problems with the packaging, such as bar codes that are unreadable
- if the packaging has been damaged through rough or improper handling as it moves through the supply chain.

As one retailer explained, *“If a product doesn’t meet our specifications, particularly for fresh food, or if the packaging is damaged, then we won’t send it to the store. The shopper wouldn’t buy it anyway unless it’s heavily discounted, so there’s no point.”*

At the retail store level, the causes of waste include:

- overstocking of shelves [2, 33], which can damage fresh produce due to compression at the bottom of the display
- poor stock rotation by staff, with older products not being moved to the front of the shelf for immediate purchase where ‘best before’ or ‘use by’ dates can be compromised
- fresh produce being thrown away because it no longer meets quality standards.

Perishable products with a short shelf life, such as fresh fruit and vegetables, baked goods, meat and seafood, have a higher tendency to become waste [37] (**Figure 11**). The increasing availability of fresh ready-made meals such as curries, pizzas, soups and salads, catering to the busy consumer, contributes to waste when these products are not sold within their designated shelf life period.

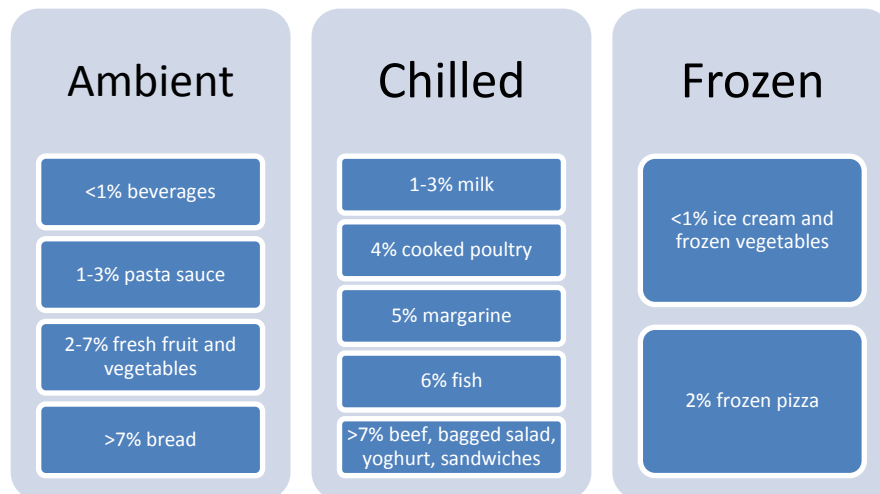


Figure 11 Product food waste at retail, UK and Spain

Source: Adapted from [37, p 653]

Food waste has been defined by the major retailers as any food product that is delivered to a supermarket and not sold [28]. The recovery and disposal of food waste in most supermarkets is guided by a hierarchy of social and environmental value. This is based on the following assumptions:

- human consumption is the optimum for food usage
- if the food is no longer fit for sale, but is still fit for human consumption, it should be redistributed through charity organisations
- if the food is no longer fit for human consumption, it should be reused as a beneficial resource. The most common uses are as livestock feed or fertiliser products.

Most of the larger retailers already have policies and programs to reduce and recover food waste. Woolworths for example, has an ambitious target of diverting all food waste from landfill by 2015 (where facilities are available). In-store strategies include improved ordering and stock rotations that limit products going out of date, and discounting blemished products or those with damaged packaging [38].

These initiatives are driven by corporate environmental commitments as well as ongoing efforts to improve supply chain efficiencies. Woolworths and Coles have already achieved significant savings and reduced product waste by improving the efficiency of their procurement, transport and distribution systems. These efficiencies have helped to reduce the length of the supply chain for many products, with associated benefits for waste reduction. A report by Deloitte Access Economics [39] noted that Coles Supermarkets reduced its costs of doing business by around \$400 million in 2011-12 through a number of supply chain improvements. Woolworths has also achieved efficiency improvements by reducing 'shrinkage' (product loss) and further reducing direct store deliveries [38]. Shorter supply chains, for example to deliver fresh produce from farms direct to DCs or supermarket shelves, are supported by innovations in distribution packaging.

Online expenditure in Australia was estimated to be around \$8.4 billion in 2010 [40, p 87] and is forecast to reach \$26.9 billion by 2016 [41]. While the proportion of food sales made online is still relatively low (around 1%) compared to countries such as the United Kingdom (3-4%) [40, p 102], this may change in the future as food retailers become more aggressive in offering online services. Smaller players in niche sectors are starting to follow suit, for example on-line farmers' markets (e.g. www.efarmersmarket.com.au and www.farmersmarketonline.com). Online shopping requires secondary packaging (such as single use expanded polystyrene boxes or corrugated boxes) to protect the product during transport from the retail or manufacturer to the household, but it doesn't need to be 'shelf ready'. This increases the amount of packaging requiring disposal or recycling in the home but there could be some potential benefits for food waste (**Figure 12**).

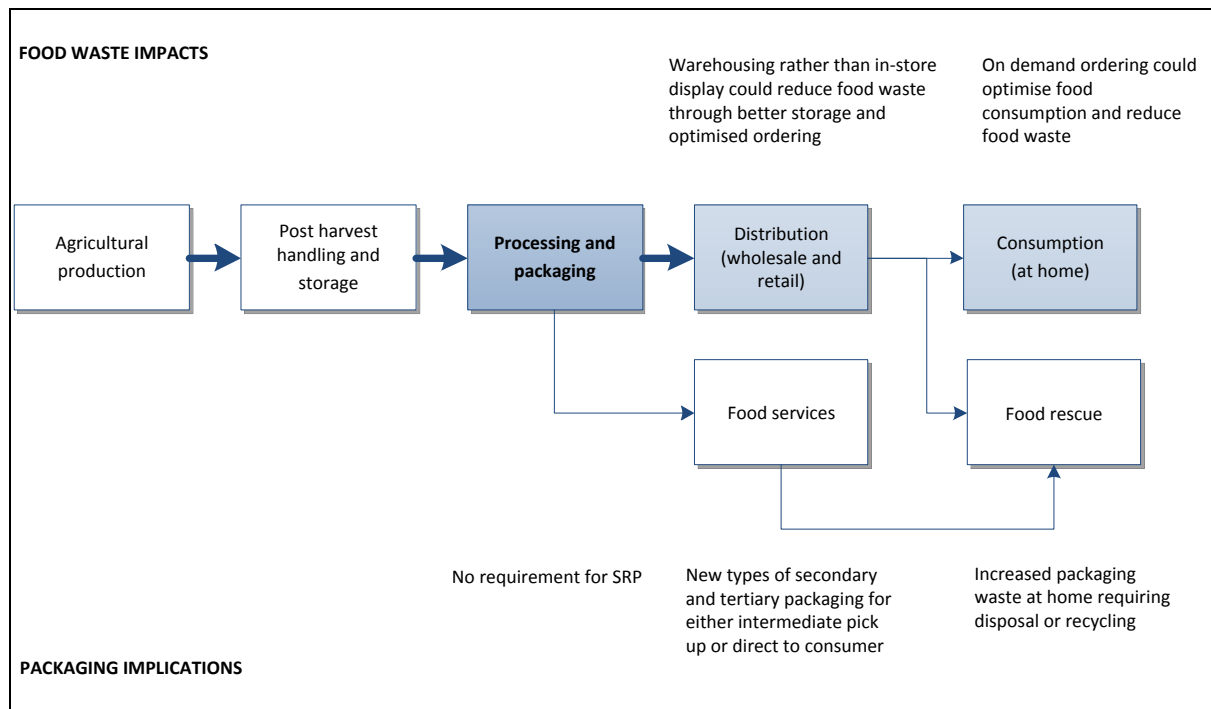


Figure 12 Trend to on-line retail – possible impacts on food and packaging waste

2.6 Food service

More food is being consumed away from home in restaurants, cafes or as ‘take-away’ food (Figure 13). This trend is linked to rising incomes, changes in the way that people choose to spend their time, and smaller households [42]. Food services are also provided by organisations such as caterers, hotels, prisons, nursing homes and hospitals.

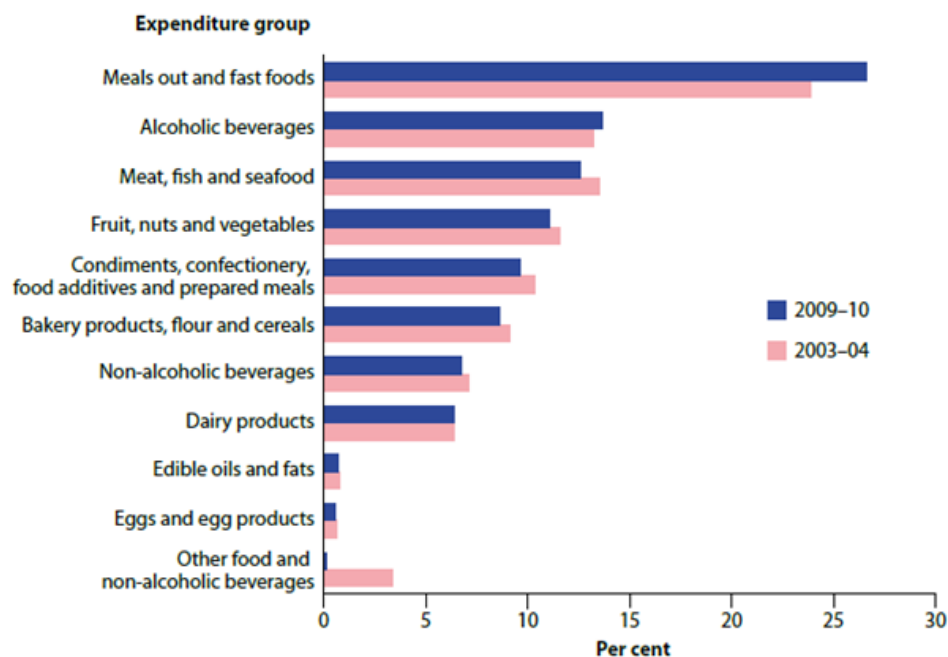


Figure 13 Proportion of total household weekly food expenditure, Australia by selected items, 2003-4 and 2009-10

Source: [43]

The food services sector is the largest single source of commercial and industrial food waste and very little of it is recovered (section 2.1). Factors that contribute to food waste include the complexities involved in balancing and managing inventory stock; the need to maintain a wide range of menu choices and therefore ingredients; improper food storage; confusion over 'use-by' and 'best-before' dates; and large serving sizes [31, 32]. In hospitals, food is often wasted because it is served in packaging that is difficult to open, particularly for patients who are elderly, frail or unwell [44].

An audit of food waste in ten restaurants in the UK by the Sustainable Restaurants Association (SRA) [45] identified three main sources of food waste (**Figure 14**). SRA estimated that if an average restaurant reduced its waste by 20% it could save more than £2,000 from avoided food costs and up to £1,700 on avoided waste collection costs.



Figure 14 Sources of food waste in 10 UK restaurants

Source: Adapted from [45]

According to a global survey by Unilever Food Solutions, consumers are interested in the way that food wastes are managed when they eat away from home. In Australia, 86% of respondents agreed that it is important for eating establishments to reduce the amount of food that is thrown away every day; and 81% believed it was important for them to dispose of food waste in an environmentally-friendly way [46]. Some businesses are already implementing waste reduction strategies:

"Leftovers are reused wherever possible, for example one day old bakery products for bread and butter pudding. We collect all of our food waste in separate bins in the restaurants and the kitchens, and it's collected for composting. This doesn't save us any money but it's the right thing to do." Interviewee (hotel)

Consumption of meals out of the home shifts waste away from the home to a restaurant and/or processing facility (e.g. for pre-prepared components provided to restaurants).

Figure 15 illustrates the potential impacts of a hamburger purchased at a fast food restaurant and consumed in a public place, compared to a hamburger cooked and consumed at home.

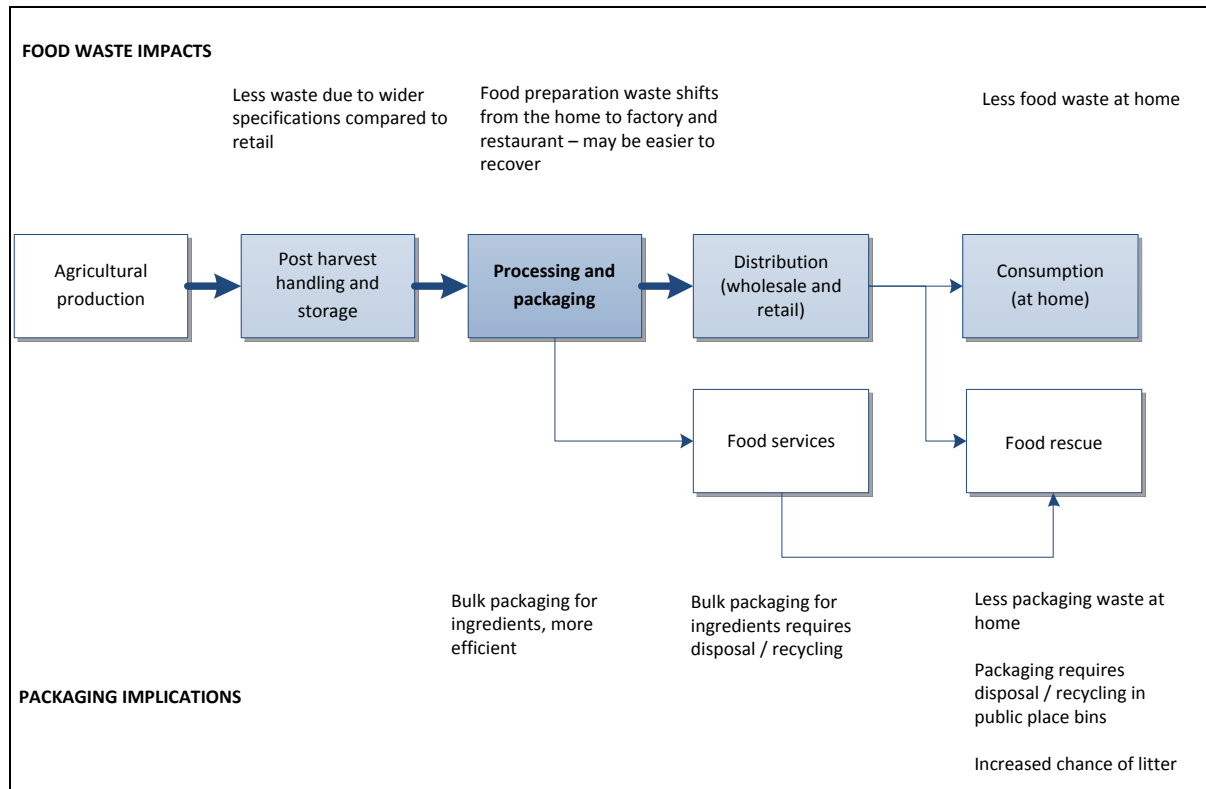


Figure 15 Consuming food away from home – possible impacts on food and packaging waste

Note: From an environmental perspective it is not possible to tell which one has the lowest impact, because this will be highly dependent on individual circumstances (for example how the consumer handles waste at home and away from home, and how the food service company handles its waste).

There are significant opportunities to reduce food waste and increase recovery in the food services sector, primarily by changing procurement and cooking practices in kitchens and by improving the infrastructure for collection and recovery of food waste. However, there may also be some opportunities related to packaging (section 3.2.2).

2.7 Consumption (at home)

In industrialised countries, the largest amount of food waste is generated by households. Australians waste an estimated \$5.2 billion worth of food every year [47, p.10]. Research into household food in other countries using interviews, food diaries and bin audits, has revealed some interesting insights [48-51]. Perishable foods such as fruit, vegetables, dairy products and pre-prepared meals are the largest contributors to food waste (**Figure 16**).

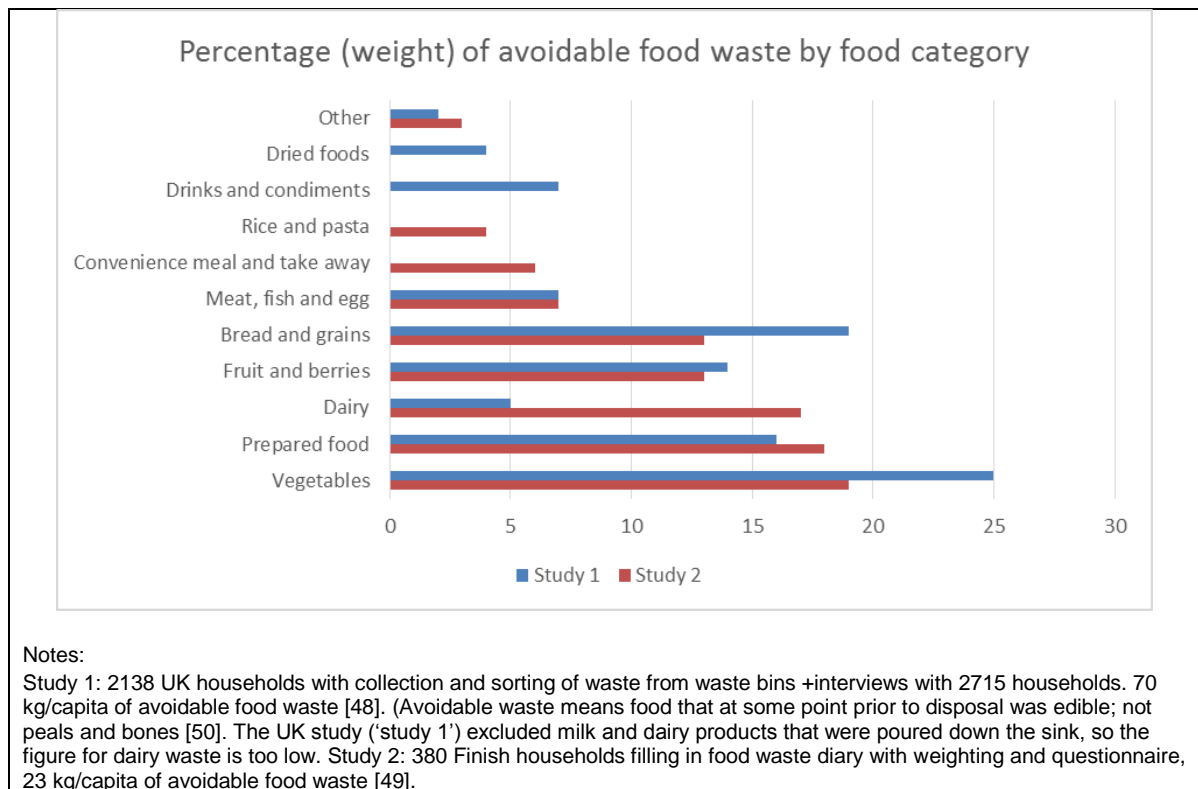


Figure 16 Percentage (weight) of avoidable food waste by food category

Overseas research also indicates why food is wasted in the home. The reasons given by participants include food being spoiled/mouldy or past its expiry date; preparing too much food; and plate waste [48, 50, 51]. Packaging was mentioned as a contributing factor in a Swedish study [51]: over 10% of those surveyed mentioned that the packaging serving size was too big or it was difficult to empty. The problem with serving sizes could be due to one of three issues: limited options to buy an appropriate serving size, purchasing errors by the household or buying packaging that is too large because of its perceived value:

"Promotions [at retail] can also increase household waste as customers might buy unusually large quantities of product. This 'forward buying' can lead to waste, particularly when product shelf-life is short" [37, p 656].

Following Costco's arrival in the Australian market, around one third of Australians are becoming frequent buyers of groceries in bulk, and this may put pressure on Coles and Woolworths to start adopting a bulk packaging and sales strategy [52]. At a household level, bulk product purchasing has the potential to reduce packaging, but this needs to be weighed against the risk of increased product wastage:

"[Larger format products] ... might be driving product into the pantry, but some product will degrade before it's consumed. '2 for 1' and large formats are going against demographic trends, which are towards smaller households and people eating alone."
 Interviewee (food brand owner)

The trend towards smaller households has important implications for food waste and packaging. Australia's population is expected to increase to 35.9 million by 2050 [53, p 5], and the highest growth will be experienced in older age groups. The number aged over 65 is expected to increase from 13.5% in 2010 to 22.7% in 2050. As the population ages there will be an increasing number of people living in single or two person households. Single occupancy households tend to waste around 45% more food per person than the average household [33], so there is clearly an opportunity for food manufacturers to cater for this group by providing smaller serving sizes or resealable packaging (section 3.2.5).

2.8 Summary

Food waste in Australia's food supply chain is predominantly generated in the food service sector (661,000 tonnes), followed by food manufacturing (312,000 tonnes), retailing (179,000 tonnes) and wholesale distribution (83,000 tonnes). Some of this waste is inevitable, for example trimmings from fresh produce, and preparation waste in manufacturing and food services. Other waste is avoidable, for example when it is due to poor inventory management, overstocking of shelves, product damage during transport and handling, or a lack of awareness or interest in recovery options. There are many potential solutions, including education programs to reduce food waste generation and improved services for collection and recovery, which are beyond the scope of this report. In the next section opportunities to minimise food waste at each point of the supply chain through packaging innovation and design are examined.

3 Opportunities to reduce food waste through packaging opportunities

Packaging plays a critical role in protecting fresh produce and processed food in transit, in storage, at point of sale and prior to consumption. In doing so it helps to deliver a wide range of functions while reducing food waste. However, while manufacturers, retailers, government agencies and food recovery organisations are implementing strategies to reduce food waste in the supply chain, there has been little attention paid to the potential contribution of packaging.

Section 2 identified many sources of food loss and waste. The sections below identify packaging opportunities that could be explored by stakeholders operating at key stages of the food supply chain (i.e., agricultural production and post-harvest handling and storage; processing and packaging; distribution (wholesale and retail)), where decisions made can influence the reduction of food waste in proceeding stages.

3.1 Agricultural production and post-harvest handling and storage

Packaging opportunities at this stage are discussed under two central themes (**Figure 17**): improved functionality and food recovery.

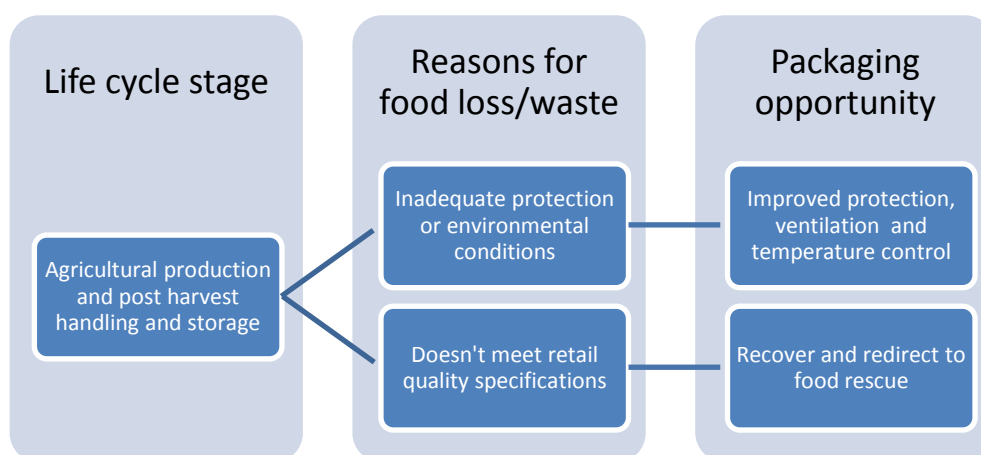


Figure 17 Packaging opportunities in agriculture production and post-harvest handling and storage to reduce food waste

3.1.1 Protecting produce as it moves through to processing and retail

Single use corrugated containers and waxed cardboard and reusable plastic crates are examples of primary and secondary packaging systems that are used to transport fresh produce from the farm or fishery through to the packaging shed, processor, wholesaler or retailer. This packaging must contain and protect the product as it moves through the supply chain, while maintaining appropriate ventilation and temperature control so that the product ripens as required. Inadequate packaging could as a result, contribute to food loss and waste.

The packaging selection process must consider the natural characteristics and shelf life of the different fruits and vegetables and the associated requirements for product protection and shelf life, along with other considerations such as logistics, transport distances and lead times, storage and handling conditions, and procurement costs:

"We need suppliers to work with us to develop solutions for particular product lines. This means working smarter; looking at shelf life requirements and how long it lasts at home. There should be a lot more innovation. We have a good working relationship with our packaging supplier but they don't put enough resources into product trials and R&D. They need to be more flexible and adaptive."
Interviewee (grower/wholesaler).

Reusable plastic packaging has been introduced as primary or secondary packaging in some supply chains to improve efficiencies or extend shelf life, particularly for fresh produce. There is evidence of lower spoilage rates for some varieties of fresh produce in reusable packaging, as a result of both improved structural functionality and better pre-cooling rates due to the increased venting area [54, 55]. This has been confirmed by company case studies [56] and growers/wholesalers interviewed for this research:

“Plastic crates allow for better ventilation and better protection. They also support better transport utilisation because the pallets can be stacked higher. They don’t require as much stretch wrap (only the top layer). There is less handling, although the crates aren’t used as much for retail display as they were originally. Plastic crates allow us to wet the product, which helps extend shelf life (you can’t do that with cardboard).
Interviewee (grower/wholesaler)

There is scope for reusable crates to be extended to additional fresh products, such as bananas, which experience a high loss rate (refer Case study 2: Banana supply chain, page 44). In 2011, ASDA in the UK introduced a reusable plastic crate for all of their imported bananas [57]. The manufacturer claimed that the crate provided better ventilation for faster cooling, as well as a waved base, increased height and stronger side walls for better product protection [58].

Other opportunities mentioned by one interviewee included a half crate for lettuces and tailored packaging solutions for punnets (e.g. cherry tomatoes), squash, ginger, garlic and shallots. Another grower also expressed interest in more products moving into reusable crates but requested a standard system across all of the major retailers to improve efficiencies:

“We’d like to see more product move into plastic crates. They have better air flow than cardboard which means the product cools down quicker and lasts longer. All products generate some heat, and breathability improves with the crates. There is also less damage in transport.

[But] we would like to see one standard crate system across all of our major customers. At the moment it’s not very efficient because we have different crates so we have to pack to order. It would be more efficient and easier to manage if there was only one system.
Interviewee (grower/wholesaler)

While plastic crates provide more robust structural options for food suppliers, these properties have both advantages and disadvantages. If a plastic crate is dropped or has a bumpy transport leg, more shock could be transferred to food within the packaging, while softer corrugated packages may absorb more impact. On the other hand, robust reusable containers may be less susceptible to piercing by sharp objects. Reusable plastic packaging can produce other environmental benefits compared to single use packaging [54, 55, 59, 60], although this is dependent on the product, the supply chain and the number of times the package is reused.

Figure 18 illustrates some of the possible impacts of reusable plastic packaging on food and packaging waste.

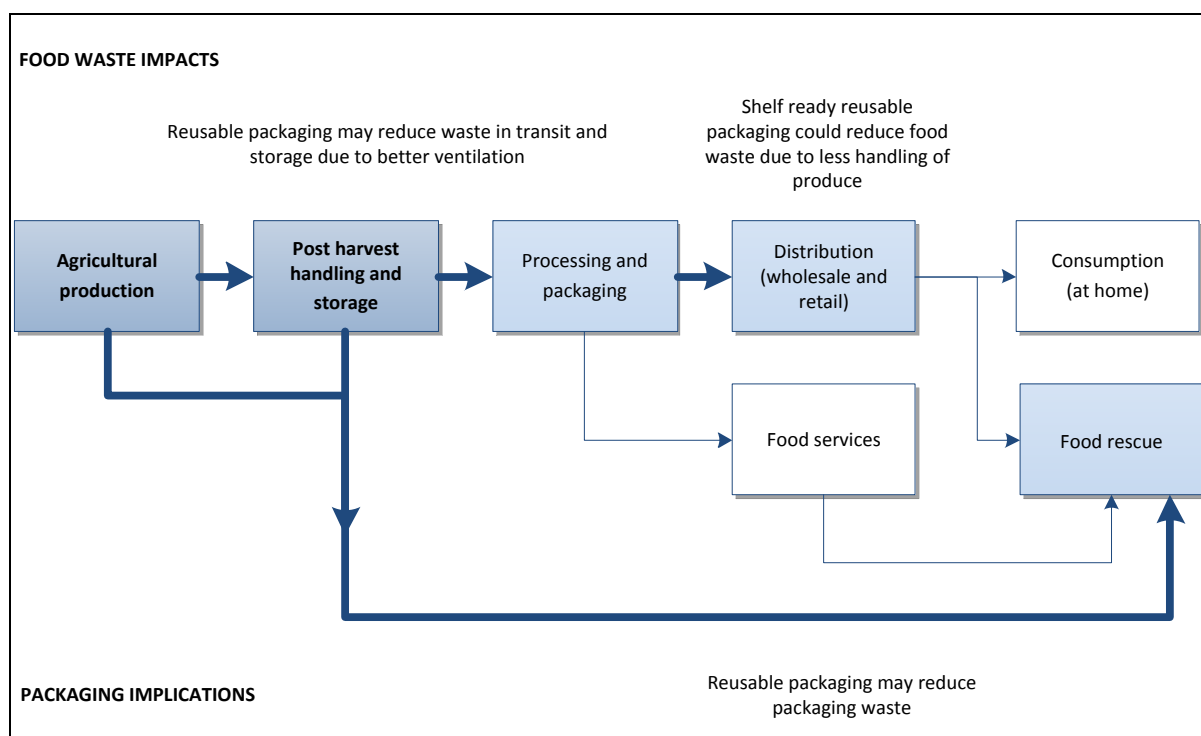


Figure 18 Packaging opportunities at agriculture production and post-harvest handling and storage and the flow on effects to reduce food loss and waste down the supply chain

Note: Thick lines indicate packaging and supply chain opportunities to reduce food loss/waste.

Recommendations for protecting produce as it moves through to the processor, wholesaler or retailer:

- Food and packaging companies to undertake further research and development to understand the impact of different packaging materials and packaging configurations (primary, secondary/tertiary) on specific categories of fresh produce to achieve longer shelf life and reduce product loss and waste.
- Farmers, marketers and packaging suppliers to continue to look for opportunities to introduce reusable plastic packaging for fresh produce where this can achieve longer shelf life through improved ventilation, ripening and temperature control and other efficiencies in the supply chain.

3.1.2 Recovering surplus and unsaleable produce and redirecting to food rescue

The supply of surplus and unsaleable processed foods to food rescue organisations (who redistribute it to charities) has plateaued, as manufacturers and retailers have become more efficient (see Case study 1: Foodbank (food rescue), page 42):

"Two years ago we saw the plateauing of processed food, followed by a decline in supply. We are now increasing supply from the farm gate, and our aim is to increase the proportion of fresh fruit and vegetables to around 40%."
Interviewee (food recovery agency).

New opportunities are currently being developed by food rescue organisations to recover excess or unsaleable fresh produce from farms. Efficient logistics in these new supply chains will require packaging systems that can hold the necessary quantities to take produce from the farm or post-harvest handling (refer Section 2.2 and 2.3) all of the way through to the charitable agencies that rely on food recovery. These packaging systems will need to accommodate the transport of bulk quantities from farm to food recovery organisations, as well as smaller orders from distribution centres to individual charities.

Recommendations for recovering surplus and unsaleable produce:

- Packaging and logistics companies to collaborate with farmers and food recovery organisations to develop packaging solutions for recovery of surplus and unsaleable fresh produce from farms and post-harvest processing facilities.
- Packaging for this purpose will need to consider produce shelf life, ventilation, temperature control and ripening conditions, and ideally provide flexibility for bulk transport from suppliers as well as redistribution to charities (e.g. through a modular configuration).

3.2 Processing and packaging

Packaging opportunities at the processing and packaging stage are discussed below under five central themes (**Figure 19**).

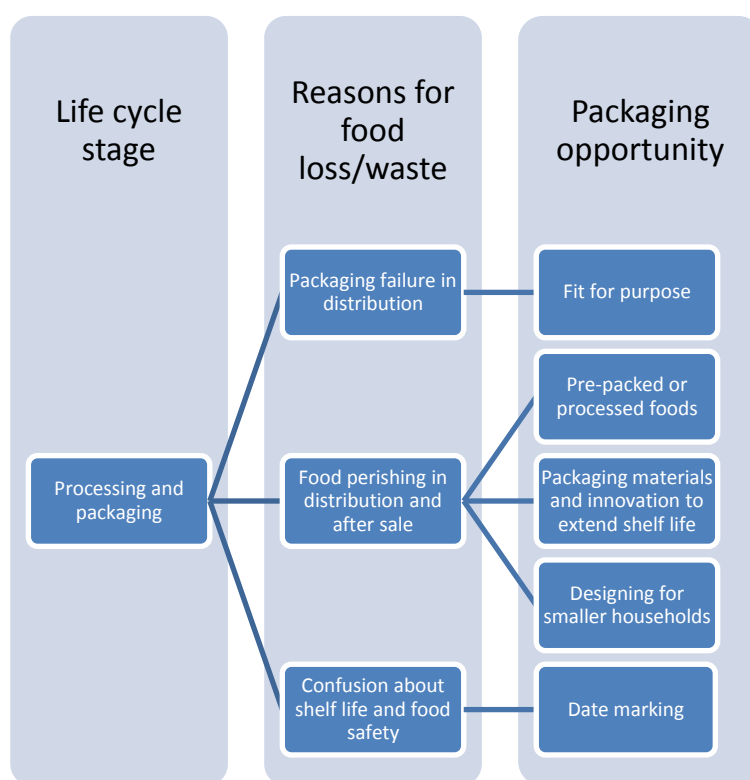


Figure 19 Packaging opportunities in processing and packaging to reduce food waste

3.2.1 Designing fit-for-purpose packaging

Many signatories to the Australian Packaging Covenant are looking for opportunities to reduce the environmental impacts of packaging by eliminating or light-weighting packaging components. If the packaging remains fit-for-purpose, this achieves environmental and financial savings. However, if it goes too far, light-weighting can contribute to packaging failure and product damage in transport and handling:

"We used to use a two piece carton [for bananas] but we believed that neck injury damage that was being sustained during transport was too high and hence moved to a stronger, higher box. Broken neck damage has been almost completely eliminated. By using a clear bag, which was introduced to our business 4 years ago, we have also increased the shelf life of the product."

Interviewee – farmer

Procurement of secondary and tertiary packaging requires an understanding of the physical demands on packaging as it travels through the supply chain:

"We purchased a company last year and found a very high rate of damaged packaging. The source of the problem was inadequate packaging design in the initial selection. It was designed without knowing that pallets are stacked two high in distribution, and it was very rare for a pallet to get through the supply chain without damage. They were relying on suppliers and co-manufacturers to provide advice on packaging but they weren't receiving good technical input. There was a lack of understanding of the distribution chain and what was required."

Interviewee – food brand owner

A fit-for-purpose packaging system balances the functions and technical performance requirements of each level of level of packaging (primary, secondary and tertiary), along with other performance criteria and procurement costs. This requires dialogue with suppliers and customers to ensure that functionality and efficiencies are maintained across the supply chain.

Recommendations for designing fit-for-purpose packaging:

- Food brand owners and contract packers to investigate their distribution chain to fully understand the demands on packaging during transport, storage and handling. This could be done through a collaborative project with logistics contractors and customers.
- Professional and training organisations to investigate options to build industry knowledge and skills in packaging design and specification; with a particular focus on managing trade-offs between packaging efficiency and food waste throughout the supply chain. This could include the development of case studies for dissemination to industry.

3.2.2 Pre-packed or processed foods

Consumers are increasingly looking for 'convenience' foods that reduce preparation and cooking time (see Section 2.5), while processors and retailers are looking to extend product shelf life. Examples include fresh produce that is pre-packed, often with some processing (e.g. cut and washed lettuce leaves) as well as foods that are ready to eat (e.g. fresh soups or frozen meals). This trend is expected to continue, driven by consumer demand as well as packaging and product innovation from suppliers:

"We will see...a lot more people looking for easy meals to cook, or ingredients that are easy to use for preparation from scratch... the time poor will drive more products in portion control or that are easy to use."

Interviewee (packaging manufacturer)

"If you look overseas, in the US for example, around 90% of fresh produce on display at retail is pre-packed. Here it's probably closer to 10% but increasing."

Interviewee (grower/wholesaler)

The ongoing trend to pre-packed fresh produce and processed foods, will be supported by continuing innovation in packaging materials (e.g. section 3.2.3) and new formats that cater to a changing demographic (section 3.2.5).

Pre-processing and packaging can reduce food waste in the supply chain and in the home by extending shelf life. A fresh produce supplier interviewed for this research noted that plastic film around a bunch of fresh herbs can extend its shelf life from two to five days. The new trend to pack fresh herbs in punnets doubles this again. The impact on shelf life may not always be positive, however. Some fresh cut vegetables may have a shorter shelf life due to washing, peeling and cutting, which result in a faster physiological deterioration and microbial degradation [61].

The challenge is to balance convenience, packaging, shelf life and product waste for each type of product (see **Figure 20**). For example, when a consumer purchases a pre-prepared food product, some of the food preparation waste is effectively shifted from the home to the manufacturing sector. This is likely to have a positive impact on food waste recovery – about 50% of organic wastes from households ends up in landfill [62], compared to 12% from food manufacturers [29]. This will be offset by increased amounts of packaging waste requiring disposal or recycling at the household level.

Packaging can also make it more difficult to recover food that has perished or passed its use-by date:

“A big issue for us is that we’re getting more produce in packaging, for example in punnets. These need to be manually handled to remove the produce for recycling. The recycler can handle some contamination but not all in one load.”
Interviewee (produce market)

The retail trend from loose fresh produce to more pre-packed and processed food products has implications for secondary and tertiary packaging. This may be simpler and less robust secondary packaging, but will need to be sufficient to protect the functional requirements of the primary packaging (e.g. containment, protection and extended shelf life).

These impacts are illustrated for a hypothetical example in **Figure 20**, which compares a pre-prepared packaged salad with a salad made from individual ingredients at home.

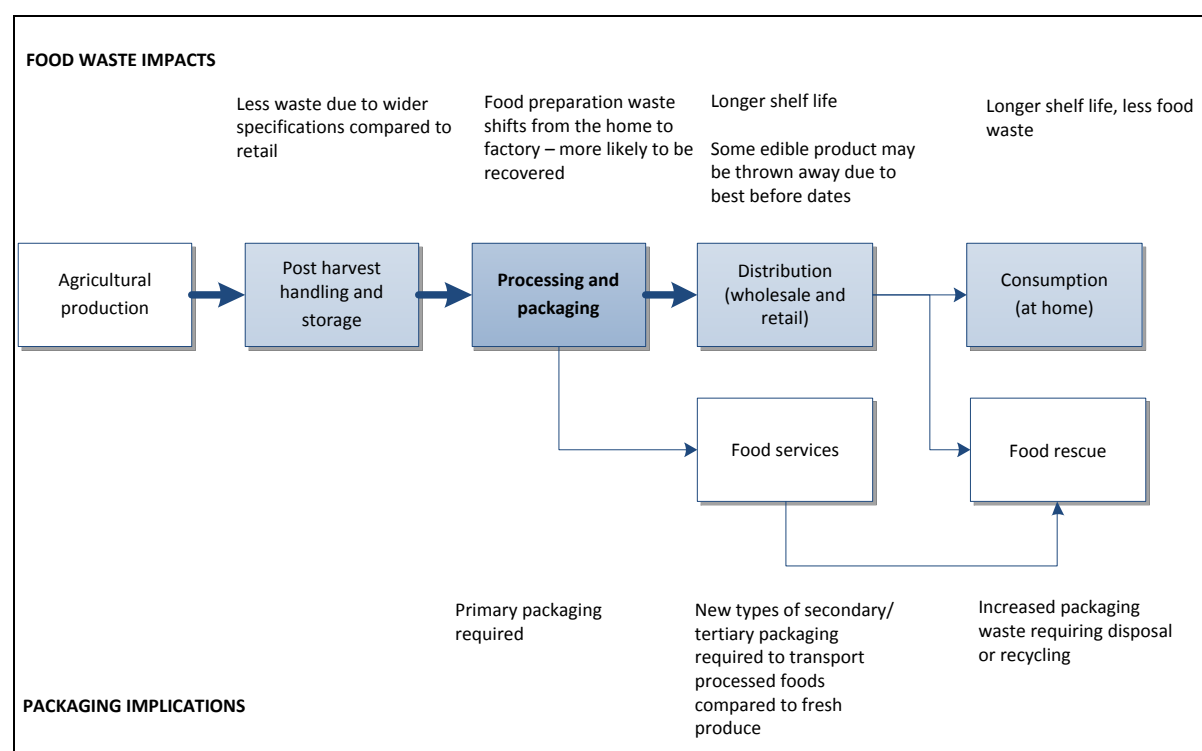


Figure 20 Buying pre-prepared foods – possible impacts on food and packaging waste

There may also be opportunities to provide more pre-packed or semi-processed products to food service establishments to help them reduce food preparation waste. Food services is the single largest source of food waste from the commercial and industrial sector (see **Figure 6**); generating around 645,000 tonnes of food waste each year and sending 98% of it to landfill [29]. Research in the UK estimated that 65% of food waste from restaurants is from preparation [45] (see **Figure 14**, page 20). While most opportunities to reduce waste are likely to be from changing behaviour e.g., ordering and cooking practices, and providing better services for recovery of food waste; manufacturers could consider the potential to reduce food preparation waste by providing more pre-prepared ingredients (e.g. cut vegetables).

There are also opportunities to focus packaging development more explicitly on design to reduce food waste, for example by ensuring that a product can be completely consumed. A recent example is the invention of the ‘LiquiGlide’ surface treatment by Massachusetts Institute of Technology in the United States, which enables sauces and other liquid products to be completely dispensed from a bottle or jar [63]. Ensuring that the product can be fully dispensed will lower the overall environmental impact of the product-packaging system [19].

Recommendations for pre-packed or processed food:

- Food brand owners and packaging manufacturers to continue to look for product and packaging innovations that extend the shelf life of fresh produce. While additional packaging may provide significant benefits in reduced food waste, it also needs to be designed for recovery at end of life.
- Government or professional organisations to compile and disseminate case studies that describe how companies have reduced food waste through new product-packaging solutions.
- Produce wholesalers and brand owners to investigate new products and packaging systems for the food services sector to reduce waste in food preparation.
- Fresh produce suppliers and food brand owners to work with the food services sector to educate and train staff about product shelf life and packaging attributes designed to reduce product waste.

3.2.3 Packaging materials and technologies that extend shelf life

Consumers now demand seasonal fresh produce all year round (refer Section 2.5). This, combined with the drive by retailers to extend shelf life, has given rise to new technologies that help to maintain freshness for longer periods:

“We are trying to achieve a better product shelf life, and packaging plays a major role in that. We are looking for any gains that we can get that will influence our ability to produce goods in advance of the dates they are required, but also to enable things to be on the shelf for longer, to allow the consumer to feel more confident about the products they are purchasing... this allows for a longer supply chain and will reduce food waste through spoilage.”
Interviewee (food brand owner)

Examples of these technologies are shown in Table 2. Some are used to create ‘active’ packaging, a term used to describe packaging that responds to or controls the environment of a product [64]. Active packaging has the potential to reduce food waste by extending time in the supply chain and the shelf life of products giving consumers the longest possible time to buy and consume.

From a cost and food waste perspective it is particularly important to protect food products with high environmental impact, like fish, meat and dairy products (refer to Section 1.5). Packaging solutions such as modified atmosphere packaging (MAP) or time-temperature food quality labels may increase shelf life [65]. However, consumers tend to be concerned about the use of new technologies with food. Participants in a Brazilian case study were more concerned about food hazards with technological origins than natural risks such as microbiological contaminants [66]. This is consistent with research from the UK [67, 68].

Food brand owners and packaging companies need to understand consumer acceptance of new technologies and if necessary develop communication strategies to support the product launch [69]. A Canadian case study suggested that information on the positive and potentially negative properties of vacuum packaging had a positive influence on consumer attitudes and their willingness to pay for vacuum-packaged beef steaks [69].

Cold or non-thermal pasteurisation technologies have developed in recent years to offer the freshness of flavour and texture that consumers want. The high pressure pasteurisation is undertaken within the pack and often has little impact on product quality. There are over 120 commercial operations that undertake this process worldwide, for products such as juices and smoothies, avocado and tomato products [70].

Most of the technologies in Table 2 are applied to primary packaging, because this is where shelf life is a critical design requirement. Secondary and tertiary packaging is generally used to facilitate the movement of the primary pack through the supply chain, rather than to extend shelf life. Design innovations for secondary packaging that help to extend shelf life, particularly for fresh produce, are discussed in sections 3.1.1 (fit-for-purpose packaging in distribution) and 3.3.3 (retail ready packaging).

Table 2 Examples of primary packaging technologies to extend shelf life

Technology	Description	Potential impact on food waste
Multi-layer barrier packaging	Packaging that contains multiple layers to provide the required barriers to moisture, gases (see MAP below) and odour. Specific requirements can be met using a combination of polymers, aluminium foil and/or coatings.	Keeping out moisture and oxygen delays product degradation.
Modified atmosphere packaging (MAP)	Gases are added to packaging before it is sealed to control the atmosphere within the pack, and then maintained by a high gas barrier film, e.g. through vacuum packaging. Carbon dioxide is added, alone or with nitrogen and sometimes oxygen, depending on the product (e.g. meat, cheese, fruit and vegetables).	Reduces respiration rates in the product and reduces growth of microorganisms.
Edible coatings	Based on a range of proteins, lipids, polysaccharides and their composites, they can be used on fruit, vegetables, meat, confectionary and other products.	Create a barrier directly around food products (rather than external packaging).
Ethylene scavengers	A range of different technologies that involve chemical reagents added to polymer films or sachets to absorb ethylene. Used for fruit and vegetables.	Removal of ethylene delays ripening and extends the shelf life of fresh produce.
Oxygen scavengers	Substances that remove oxygen from a closed package. They are often in powder form (e.g. rust powder) in a sachet. New technologies include oxygen scavengers in the film itself. Used for sliced processed meat, ready-to-eat meals, beer and bakery products.	Oxygen accelerates degradation of food by causing off-flavour, colour change, nutrient loss and microbial attack (bacteria and fungi). Removing oxygen slows the degradation process and extends the shelf life of the food.
Moisture absorbers	Pads made from super-absorbent polymers, which absorb moisture. Used for fresh meat, poultry, and fresh fish.	Maintain conditions that are less favourable for growth or microorganisms.
Aseptic packaging	Packaging that has been sterilized prior to filling with Ultra High Temperature (UHT) treated food. This gives a shelf life of over 6 months without preservatives. Formats include liquidpaperboard, pouches and bag-in-box.	High temperatures kill microorganisms and tight seals on the packaging prevent the entry of microorganisms, gas or moisture that could promote degradation.

Recommendations for primary packaging technologies to extend product shelf life:

- Packaging suppliers and research organisations to continue innovation in primary packaging technologies to extend the shelf life of perishable products such as fruit, vegetables, meat and ready-made meals.
- Packaging developers to take a holistic approach to the design of the packaging system (primary, secondary and tertiary) to ensure that the system as a whole will protect and maintain the shelf life extension technologies in the primary packaging.
- Food brand owners to provide education and awareness programs for consumers (e.g. through on pack communications), regarding product shelf life and packaging features that have been designed to extend shelf life (e.g., resealability).

3.2.4 Date marking

Best-before and use-by dates are provided on fresh and processed foods to provide retail staff and consumers with information on remaining shelf life (see Section 2.5). However, these terms have different definitions and are often used incorrectly. The AFGC's guidelines on date marking⁵, which are based on the Food Standards Code, include the following definitions:

- *Best before date, in relation to a package of food, means the date which signifies the end of the period during which the intact package of food, if stored in accordance with any stated storage conditions, will remain fully marketable and will retain any specific qualities for which express or implied claims have been made*
- *Use by date, in relation to a package of food, means the date which signifies the end of the estimated period if stored in accordance with any stated storage conditions, after which the intact package of food should not be consumed because of health and safety reasons.*

Confusion about the meaning of these terms can result in food that is still edible being removed from supermarket shelves and thrown away [2, 33]. The Food Standards Code only requires a use-by or best-before date on packaged food with a shelf life of less than two years. Despite this, dates are increasingly being added on products with a shelf life longer than two years to aid with stock management and to help consumers identify how long a food has been in their pantry [71, p 3].

Manufacturers need to ensure that 'use by' and 'best before' dates on packaging are visible and easy to read. Missing or inadequate labelling may prompt consumers or retailers to throw food away when it is still edible.

Recommendations for date marking:

- Government, industry and professional organisations to educate stakeholders, including food manufacturers, retailers and consumers, about the meaning of best-before and use-by dates, building on AFGC's *A guide to the application of date marking of food*.
- Food brand owners to ensure that best-before and use-by dates are clearly communicated on primary packaging, and inform consumers about date marking and packaging features to maintain product quality and shelf life after opening.

3.2.5 Design for smaller households

Packaging innovations such as those described above (Section 3.2.3) can reduce food waste by extending a product's shelf life. There are also opportunities to redesign packaging to help consumers reduce waste through different packs sizes and other convenience features. The challenge is to design primary packaging and secondary packaging that accommodates the changing wants and needs of consumers. Significant social and lifestyle changes include a trend towards online shopping (Section 2.5), an ageing population, smaller households, and demand for more convenience and pre-prepared foods (Section 2.7). For example, the trend towards bulk retailing to provide value for consumers may increase food waste if consumers end up buying more than they need:

"Because of their focus on value, retailers are pushing for larger format products ... This might be driving product into the pantry, but some product will degrade before it's consumed. 'Two for one' and large formats are going against demographic trends, which are towards smaller households and people eating alone."

Interviewee (food brand owner)

⁵ www.afgc.org.au/health-and-nutrition/labelling.html

When this occurs the product is more likely to go out of date before it can be completely consumed, resulting in the generation of food waste. With an ageing population and a trend towards single or two person households, manufacturers need to consider how they can meet consumer demand for smaller or more flexible pack sizes:

“Pack sizes have been reduced for many cereals. This was driven by the desire to offer a more affordable option for consumers, but we found that many of these products were being purchased by pensioners because they had trouble consuming the larger boxes before they lost freshness.”

Interviewee (food brand owner)

Examples of design strategies for primary packaging to reduce food waste are described in **Table 3**. The same considerations apply to primary packaging whether the product is sold in-store or on-line.

Table 3: Examples of primary packaging design to reduce food waste in the home

Design feature	Description	Potential impact on food waste
Reclosable packs	Examples include zip-lock bags and pouches, resalable cheese and cereal bags, and ‘fridge packs’ (plastic screw top jars) for products like baked beans	Being able to reseal packs helps to keep food fresh for longer.
Smaller packs	Examples include half loaves of bread, single serves of yoghurt	Allow smaller households to only buy what they need.
Sub-divided packs	Packs divided into portions, for example sliced meat in separate compartments.	Allows consumers to use what they need and keep the remainder sealed in the packaging.
Detailed storage advice on the label	This could include where to store the food, for example whether or not it should be stored in the fridge, or encouraging consumers to ‘freeze before the date’.	Could improve food storage practices and extend shelf life in the home.

Recommendations for design for smaller households:

- Industry and professional organisations to design training programs or events to promote design initiatives that reduce food waste in the home and disseminate these as case studies to industry and consumers.
- Support research that investigates and calculates the environmental, economic and social impacts of different packaging formats (ambient, chilled, and frozen) for fresh and processed food and communicate these to industry, government and consumers.

3.3 Distribution (wholesale and retail)

Packaging opportunities to reduce food waste at the distribution stage are discussed below under three central themes (**Figure 21**).

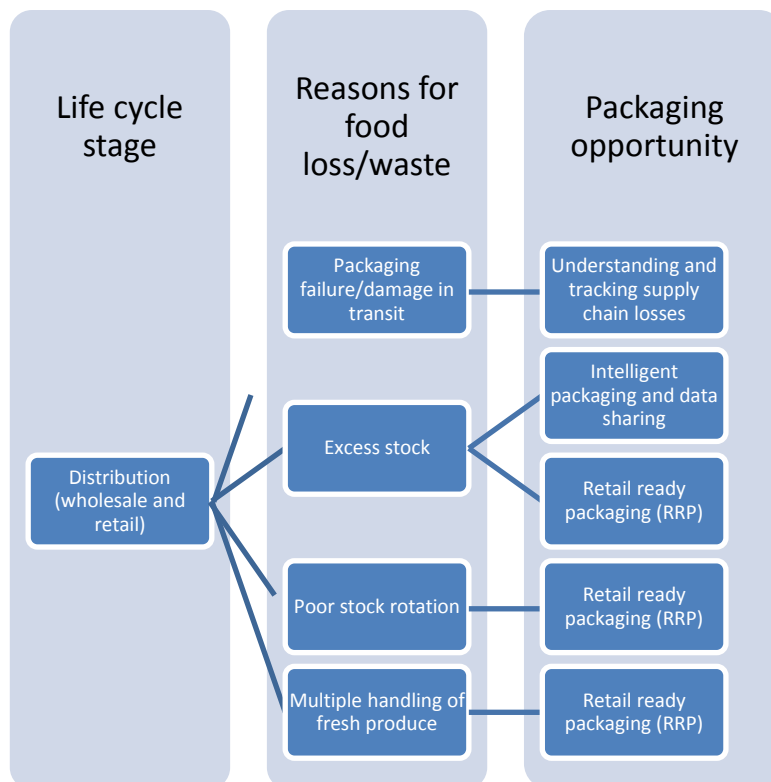


Figure 21 Packaging opportunities in distribution to reduce food waste

3.3.1 Understanding and tracking supply chain losses

Section 2 identified sources of food waste during distribution including inadequate packaging. The primary and secondary/tertiary packaging needs to protect fresh and processed food from physical stresses in transport and handling, and fresh produce also needs to be kept within a certain temperature range to maintain shelf life. Some of those interviewed for this study were able to estimate product losses within their own business:

"We aim to waste no more than 5% of our [produce] in the packaging plant. This is not being monitored properly at the moment so we're putting a process in place to collect better data. We already know our daily output and we're putting scales on the line to weigh product coming into the facility."

Interviewee – grower

However, most companies have a poor understanding of total losses from the initial production or processing point through to the retailer. There is an opportunity for growers and manufacturers to work more closely with retailers to understand and monitor food waste in the supply chain. A large brand owner in the US, for example, works closely with its retail customers to audit the quantity of 'unsaleable' products [72]. Week-long audits are conducted at their customers' warehouses and retail stores to identify any sources of waste and to identify opportunities to improve efficiencies. Over the past 10 years the quantity of unsaleable products has fallen by almost 50 percent.

Recommendations for understanding and tracking supply chain losses:

- Companies in the food supply chain to put systems in place to measure and monitor product loss as a key performance indicator.
- Education of packaging professionals, technologists, designers and specifiers about the need to understand the distribution chain, packaging performance requirements to minimise food waste, and the reverse logistics process.
- Brand owners to audit product loss at every point in the supply chain in collaboration with suppliers and customers, and identify opportunities to reduce waste through improved packaging.

3.3.2 Intelligent packaging and data sharing

The future supply chain is likely to involve increased collaboration and information transparency, which will ‘enable a more synchronised value chain with greater visibility and traceability’ [73, p 21]. Some manufacturers and retailers have already reduced costs and product waste by improving systems that forecast demand and by sharing data on sales and stock levels. For example, Coles Supermarkets are now buying grocery and dairy products through an automated sales-based system that forecasts demand for a particular store and makes orders based on a just-in-time approach [74].

Retailers are starting to share data on sales and demand forecasts with their major suppliers, and this helps manufacturers to improve their production planning, achieve faster stock turnover and reduce waste:

“Now that we’ve got an integrated data management system, we can see what the customer has in stock and we can work out what we need to make and what we need to send them. This means that we can keep our inventory as low as possible. We used to get truckloads of stuff out of date – it just wasn’t moving. That tends not to happen these days. We are more in control of it, so we’ve moved onto other things.”

Interviewee (food brand owner)

Supply chain collaboration and data sharing could be facilitated by ‘intelligent’ or ‘interactive’ packaging technologies (some examples are shown in **Table 4**). Intelligent food packaging can provide real time use-by or expiration data, product tracing and temperature indicators, which are either time based, activated by certain chemicals, driven by radio frequency identification data (RFID), or have thermal sensors, to provide better ‘on demand’ feedback to various supply chain stakeholders [75].

Intelligent interactive technologies in primary, secondary or tertiary packaging has the potential to reduce food waste in the supply chain by sending information back to suppliers on quality, safety, shelf life and logistics efficiency [76]. This information can be used to reduce the amount of time that products spend in the supply chain; thus extending shelf life and reducing the likelihood that product will spoil in transit or storage.

Table 4: Examples of intelligent packaging and impacts on food waste

Technology	Description	Potential impact on food waste	Challenges
Radio frequency identification (RFID) tag ('smart tag') in primary, secondary or tertiary packaging	Contains a microchip, normally enclosed in plastic, which stores data on the product, e.g. use-by date. Hundreds of tags can be read simultaneously from metres away.	Can be used to trace products throughout the supply chain (in transport, at the distribution centre, entering and leaving the backroom at the retail store etc.). RFID tags improve inventory control, minimising 'out of stock' [97] and ensuring that products are sold before they are out of date and require disposal. They can also record the temperature history of the product (see below).	High infrastructure costs compared to bar codes. Accuracy problems in applications involving a large amount of metal or water.
Thermal sensors	A range of technologies that can indicate the time-temperature history of the product, e.g. thermochromic inks that change colour when a temperature has been exceeded or changed, or digital data loggers that can indicate the period during which a product experienced out-of-tolerance temperatures.	Can be used to ensure that products stay within their required temperature range during distribution, particularly in cold chains. Time-temperature labels on consumer packaging can also help consumers to know when a product is safe to eat.	Higher packaging costs. Exposure of thermochromic inks to UV light, high temperatures or solvents may degrade colours or functionality.

Recommendations for intelligent packaging and data sharing:

- Retailers and brand owners to continue to implement data sharing arrangements that support more accurate forecasting and inventory management in the supply chain.
- Manufacturers to investigate the value that could be added by intelligent packaging solutions to improve inventory management and reducing waste.

3.3.3 Retail ready packaging (RRP)

Retail ready packaging (RRP) is a general term used to describe packaging that delivers products from the grower or processor direct to the retail store in a ready-to-sell merchandised unit. It includes merchandising units for display on a shelf ('shelf ready packaging' or SRP) or on the shop floor (full or fractional pallets). These can be either one-way or reusable.

The benefits of SRP to retailers include improved operational efficiencies at the store level and faster restocking. This is achieved by 'designing from the shelf back', with packaging configurations developed to reflect the sales volume and to maximise layout considerations [77].

There are associated benefits for food manufacturers because faster restocking helps to ensure that their product is always available on the shelf:

“SRP has been introduced to improve productivity, but it may have some benefits for food waste. If there is product at the back of the shelf the customer won’t see it, whereas SRP helps to keep the product front and centre.”

Interviewee (retailer)

New secondary packaging formats and new planograms have been developed to meet retailer requirements for SRP, with a reduced number of retail units in each secondary pack and ‘easy opening’ features.

Retailers claim that single use SRP (generally cartons and boxes) reduces product waste because it promotes more efficient stock rotation by increasing sales (through better visibility and availability) and increasing the speed of replenishment [78]. SRP could also facilitate better product recall processes, promoting more efficient stock accountability and potentially less waste in the process [79].

However, some brand owners argue that single use SRP increases product waste in transport and storage. One of the most common formats is a perforated shipper, which allows for easy opening but reduces box strength. It is therefore more likely to be crushed during transport, storage and handling:

“SRP is not decreasing product waste; probably the opposite [because] perforation reduces box strength. The board is strengthened to accommodate this but it’s impossible to control perforation exactly at the point of production ... If there’s not enough cut you can’t open the board; and if there’s too much it will open in transport, and we’ve experienced that. It’s an inherent problem with perforation. There is a solution, ‘tray and hood’, but this requires capital investment that is difficult to justify.”

Interviewee (food brand owner)

There are a number of reusable packaging systems for distributing fresh produce, packaged food and beverages, and some of these are available in retail ready formats (plastic crates or pallets). Whilst reusable distribution packaging has the potential to significantly reduce packaging waste, there has been little research on whether or not it can also reduce food waste. Reusable crates are likely to reduce product damage because they are packed at the farm or packaging shed and then transport the produce all of the way through to the retail shelf. Eliminating the need to unpack produce at the store for retail display reduces the amount of handling and the likelihood of product damage, particularly for soft fruits (see also Case study 2: Banana supply chain on page 44).

More recently, reusable display pallets have been adopted by some supermarket chains. These can provide a ‘one-touch solution’ that deliver products from the point of manufacture through to the point of sale. They reduce handling and product damage in the distribution chain because they don’t need to be unpacked at the distribution centre or retail store.

Fractional pallets (half or quarter size) can improve stock rotation by allowing stores to match the merchandising unit with the rate of sales. This can also have benefits for waste if it reduces the likelihood of product going out of date.

A summary of the possible impacts of RRP on food and packaging waste is presented in **Figure 22**.

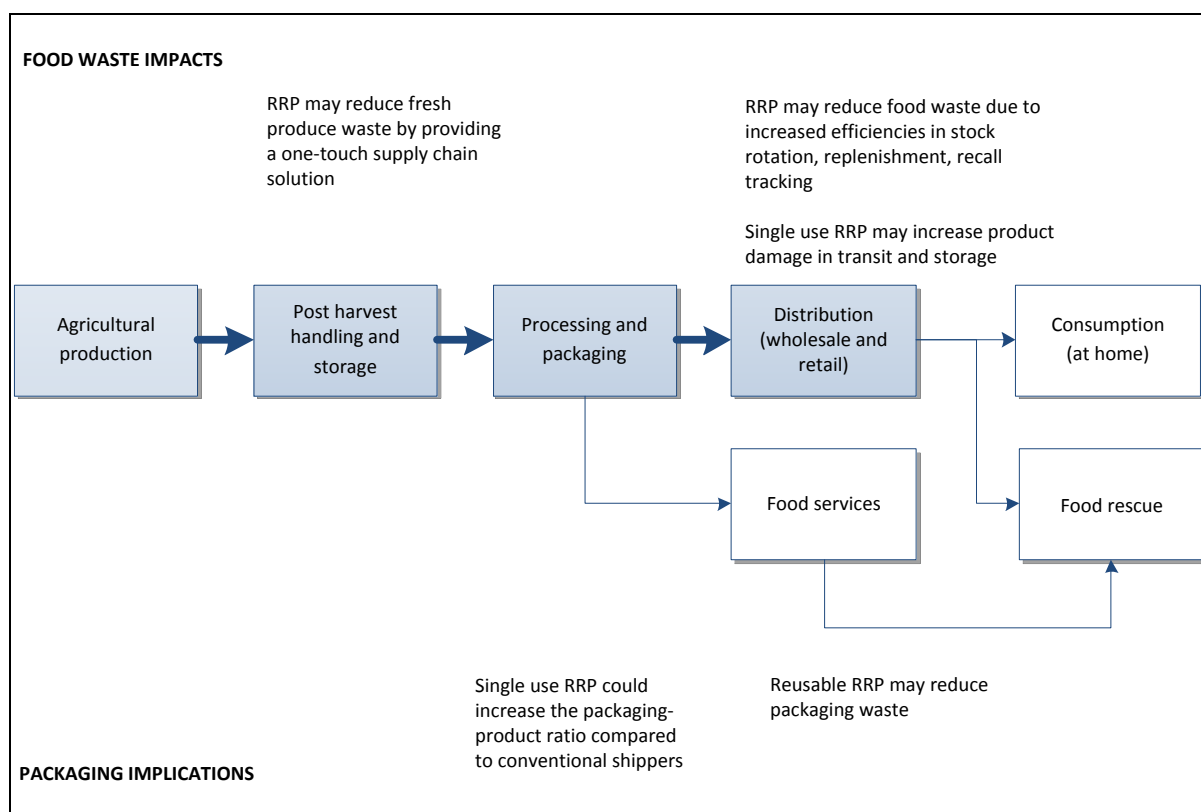


Figure 22 Retail ready packaging – possible impacts on food and packaging waste

Recommendations for retail ready packaging:

- Retailers and brand owners to collaborate to undertake research on the impact of retail ready packaging on stock turnover and food waste.
- Packaging companies to continue to develop new forms of distribution packaging to take produce from farms through to retail, to minimise handling in the supply chain. Retail ready packaging formats such as reusable crates and retail ready pallets provide a ‘one-touch’ solution that minimises handling of produce.

3.4 Summary

The previous discussion identified a number of global trends in supply chain management, product development and packaging innovation that could be adopted more widely in Australia to reduce food waste. Most of these are driven by other business imperatives, such as the search for improved efficiencies and cost savings in the supply chain, or new market opportunities for pre-prepared and processed foods. However, an increasing focus on the business and environmental costs of food waste will support the business case for many of these products and technologies.

Within the fresh produce sector there are opportunities to develop new forms of distribution packaging for target markets. Loss and damage to fresh fruits and vegetables during distribution could be reduced through targeted packaging solutions that meet individual requirements for product protection, ventilation and ripening. The trend towards pre-packing fresh produce for the consumer market is likely to accelerate due to market demand, but this will become increasingly important as a way of reducing waste in the supply chain and at the point of consumption (homes and food service providers). New packaging materials and technologies provide additional opportunities to extend shelf life and reduce waste.

Supply chain collaboration is essential to understand and monitor product waste, and to identify solutions. Packaging developers in particular, need to understand the distribution process and design fit-for-purpose packaging that minimises avoidable food waste. In some cases this may require more packaging rather than less, recognising that the environmental impacts of the food supply chain greatly exceed those of the packaging. Other considerations such as materials efficiency and resource recovery of the packaging at end of life also need to be considered to optimise the sustainability of the product-packaging system as a whole.

Concluding comments and further research opportunities are presented in Section 4.

4 Conclusions and further research

There are significant opportunities to reduce food waste in the supply chain through improvements and innovation in packaging and by communicating these benefits and opportunities to industry stakeholders.

Food is lost and wasted for many reasons, including damage in the field from severe weather events and disposal of inedible components during food preparation. While this loss/waste is largely unavoidable, other waste occurs due to inefficiencies or poor handling in the supply chain. This is where packaging can play an important role, for example by reducing damage in transit and handling or by extending shelf life. A number of packaging opportunities to reduce waste have been identified in this report, based on an extensive literature review and interviews with stakeholders. They are:

- 1) Distribution packaging that provides **better protection and shelf life for fresh produce** as it moves from the farm to the processor, wholesaler or retailer. This may require the development of tailored solutions for individual products.
- 2) Distribution packaging that supports **recovery of surplus and unsaleable fresh produce** from farms and redirects it to food rescue organisations.
- 3) Improved design of secondary packaging to ensure that it is **fit-for-purpose**, i.e. that it adequately protects food products as they move through the supply chain. Packaging developers need to understand the distribution process and where and why waste occurs.
- 4) A continuing shift to **pre-packed and processed foods** to extend the shelf life of food products and reduce waste in distribution and at the point of consumption (the home or food services provider). The packaging itself also needs to be recoverable to minimise overall environmental impacts.
- 5) Adoption of **new packaging materials and technologies**, such as modified atmosphere packaging and oxygen scavengers, to extend the shelf life of foods.
- 6) Education of manufacturers, retailers and consumers about the meaning of **use-by and best-before date marks** on primary packaging to ensure that these are used appropriately. Confusion about date marking results in food being thrown away when it is still safe to eat.
- 7) Product and packaging development to cater for **changing consumption patterns and smaller households**. Single and smaller serve products will reduce waste by meeting the needs of single and two person households.
- 8) Collaboration between manufacturers and retailers to **improve the industry's understanding of food waste** in the supply chain. Greater attention to be given to where and why this occurs, tracking over time, will reduce the costs and environmental impacts of waste.
- 9) More synchronised supply chains that use **intelligent packaging and data sharing** to reduce excess or out-of-date stock.
- 10) Increased use of **retail ready packaging** to reduce double handling and damage and improve stock turnover, while ensuring that it is designed for effective product protection and recoverability (reuse or recycling) at end of life.

The implementation of these initiatives could be supported through further research and communication activities to highlight the critical links and trade-offs between packaging consumption, protection and containment of food, and food waste.

There is very limited Australian data on the quantities of food that are lost at each stage of the supply chain and the reasons for this loss. Research that could assist efforts to improve packaging and product management include:

- Detailed analysis of food waste using direct observations and sampling at key aggregation points, such as post-harvest grading, sorting and packing. The reasons for waste would be documented and analysed in the context of supply chain trends, to identify opportunities for improvement.
- Research into the potential for packaging systems to be improved to reduce food waste in specific food supply chains, ideally in combination between industry associations, individual companies, government departments, scientific organisations and universities. Agricultural products and processed food items could be selected based on their contribution to the economy, unit sales value, environmental impact, or waste volumes in the supply chain.
- Research into the reasons for waste in different food services premises (e.g., hotel, café, restaurant, take away, hospital). The aim would be to identify opportunities for packaging innovation and improvement and better systems to capture waste from these premises to end of life waste management treatment facilities.
- Life cycle assessment of primary packaging formats (e.g., MAP) that extend shelf life to better understand the trade-offs between packaging use and food waste and the interplay between primary, secondary and tertiary packaging.
- Life cycle assessment of packaging formats (e.g., single serves, bulk packaging) and ambient, chilled and frozen products to understand the entire life cycle impacts on product protection and food waste.

There is also a critical need to raise awareness and educate stakeholders in the food and packaging supply chain on opportunities to further reduce food waste through packaging innovation. Government, industry and professional organisations already play a vital educational role and could assist in delivery of education and training programs targeting food waste and packaging. Existing programs such as the NSW Government's Love Food Hate Waste program could include more information on the role of packaging in extending shelf life, and opportunities to use it more effectively. Additional industry case studies could showcase packaging innovations and related supply chain improvements that have reduced food waste.

There is also a need to address gaps in consumer knowledge. Consumers are generally unaware of the role that packaging can play in keeping a product safe and fresh. Research in the UK [80] found that they sometimes have the opposite view (i.e. that keeping products in packaging leads to them spoiling more quickly). This leads many people to remove food from packaging after purchase or piercing it to 'let it breath', even where the packaging is designed to keep food fresher for longer. However, consumers are interested in packaging that gives clear messages about how to store food correctly, whether or not it can be frozen, and use-by and best-before dates.

This research represents the beginning of a process to try to understand and reduce food waste in the food supply chain. It has identified a series of opportunities that could be used to start a dialogue within the supply chain about the complex interactions between packaging and food waste, and the need to find solutions that achieve optimal environmental and commercial outcomes.

The National Food Plan [81] highlights many of the challenges and opportunities facing the Australian food industry, including strong growth in demand from Asian economies and the sustainability of agricultural production and manufacturing. One of the sustainability goals within the plan is to reduce Australia's per capita level of food waste. Designing fit-for-purpose food product-packaging systems that maximise efficiency and reduce waste at all stages of the supply chain will be a prime concern in the context of an increasingly resource constrained world.

Case study 1: Foodbank (food rescue)

Situation

Foodbank is Australia's leading not for profit food recovery organisation, supplying 24 million kg of surplus or unsalable products from farmers, food processors and retailers. This is redistributed to over 2,500 welfare agencies that provide emergency food relief to the homeless or disadvantaged. With almost 2 million people in Australia living below the poverty line or under financial stress, the challenge for food rescue organisations such as Foodbank is to capture and redistribute enough of this food to meet demand. This involves:

- identifying and sourcing surplus product across the food supply chain
- collecting this product (or having it delivered to them) from the supplier, processor or retailer
- ensuring transport to Foodbank is undertaken as efficiently as possible
- registering the products in their online portal, where welfare agencies are able to select and place their order
- ensuring product is moved through their part of the supply chain in a cost-effective and timely manner.



Figure 23 Foodbank's Melbourne warehouse

Photos by Simon Lockrey

Objectives

1. To increase the amount of product collected from food processors and retailers.
2. To identify new sources of surplus/unsaleable product, e.g., fresh fruit and vegetables from farmers and processors.
3. To identify new sources for products that are experiencing falling donations or that are under-represented, e.g., meat products from farmers and processors, key grocery staples (cereal, milk, canned meals, pasta and rice).
4. To maintain and enhance the online system to register products that is available for selection and redistribution to welfare agencies/charities.

Process

Foodbank is working closely with their 60 leading food donors and 600 smaller producers to collect and redistribute surplus/unsaleable product. As processors become more efficient in their own operations and reduce the amount of waste or surplus they generate this increasingly involves special production runs for Foodbank. Foodbank is also developing new partnerships with suppliers and processors to source and manufacture either declining or under-represented product, such as fresh fruit and vegetables, meat products such as sausages and key grocery staples such as cereal.

Long term relationships with suppliers are critical. They assist Foodbank to meet demand for donations (both ongoing and in urgent instances such as disaster relief), and help to ensure efficient donation channels for suppliers.

Foodbank's recently implemented online portal enables them to register donated product so that welfare agencies/charities can view available suppliers and order to their requirements. The portal is also linked to a dynamic tracking information system that enables Foodbank to provide suppliers with monthly or annual reports on quantities and types of products that have been donated. The long term vision is to use GS1 data to increase automation and efficiency.

Results and ongoing challenges

The challenge for Foodbank is to increasingly source shelf stable processed surplus and unsaleable products, while traditional sources from food processors and retailers decline as they become more efficient. The process is to develop new sources of supply and long term partnerships. The results include special production runs and more fresh produce directly from farms and post-harvest operations.

Currently fresh fruit and vegetables, from retail or farm (e.g., Figure 24), account for 20% (5 million kg). Foodbank is identifying opportunities to source directly from farmers to increase this to 40% (10 million kg) annually. Ensuring the correct packaging systems and logistic operations are in place to source, collect and deliver this produce to Foodbank is critical. Close partnerships with food producers will be critical to ensure the surplus produce is redistributed effectively in conjunction with packaging solutions that maximise produce collection and tracking in the online portal.



Figure 24 Fresh fruit and vegetables, the growth area for Foodbank

Photos by Simon Lockrey

Foodbank is also continually identifying new opportunities to collaborate with food suppliers and processors to establish new product lines to fill unrepresented product, such as meat products. In this instance, farmers supply stock to abattoirs that process the meat and send to meat processors who produce sausages to Foodbank. New packaging solutions will need to be implemented for these new opportunity products, maximising product integrity and shelf life, and reducing transport requirements, through the Foodbank system and onto recipients.

Case study 2: Banana supply chain

Situation

Bananas are Australia's most consumed fresh fruit (13kg/capita) with an annual production of 310,000 tonnes and a farm gate value of \$450 million. The majority (90%) of Australia's bananas are grown in Queensland [82] and distributed (via road and rail) through ripening rooms in the major cities.



Between 10–30% of the total banana crop is rejected at the pack house because they don't meet customer specifications for sale as fresh fruit [82]. This represents a loss of around 37,000 tonnes of bananas every year [82].

Trials undertaken by the NSW Department of Primary Industries found the following damage to bananas in transit [83, p 2]:

“Neck injury mainly occurred between the farm and the distribution centre. Bruises and skin marks increased markedly between the centre and the retail store. The top layer of fruit inside each carton was most likely to have neck injury, especially if it was on the middle or bottom layers of the pallet. Conversely, fruit in top layers of pallets were more likely to have rub marks and scuffing. Temperatures were monitored, and were found to fall dangerously low during distribution to retail stores, with some fruit below 7°C when delivered.”

Other studies have quantified the losses due to fruit damage in transport, storage and handling (**Table 5**). Damage occurs in supermarkets due to poor staff handling (inadequate training) and consumer handling (lack of awareness).

Table 5 Summary of damage to bananas in North Queensland and New South Wales supply chain (1996-99)

Fruit handling stage	Range of losses (% harvested fruit)	Average losses (% harvested fruit)
Pre-harvest	0-11	4
Harvesting and transport to packing shed	1-11	4
Incorrectly culled	0-10	3
Packing and transport to wholesale	0-2	0.5
Total	2-29	11.5
Source: [84]		

Objectives

1. To reduce damage to bananas throughout the supply chain from farm to retail.
2. To provide adequate training to staff regarding handling of bananas during picking, sorting, packaging and retail sale.
3. Identify opportunities to redirect surplus/unsaleable bananas through other channels.

Process

Banana growers are working with packaging companies, state primary industry departments and retailers to identify the major causes of fruit damage in the supply chain and to identify solutions. These include opportunities to modify packaging solutions and to improve education of staff at critical handling points [83].

Results

Supply chain efficiencies

Supply chains have become more streamlined. Retailers such as Woolworths and Coles are building their own ripening facilities, which mean product no longer has to go to wholesale markets and then moved again. In the mid-1990s, research undertaken by a major Australian retail chain led to [84]:

- the introduction of cluster packing
- the development of the 6 per layer carton
- use of absorbent paper for sap control
- development of product specifications and systematic quality assurance to monitor fruit out-turn at points along the chain
- implementation of improved cool chain facilities and processes from harvest through to retail.

Shifting to a stronger and higher shipper has almost eliminated banana neck injuries during transport. Packing fruit into bags instead of standard liners, which was introduced about 4 years ago, has also increased the shelf life of the product. The use of returnable plastic crates is currently being investigated. The additional strength provided by RPCs could further reduce fruit damage in transport and handling, and enhanced ventilation features would allow more efficient cooling of bananas after harvest (extending shelf life).

Education and training

It is easy to damage bananas in the picking and packing area. Staff need to be trained in correct handling, and this needs to be monitored to ensure that damage is minimised. Well-designed packaging is also required.

Consumers need to be educated about how fragile bananas are and why they should be handled as little as possible. There is an opportunity to explore consumer acceptance of bananas that are pre-packed by the grower, thereby eliminating unnecessary handling and damage. The potential disadvantage of pre-packing is that it limits the flexibility of consumers to purchase the number of bananas they wish to purchase, and could lead to waste at the household level if excess bananas are purchased and not consumed in time.

Opportunities for damage/unsaleable bananas

Horticulture Australia Limited has funded research through and the Australian Banana Growers Council to look at opportunities to recover some of the lost value from damaged or unsaleable bananas. Up to 80% of rejected bananas were found to be suitable for food processing. Different uses were identified, including frozen bananas, juice and syrups. The study concluded that the best options for Australian bananas are niche products, snacks or functional foods involving new technologies such as cold pasteurisation, because in juice and syrup markets it will be difficult to compete with low cost imported ingredients [85].

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References

1. DEWHA, *National waste policy: less waste, more resources*, W. Department of the Environment, Heritage and the Arts, Editor. 2009, Commonwealth of Australia: Canberra.
2. Gunders, D., *Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill*. 2012, Natural Resources Defense Council: New York.
3. Gustavsson, J., C. Cederberg, and U. Sonesson, *Global food losses and food waste: extent, causes and prevention*. 2011, Report by the Swedish Institute for Food and Biotechnology for the Food and Agriculture Organization of the United Nations: Rome.
4. WRAP, *Fruit and vegetable resource maps - Final report*. 2011, Waste and Resources Action Programme (WRAP): Banbury, Oxon, UK.
5. Terry, L.A., C. Mena, A. Williams, N. Jenney, and P. Whitehead, *Fruit and vegetable resource maps: Mapping fruit and vegetable waste through the retail and wholesale supply chain*. 2011.

6. Linehan, V., S. Thorpe, N. Andrews, Y. Kim, and F. Beaini. *Food demand to 2050: Opportunities for Australian agriculture*. in *42nd ABARES Outlook conference 6-7 March*. 2012. Canberra: ABARES - Australian Bureau of Agricultural and Resource Economics and Sciences.
7. Bailey, R., *Growing a Better Future: Food justice in a resource-constrained world*. 2011, Oxfam International: Oxford, UK.
8. Verghese, K., S. Clune, S. Lockrey, H. Lewis, and P. Crittenden, *Future of Packaging White Paper*. 2012, Australian Food and Grocery Council: Canberra.
9. Parfitt, J., M. Barthel, and S. MacNaughton, *Food waste within food supply chains: quantification and potential for change to 2050*. *Phil. Trans. R. Soc.* 2010. **365**: p. 3065-3081.
10. Mason, L., T. Boyle, J. Fyfe, T. Smith, and D. Cordell, *National food waste assessment: final report*. 2011, Prepared for the Department of Sustainability, Environment, Water, Population and Communities, by the Institute for Sustainable Futures, University of Technology Sydney.
11. United Nations. *World population prospects, the 2010 revision*. 2011; Available from: <http://esa.un.org/unpd/wpp/index.htm>.
12. DAFF, *National Food Plan green paper*. 2012, Department of Agriculture, Fisheries and Forestry: Canberra.
13. Institution of Mechanical Engineers, *Global food waste not want not*. 2013: London.
14. FAO, *The state of food insecurity in the world 2010, addressing food security in protracted crises*. 2010, Food and Agriculture Organization of the United Nations: Rome.
15. TCGF, *A Global Language for Packaging and Sustainability. A framework and a measurement system for our industry*. 2011, The Consumer Goods Forum: Lissy-les-Moulineaux, France.
16. APCC, *Australian Packaging Covenant. A commitment by governments and industry to the sustainable design, use and recovery of packaging*. 2010, Australian Packaging Covenant Council: Melbourne.
17. INCPEN, *Table for one*. 2009, The Industry Council for Packaging and the Environment: Reading.
18. Williams, H. and F. Wikström, *Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items*. *Journal of Cleaner Production*, 2011. **19** (1): p. 43-48.
19. Wikstrom, F., H. Williams, K. Verghese, and S. Clune, *The influence of packaging attributes on consumer behaviour in food-packaging LCA studies - a neglected topic*. *Journal of Cleaner Production*, Submitted April 2013.
20. Azzi, A., D. Battini, A. Person, and F. Sgarbossa, *Packaging Design: General Framework and Research Agenda*. *Packaging Technology and Science*, 2012. **25**: p. 435-456.
21. Olsson, A., M. Petterson, and G. Jonson, *Packaging demands in food service industry*. *Food Service Technology*, 2004. **4**: p. 97-105.
22. Hellstrom, D. and M. Saghir, *Packaging and Logistics Interactions in Retail Supply Chains*. *Packaging Technology and Science*, 2007. **20**: p. 197-216.
23. Robertson, G.L., *Food Packaging and Shelf Life*, in *Food Packaging and Shelf Life: A Practical Guide*, G.L. Robertson, Editor. 2009, CRC Press: Boca Raton, Florida. p. 1-16.
24. Hall, K.D., J. Guo, M. Dore, and C.C. Chow, *The Progressive Increase of Food Waste in America and Its Environmental Impact*. 2009, National Institute of Diabetes and Digestive and Kidney Diseases.
25. ABS. *Population Clock*. 2013 [cited 2013 20 January].
26. OEH, *Food waste avoidance benchmark study 2009 at a glance 2011*, Office of Environment and Heritage: Sydney.
27. DEWHA, *National waste report*, W. Department of the Environment, Heritage and the Arts (DEWHA) and Environment Protection and Heritage Council (EPHC), Editor. 2010, Commonwealth of Australia: Canberra.
28. Viridis, *Supermarket food waste benchmarking study*. 2012, Report to the Department of Sustainability, Environment, Water, Population and Communities: Canberra.
29. Encycle Consulting and Sustainable Resource Use, *A study into commercial & industrial (C&I) waste and recycling in Australia by industry division (unpublished draft)*. 2012, Report to the Department of Sustainability, Environment, Water, Population and Communities: Canberra.
30. Kumm, M., H. de Moel, M. Porkka, S. Siebert, O. Varis, and P. Ward, *Lost food, wasted resources: Global food supply chain losses and their impact on freshwater, cropland and fertiliser use*. *Science of the Total Environment*, 2012. **438**: p. 477-489.

31. Mason, L., T. Boyle, J. Fyfe, T. Smith, and D. Cordell, *National Food Waste Assessment*. 2011, Institute for Sustainable Futures, UTS for The Department Of Sustainability, Environment, Water, Population And Communities (DSEWPC): Sydney.
32. Reidy, C., J. Herriman, C. Dovey, and T. Boyle, *Reducing commercial and industrial food waste: literature review and options*. 2010, Prepared for the Department of Environment, Climate Change and Water (NSW) by the Institute for Sustainable Futures, University of Technology, Sydney.
33. Stuart, T., *Waste: Uncovering the global food scandal*. 2009, New York: Penguin Group.
34. AFGC and AT Kearney, *Impact of carbon pricing 2011: potential impacts across the supply chain*. 2011, Australian Food and Grocery Council: Canberra.
35. ABS, *5368.0 International Trade in Goods and Services, Australia*, A.B.o. Statistics, Editor. 2013, Commonwealth of Australia: Canberra.
36. AFGC, *Sustainability commitment, 2010-2011 report*. 2012, Australian Food and Grocery Council: Canberra.
37. Mena, C., B. Adenso-Diaz, and O. Yurt, *The causes of food waste in the supplier-retailer interface: Evidence from the UK and Spain*. *Resources Conservation and Recycling* 2011. **55**: p. 648-658.
38. Woolworths Limited, *Corporate social responsibility report*. 2012: Sydney.
39. Australian Institute of Health and Welfare, *Australia's food & nutrition 2012*. 2012, AIHW: Canberra, Australia.
40. Productivity Commission, *Economic structure and performance of the Australian retail Industry*. 2011, Productivity Commission: Melbourne.
41. PwC. *Record levels of online shopping causing retailers to rethink strategy*. 2012; Available from: www.pwc.com.au/media-centre/2012/online-shopping-strategy-jul12.htm.
42. AIHW, *Australian Food and Nutrition 2012*. 2012, Australian Institute of Health and Welfare: Canberra.
43. ABS, *Household Expenditure Survey, Australia: detailed expenditure items, 2009–10*. 2011, Australian Bureau of Statistics: Canberra.
44. I-grafix. *Accessibility and impact*. 2012, Wednesday 11 July [cited 2013 28 May]; Available from: <http://www.i-grafix.com/index.php/articles/articles/accessibility-and-impact.html>.
45. Sustainable Restaurant Association, *Too good to waste: restaurant food waste survey report 2010*. 2010: UK.
46. Unilever Food Solutions, *World menu report: global research findings*. 2011.
47. Baker, D., J. Fear, and R. Denniss, *What a waste: An analysis of household expenditure on food*, in *Policy Brief No. 6*. 2009, The Australia Institute: Canberra.
48. Ventour, L., *Food waste report v2*, in *The food we waste*. 2008, WRAP and Exodus Market Research: Weston-super-Mare.
49. Katajajuuri, J.-M., K. Silvennoinen, H. Hartikainen, L. Jalkanen, H.-K. Koivupuro, and A. Reinikainen, *Food waste in the food chain and related climate impacts*, in *LCA FOOD St Malo* 2012.
50. Quested, T. and H. Johnson, *Household Food and Drink Waste in the UK .A report containing quantification of the amount and types of household*. . 2009, WRAP: Oxon, UK.
51. Williams, H., F. Wikström, T. Otterbring, M. Löfgren, and A. Gustafsson, *Reasons for household food waste with special attention to packaging*. *Journal of Cleaner Production*, 2012. **24**(0): p. 141-148.
52. Cambridge Dictionaries Online. *Cambridge Advanced Learner's Dictionary*. 2011 [cited 2012 14 May].
53. Commonwealth of Australia, *Australia to 2050: future challenges*. 2010: Canberra.
54. Chonhenchob, V. and S.P. Singh, *A comparison of corrugated boxes and re-usable plastic containers for mango distribution*. *Packaging Technology and Science*, 2003. **16**: p. 231–237.
55. Chonhenchob, V. and S.P. Singh, *Packaging performance comparison for distribution and export of papaya fruit*. *Packaging Technology and Science*, 2005. **18**: p. 125–131.
56. CHEP. 2013 2013 01/02/13; Available from: www.chep.com/resources/case_studies/Reduce_Fruit_Damage_Reusable_Fruit_Crates/.
57. Leblanc, R. *Asda to Use IFCO's Banana RPC. At Packaging Revolution*. 2011 [cited 2013 1 May].
58. IFCO Systems. *RPCKiosk. 6421 Caja de Oro-RPC for bananas*. unknown [cited 2013 1 May]; Available from: <http://rpckiosk.com/pdf/ifco-caja-de-oro-banana-rpc-features-and-benefits-1.pdf>.

59. Lee, S.G. and X. Xu, *A Simplified Life Cycle Assessment of Re-usable and Single-use Bulk Transit Packaging*. PackagingTechnology and Science, 2004. **17**: p. 67–83.
60. Singh, S.P., V. Chonhenchob, and J. Singh, *Life Cycle Inventory and Analysis of Re-usable Plastic Containers and Display-ready Corrugated Containers Used for Packaging Fresh Fruits and Vegetables*. PackagingTechnology and Science, 2006. **19**: p. 279–293.
61. Ragaert, P., F. Devlieghere, and J. Debevere, *Role of microbiological and physiological spoilagemechanisms during storage of minimally processed vegetables*. . Postharvest Biology and Technology, 2007. **44** p. 185-194.
62. ABS, *Australian social trends 2007: Article Household Waste*, A.B.o. Statistics, Editor. 2007, Commonwealth of Australia: Canberra.
63. Lingle, R., *LiquiGlide gives foods the slip to reduce waste*, in *Packaging Digest*. 2013.
64. Packaging Council of New Zealand, *PAC-IT: An introduction to packaging in New Zealand, Teacher guide*. 2000.
65. Mahalik, N.P. and A.N. Nambiar, *Trends in food packaging and manufacturing systems and technology*. Trends in Food Science & Technology, 2010. **21** (3): p. 117-128.
66. Behrens, J.H., M.N. Barcellos, L.J. Frewer, T.P. Nunes, B.D.G.M. Franco, M.T. Destro, and M. Landgraf, *Consumer purchase habits and views on food safety: A Brazilian study*. Food Control, 2010. **21**(7): p. 963-969.
67. Kirk, Greenwood, Cade, and Pearman, *Public perception of a range of potential food risks in the United Kingdom Appetite* [0195-6663] 2002. . **38** (3): p. 189.
68. Miles, S., M. Brennan, S. Kuznesof, M. Ness, C. Ritson, and L.J. Frewer, *Public worry about specific food safety issues*. British Food Journal, 2004 **106**(1): p. 9-22.
69. Chen, Q., S. Anders, and H. An, *Measuring consumer resistance to a new food technology: A choice experiment in meat packaging*. Food Quality and Preference, 2013. **28**(2): p. 419-428.
70. Quested, T.E., P.E. Cook, L.G.M. Gorris, and M.B. Cole, *Trends in technology, trade and consumption likely to impact on microbial food safety* International journal of food microbiology, 2010. **139** Suppl(S29-42).
71. AFGC, *A guide to the application of date marking of food*. 2010, Australian Food and Grocery Council: Canberra.
72. Spinner, J., *Kellogg exec offers packaging sustainability insight*, in *Packaging Digest*. 2013.
73. The Consumer Goods Forum, Capgemini, HP, and Microsoft, *Building strategies for the new decade*. 2011, The Consumer Goods Forum: Paris.
74. Deloitte Access Economics, *Analysis of the grocery industry. Report to Coles Supermarkets Australia*. 2012, Deloitte Access Economics: Barton, Canberra, Australia.
75. iRAP, *Global market for nano-enabled food and beverage packaging to cross \$7 billion by 2014*. 2013: Stamford, USA. p. 1.
76. Manzini, R. and R. Accorsi, *The new conceptual framework for food supply chain assessment*. Journal of Food Engineering, 2013. **115**: p. 251–263.
77. AFGC, *Efficient consumer response Australasia: retail ready packaging, edition 3*. 2013, Australian Food and Grocery Council: Canberra.
78. Jackson, C., *Retail-ready packaging set to be the norm*, in *foodprocessing.com.au*. 2012: Melbourne, VIC.
79. Zaccpac. *Australian packaging companies seeing the benefits of shelf ready packaging*. 2012 15/12/12 18/01/13]; Available from: www.zaccpac.com.au/australian-packaging-companies-seeing-the-benefits-of-shelf-ready-packaging.
80. Plumb, Downing, and Parry, *Consumer Attitudes to Food Waste and Food Packaging 2013* WRAP: Oxford, London.
81. DAFF, *National Food Plan, Our food future*. 2013, Department of Agriculture, Fisheries and Forestry. Commonwealth of Australia: Canberra.
82. White, A., D. Gallegos, and T. Hundloe, *The impact of fresh produce specifications on the Australian food and nutrition system: a case study of the north Queensland banana industry*. Public Health Nutrition, 2011. **14**(8): p. 1489-1495.
83. Horticultural Australia Limited and Australian Banana Growers Council, *Banana. Industry Annual Report 2011/12*. 2012, Horticultural Australia Limited: Sydney.
84. Ekman, Lindsay, and Gething, in *Improved handling in banana supply chains*. BA10016 2011, Horticulture Australia: Sydney.
85. Horticulture Australia and The Australian Banana Growers Council. *Banana Industry Annual Report 2011/12*. 2012 [cited 2013 11 March]; Available from: http://cms2live.horticulture.com.au/admin/assets/library/annual_reports/pdfs/PDF_File_195.pdf.