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Emerging technologies and trends for packaging red meat

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Glossary

Term	Definition
Active packaging	Packaging which incorporates specific bio-active compounds
BHA	Butylated hydroxyanisole, a substance which can be used in active packaging
BHT	Butylated hydroxytoluene, a substance which can be used in active packaging
Chitosan	A by-product which can be produced through the reaction of crustacean shells with sodium hydroxide
EVOH	Ethylene vinyl alcohol; a plastic used in packaging, particularly as an oxygen barrier film
FSANZ	Food Standards Australia and New Zealand
HACCP	Hazard analysis and critical control point; a framework typically used for food-safety
HHP	High hydrostatic pressure
Intelligent packaging	Packaging systems that monitor and provide information on food condition
LDPE	Low-density polyethylene; a sub-class of polyethylene, a plastic used in packaging
MAP	Modified atmosphere packaging
Nanotechnology	Use of nano-scale materials. Nano refers to the size 1×10^{-9} m; one billionth of a metre
PA	Polyamide; a plastic used in packaging
Pathogen	A micro-organism which can cause illness
PE	Polyethylene; a plastic used in packaging
PET	Polyethylene terephthalate; a plastic used in packaging
PP	Polypropylene; a plastic used in packaging
Primal cut	Major cuts into which carcasses are separated
Primary packaging	Packaging which is typically in direct contact with the product.
PVC	Polyvinyl chloride; a plastic used in packaging
PVOH	Polyvinyl alcohol
Retail cut	Cuts of meat sold to the retail market
RFID	Radio-frequency identification; a type of intelligent packaging

Term	Definition
RTE meats	Ready-to-eat meats
Secondary packaging	Packaging used to contain primary packaging. For example, corrugated cardboard shippers
Sub-primal cut	Cuts of meat from primal cuts, which are then used to produce retail cuts
Tertiary packaging	Packaging used to contain secondary packaging. For example, plastic film used for pallet-wrap
TTI	Time-temperature indicator
VSP	Vacuum skin pack
WSN	Wireless sensor networks

Executive Summary

The red meat supply chain relies upon packaging at varies stages of the supply chain, to protect, contain, distribute, promote and sell its products. Food safety compliance and product integrity are also paramount. Meat and Livestock Australia (MLA), who deliver marketing, research and development services for Australia's cattle, sheep and goat producers are interested in understanding the role packaging plays and the trends within the red meat supply chain that enable them to help position Australian red meat producers, both domestically and in export.

This report presents a review of current and emerging packaging technologies and trends related to red meat (beef, veal, sheep, goat and mutton). The review comprised of a desk-top literature review, attendance at local packaging conference held in May and June 2014 in Australia and interviewing a suite of stakeholders across the red meat supply chain.

Emerging packaging technologies included in this review are modified atmosphere (MAP) and vacuum packaging; active packaging that incorporates specific compounds into a packaging material, on its surface, onto the product directly or as a separate co-packaged component; and intelligent packaging technologies such as integrity and freshness sensors, time-temperature indicators and radio frequency identification tags (RFIDs). Existing knowledge of these technologies are presented alongside challenges and barriers but also opportunities to exploit.

Sustainability, supply chain and consumer trends and issues were also explored. Demographic and lifestyle changes such as the ageing population and rise in the middle class, both domestically and internationally, increasing requirements and expectations from consumers for convenience and portioning, accessibility of pack and traceability of product are important trends that need to be understood in the context of packaging design. Understanding who the consumer is, what their needs and wants are, their expectations of, their perceptions, understanding and acceptance of packaging formats and technologies will be crucial for acceptance of packaged red meat domestically and on global export markets, both now and into the future.

1 Introduction

Meat and Livestock Australia Limited (MLA) delivers marketing, research and development services for Australia's cattle, sheep and goat producers. Areas of strategic focus for MLA include maintaining and improving market access both domestic and export; growing demand for beef and lamb in the domestic and export markets; identifying and delivering increasing productivity across the supply chain; and supporting on-farm and off-farm integrity and sustainability.

This review report identifies industry and consumer trends relating to emerging packaging innovation for red meat across the whole value chain. The research derived from a desk-top literature review of relevant academic journals, industry websites, and attendance at several packaging related conferences and interviews with stakeholders. The insights presented in this report can be used by MLA in conjunction with other strategy development to focus on optimising packaging so that it supports and adds value to the red meat supply chain, both in domestic and export markets.

The following section provides an overview of the scope of the report and the methodology utilised in data collection (Section 1.1). The role of packaging is then presented (Section 1.2), followed by market trends for red meat (Section 2). Emerging food packaging technologies are presented (Section 3) followed by a discussion on sustainability including food waste (Section 4), supply chain, consumer trends and regulations (Section 5). The report concludes with opportunities for future research (Section 6).

1.1 Scope and methodology

This report provides MLA with a critical review of emerging packaging trends related to red meat (both raw and cooked beef, veal, goat, lamb, mutton) packaging across the whole value chain (understanding opportunities in manufacturing, warehousing and distribution, foodservice, retail merchandising, and household contexts for packaging innovation). The outcomes of this research can be used by MLA to identify potential research themes for its future investment and contribute to the Knowledge + Ideas portal as part of AOP 2015/2.3.1.2.

The following topics are included in this review:

- Emerging market trends and consumer behaviour relating to drivers for innovative food and red meat packaging systems and solutions
- Tracking systems
- Food packaging technologies, including active and smart packaging (e.g. edible films, barrier films etc.) that add value to red meat
- Sustainability, including food waste,
- Convenience drivers for packaging innovation, including at the consumer (e.g. ready-made foods) and retail levels (e.g. shelf-ready packs)
- Legislative requirements, including labelling

The scope of the tracking systems and food packaging technologies focuses on those currently commercially available on a global scale, and also those that are not yet commercially available across the wider food industry (not just red meat sector). The study focuses on both short-term (3-5 years) and mid to long-term (5 - 20 years) time horizons. Assessment of consumer market trends are limited to Australia and export to Asia. The sustainability review covers packaging-related aspects associated to red meat processing, distribution, retail and consumption.

The research comprised of a desktop literature review, attendance at key local conferences and interviewing a suite of stakeholders associated with the above topics, as outlined below:

1. Review of existing body of knowledge and research related to the topics above, comprising of:

    - Recent peer-reviewed journal articles (since 2009) and accessible conference proceedings (since 2009)
    - Review of recent patents relating to meat packaging

2. Attendance and summation of key outcomes and emerging themes from the following local conferences:

    - Foodservice Suppliers Association of Australia "Foodservice Today and Tomorrow Conference", Sydney[1] (26th May 2014);
    - International Association of Packaging Research Institutes (IAPRI) 19th World Conference on Packaging, Melbourne[2] (16-18 June 2014)
    - Australian Institute of Packaging (AIP) National Conference, Sydney[3] (17-18 June 2014)
    - 2014 Australasian Packaging & Industrial Paper Market Outlook (APPITA[4]) forum, Melbourne[5] (19-20 June 2014)
    - FoodPro and the 47th Annual AIFST[6] Convention, Melbourne (23-24 June 2014).

3. Stakeholder interviews[7]: Forty one (41) stakeholders from academia, research organisations, packaging companies, consumer and not-for-profit organisations and retail were invited to participate in a one hour semi-structured interview. There were ten (10) interviews conducted (24% response rate) and their insights are presented as quotes throughout this report.

1.2 The role of packaging in food protection

While consumers may say there is too much packaging and it is bad for the environment [1], all levels of packaging, including primary, secondary and tertiary materials, play a critical role in the containment, protection and distribution of food on a global scale. Key to this is selection and designing the right packaging materials and format for the right application while meeting product requirements and consumer requirements (see Section 4.4).

Functions of packaging include [2]:

- Protection, including preventing breakage, spoilage and contamination
- Promotion, including describing product features, ingredients and branding
- Information, including product identification, product preparation and end-of life management
- Convenience, including preparation and portioning
- Utilisation and handling, including providing for transport and retailing
- Waste reduction, including increasing shelf-life.

Decisions that need to be made across the food packaging supply chain are listed in Figure 1-1 and further expand into product and packaging integrity and traceability (see Section 4.10); sustainability and social responsibility (see Section 4); quality assurance, capacity and technical support of packaging suppliers and co-packers; and damage reduction and supply chain robustness [3]}[4]. Of these functions, of primary importance is the protection of the product [5]. Packaging serves to protect the food it contains and as such has the potential to reduce waste through the supply chain [1]. Food safety compliance and product integrity are paramount in this context along with risk mitigation to ensure that the supply chain is providing the best product-packaging solution to get the product safely and efficiently to market [1, 3, 4].

[1] Program download at http://fsaa.org.au/images/docs/Booking_Flyer_2014.pdf
[2] Program download at http://www.vu.edu.au/sites/default/files/engineering-science/pdfs/IAPRI-2014-preliminary-program.pdf
[3] Program download at http://www.aipack.com.au/Content/Attachment/2014_AIP_NC_Program.pdf
[4] APPITA – Australian Pulp and Paper Industry Technical Association
[5] Program download at http://www.appita.com.au/packagingforum-program/forum-timetable
[6] AIFST – Australian Institute of Food Science and Technology
[7] RMIT Ethics Approval (Project Number: CHEAN A 0000018686-05/14)

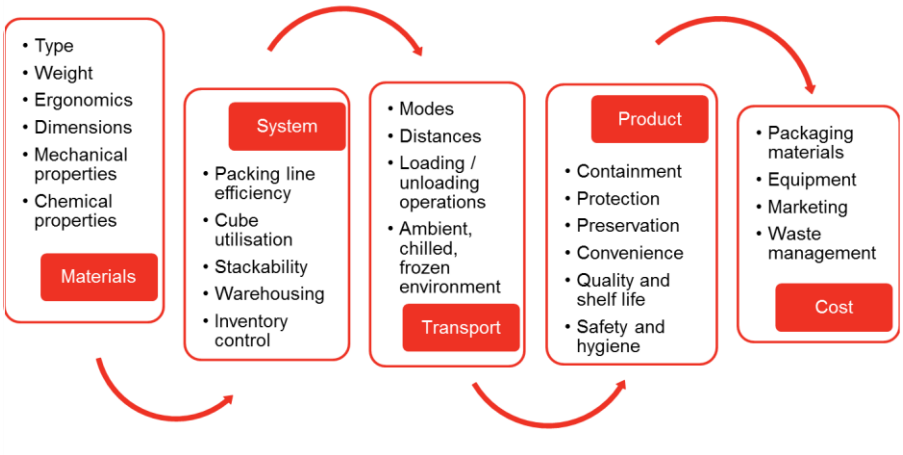

Figure 1-1 Examples of packaging decisions for fresh and processed foods

Source: [6] adapted from [7-10]

In the case of the protection of meat products, packaging material formats aim at minimising the following attributes [11]:

- Discolouration
- Off-flavour and off-odour development
- Nutrient loss
- Texture changes
- Transfer of disease (pathogenicity)

Packaging research has been focussed on minimising these attributes, which can also affect consumer perception and affect consumer behaviour [12, 13] (see Section 4.4). Of particular importance is the need to understand consumer preferences and behaviours; by doing so enables packaging to be designed to meet specific consumer needs [5]. Understanding consumer drivers and trends and how the consumer interacts with the product, is also an important component of packaging design (see Section 4.5). Issues such as demographic changes, ageing population, convenience, on the go food purchasing, and the ever increasing focus upon food waste across global supply chains, make the consideration of the following packaging attributes imperative in assisting in improving efficiencies through the supply chain [5]:

- Contain the desired quantity
- Mechanical protection
- Physical-chemical protection of the product
- Resealability
- Accessibility – easy to: open, grip, does and empty
- Contains the required functionality – e.g., materials that can be used in “ready to heat” packaging formats linked with convenience
- Food safety / freshness information
- Facilitate sorting of household waste

Packaging plays a multitude of roles, and as this report will document, many considerations and trade-offs need to be made at every stage of the red meat supply chain. The need to value add and provide different cooking and eating experiences, packaging technologies will play an integral role in delivering red meat into domestic markets and differentiating Australian red meat into export markets. The following section provides the context of the market trends for red meat in both the domestic and export markets (Section 2) followed by details on emerging packaging technologies (Section 3).

2 Market trends

2.1 Domestic

According to the Australian Government's Department of Agriculture, Fisheries and Forestry, there was 1,470,000 tonnes of beef meat processed with 985,000 tonnes being exported in 2010 (Figure 2-1). Domestically, the breakdown of beef sales was 57% through supermarkets, 27% food services and 16% specialty. Food service is an expanding and developing market channel [14] which should be exploited both domestically and internationally.

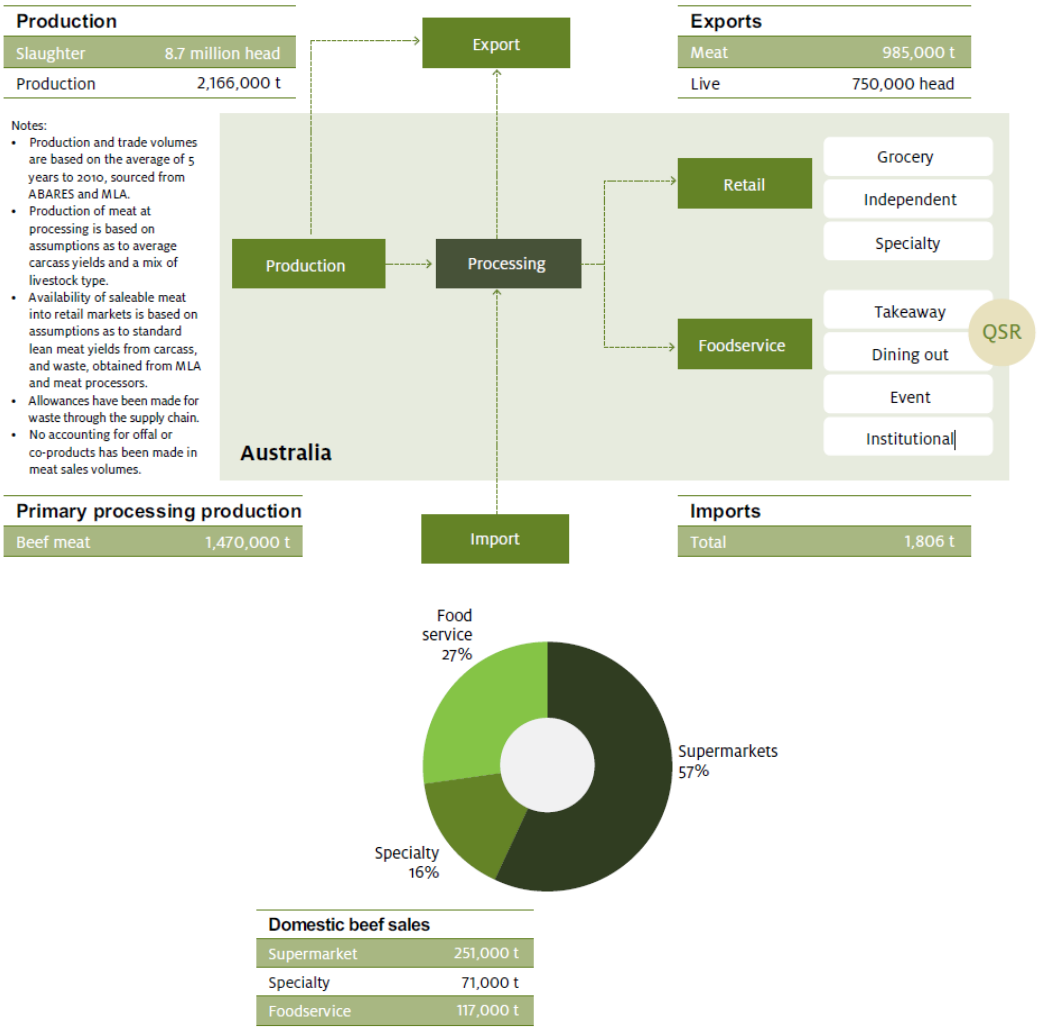

Figure 2-1 Beef product supply chain value map

Source: [15, 39]

The breakdown for the lamb supply chain is presented in Figure 2-2.

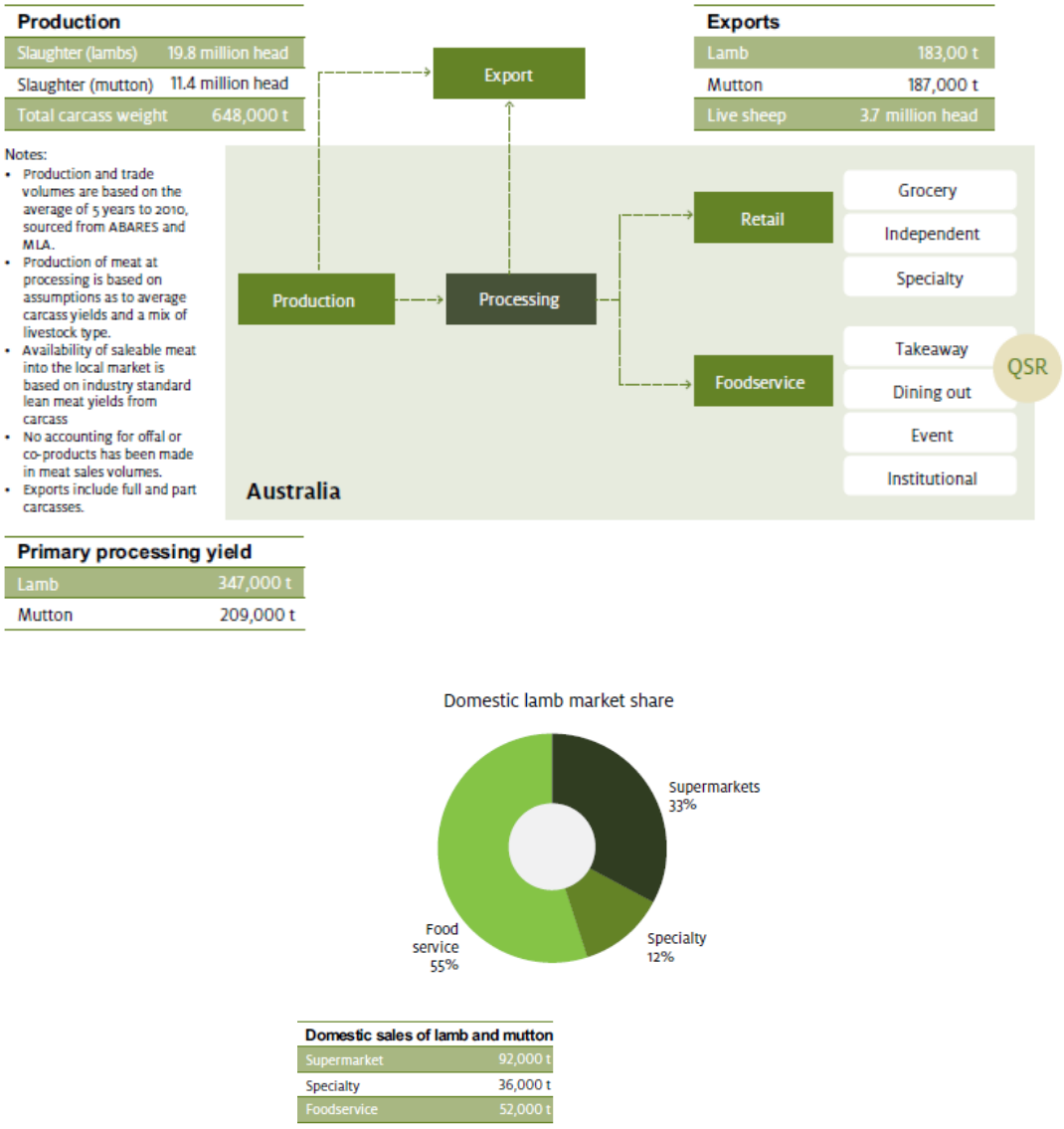

Figure 2-2 Lamb product supply chain value map

Source: [15, 43]

Another way to look at the domestic beef and lamb sales data is using data from 2011. Figure 2-3 presents the breakdown (by volume) of beef and lamb sold in Australia through supermarkets and speciality butchers [16].

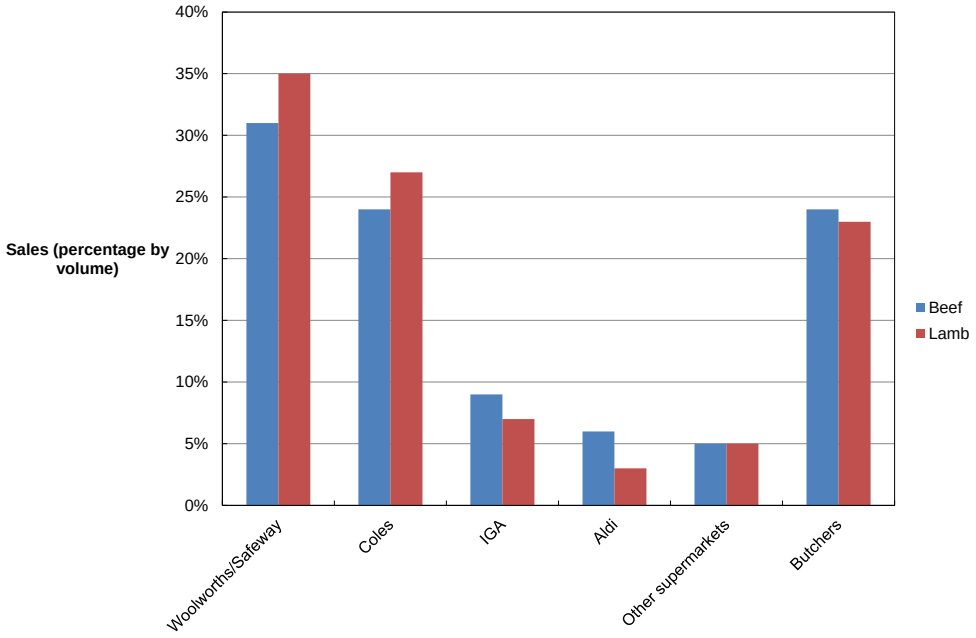

Figure 2-3. Percentage (by volume) of sales of beef and lamb in Australia by outlet in 2011

Source: Data from [16]

Consumer's purchase of meat in supermarkets has increased significantly since the 1980's, when the majority of meat was purchased from butchers [17]. As one stakeholder pointed out:

> *"The market power of the butcher is diminishing, somewhat more than the green grocer. There may be opportunities for the meat industry to engage in sustainability initiatives in niche markets such as organics, and farm gate"* (Interviewee I).

Figure 2-4 presents beef and lamb cut trends from 2011.

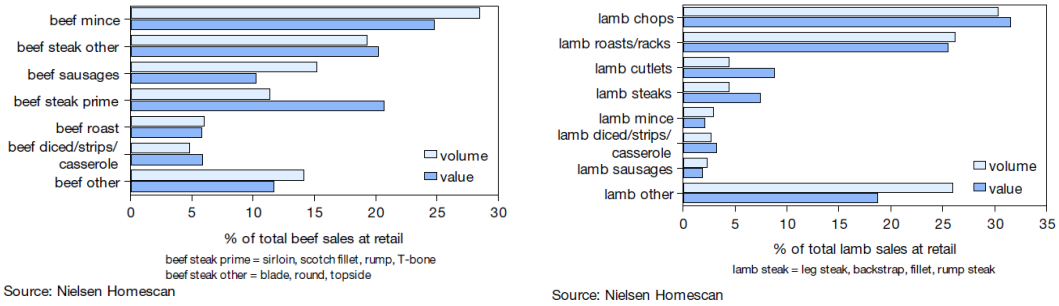

Figure 2-4 Beef and lamb cut trends at retail 2011

Source: Data from [16]

The mode of meat being sold in supermarkets has also changed [17], with meat now being largely pre-selected for consumers, whereas previously meat was prepared according to the customer's specific requirements:

> *"There has been a big increase improvement away from cling-wrap to retail ready packaging. Delivered into store, rather than processed/made in house"* (Interviewee C).
>
> *and*
>
> *"Trend to pre-packed retail cuts has not fully run its course. I expect to see supermarkets*

continue to move away from back of house to case ready" (Interviewee B).

In Australia, lack of skilled labour in butchery has led to retail butchers purchasing sub-primal cuts, rather than carcase-cuts [17]. These primal cuts are typically supplied in cartons:

> *"Main reason for case-ready packed meat; lower processing cost. In terms of types of packaging: key format of the past was MAP [modified atmosphere packaging], thermoformed. Emerging trends towards skin or bagged vacuum pack. This is underpinned by shelf life and quality of life eating experience. MAP is capped at around 9 days, compared with vacuum skin is 21 days. Trend on this is particularly for high-value cuts. Driven also by variety; e.g. grain fed, corn fed etc. Also spins out to offal" (Interviewee B).*

Following on from this insight, discussion on emerging packaging trends is presented in Section 3.2. Research also indicates that consumers make 74-76% of their impulse purchasing decisions in store [18, 19]. Packaging and branding assists in promoting the product and colour, graphic design and structural design are the biggest attributes [19]. It is therefore important to engage the consumer, understand their behaviours and perceptions. These will be discussed in more detail in Section 4.4 and 4.5.

2.2 Export

The projected increase in demand for meat in Asia is broadly associated with projections in increased income, urbanization and population increases [20, 21] (refer Figure 2-5).

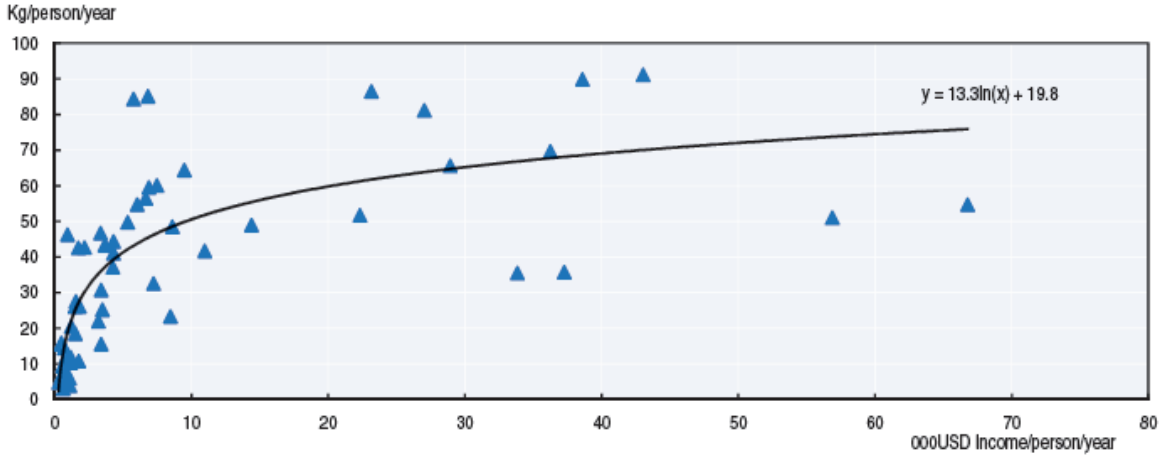

Figure 2-5 Relationship between per-capita meat consumption and personal income; meat consumption increases then plateaus as income grows

Note: From [21]

The expected increase in meat consumption in Asia, in particular China, secondly India, is attributed to a range of factors, including high income growth, price prospects, changing diets and urban migration [21, 22]. The United Nations Food and Agricultural Organisation (FAO) suggest that the projected increases in consumption in China may be underestimated, due to a potential causal relationship between refrigerator ownership and meat consumption [21]. However, a demonstrable causal relationship between refrigerator ownership and red meat consumption has not been established, particularly for urban areas [23].

2.2.1 Beef and veal

Projected per capita (Figure 2-6) and total consumption (Figure 2-6) for beef and veal for Australia and Asian countries are presented below.

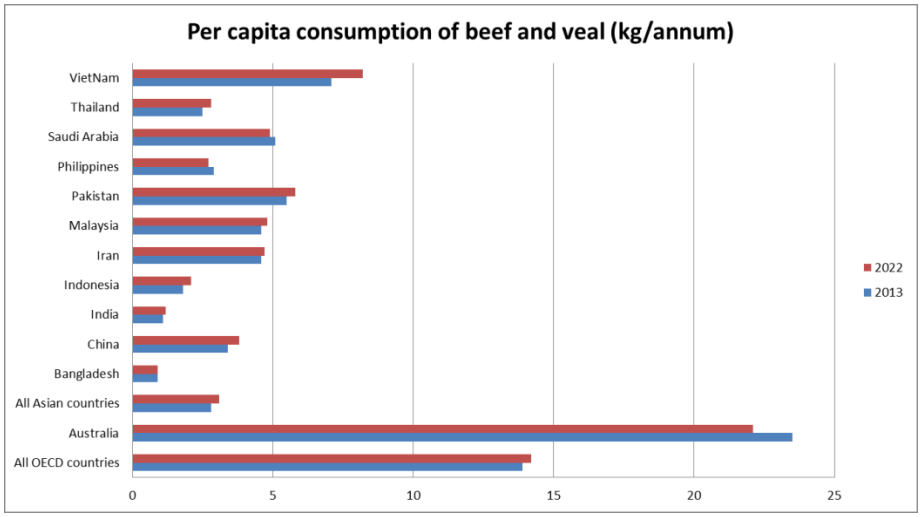

Figure 2-6 Per capita beef and veal consumption for regions of interest

Source: From [21]

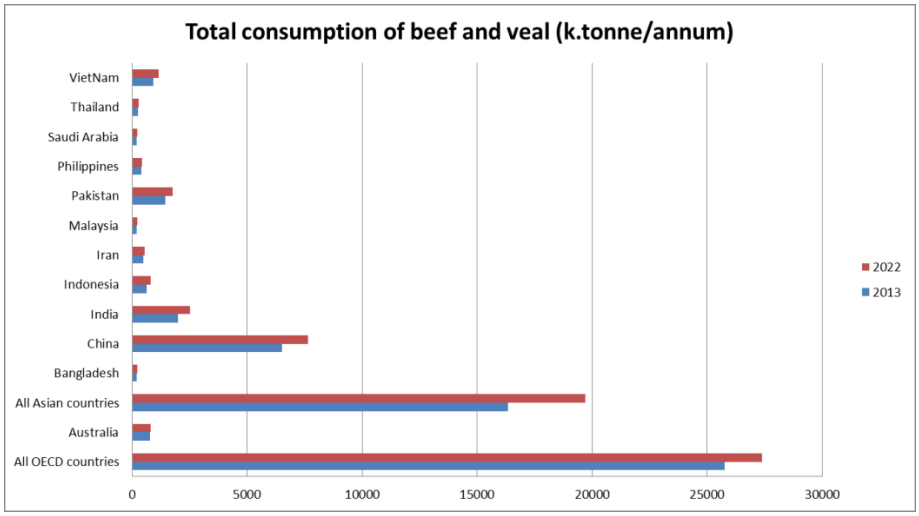

Figure 2-7 Total beef and veal consumption for regions of interest

Source: From [21]

The Australian per-capita consumption for beef and veal are projected to decline by 6% over 2013-2022. However, the increase in the Australian population will counter this; resulting in a projected increase in total consumption of 4% over the same period [21].

The FAO projects that the total Asian consumption of beef and veal will grow by 20% between 2012 and 2022 [21]. On a tonnage basis, China, India, Pakistan, Vietnam and Indonesia dominate the growth projections, with projected consumption increases of 1,133.1 k.tonne, 517.1 k.tonne, 309.7 k.tonne, 228.1 k.tonne and 162.7 k.tonne respectively over the 2013-2022 period. Of the regions considered, total consumption is dominated by China, which accounts for approximately 40% of consumption within Asia. The market for beef imports is expected to be driven by demand for high-quality meat, predominantly from food services (e.g. hotels) and high-income consumers, tourists and expatriates [24]. A significant proportion of beef in China is consumed outside of the home, attributed to a lack of familiarity with cooking techniques [24] and facilities available in the home due to

urbanisation.

2.2.2 Sheepmeat and goatmeat

Projected per capita (Figure 2-8) and total consumption (Figure 2-9) for sheepmeat for Australia and Asian countries is presented below.

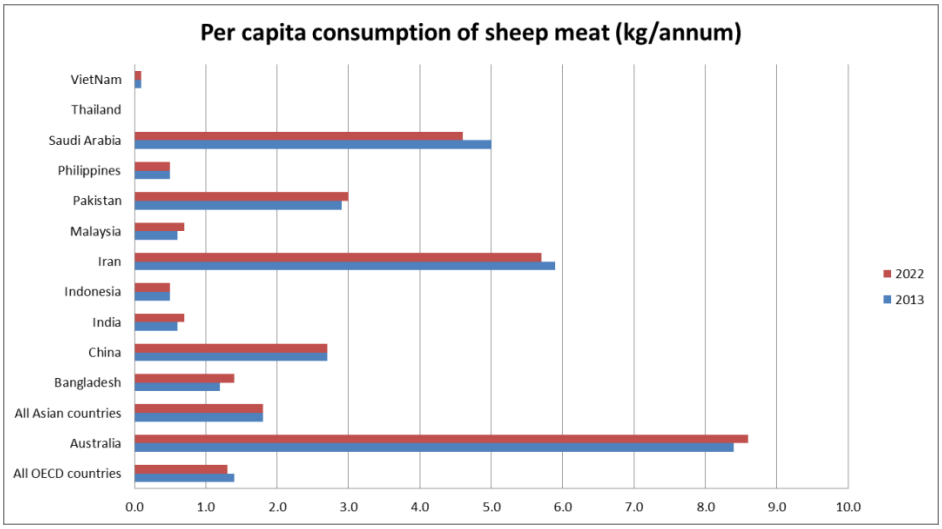

Figure 2-8 Per capita sheepmeat consumption for regions of interest

Note: From [21]

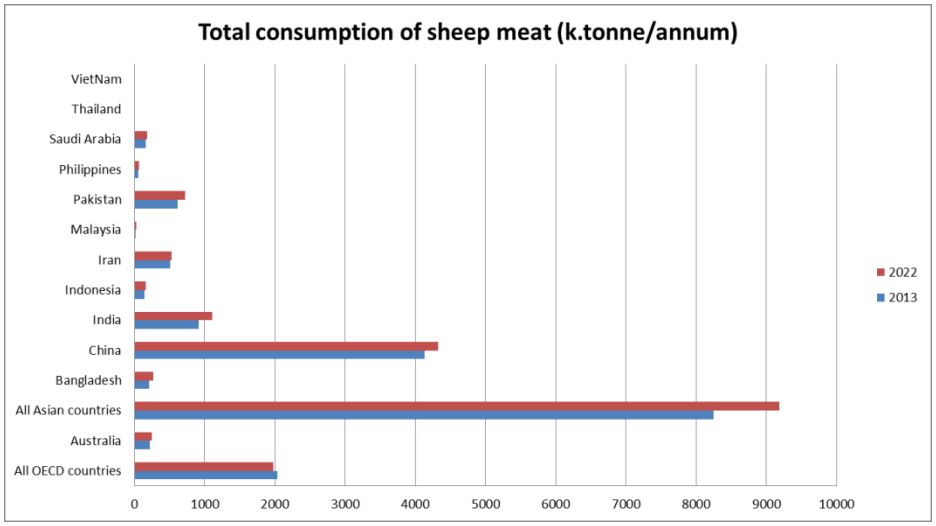

Figure 2-9 Total sheepmeat consumption for regions of interest

Note: From [21]

In contrast to beef and veal consumption projections, the Australian per-capita consumption for sheepmeat is projected to increase by 2% over 2013-2022 [21]. When coupled with Australia's projected population increase, the total sheepmeat consumption is projected to increase by 13% over this same period.

For Asia, increases in per-capita sheepmeat consumption are projected for Bangladesh, India and Malaysia, and decreases for Iran and Saudi Arabia [21]. As for beef and veal consumption, total sheepmeat consumption is dominated by China, which accounts for approximately 50% of total

consumption in Asia. India's total consumption is projected to grow by 22% over the 2013-22 period driven by increases in both per-capita consumption and population.

Although goatmeat is the most-consumed red meat globally [25], forecasts in changes to demand are not well established, internationally nor in Australia.

2.3 Current packaging materials

Typical packaging materials and formats (examples presented in Figure 2-10) that are used domestically for fresh red meat include[8]:

- Expanded polystyrene (EPS) trays with polyvinyl chloride (PVC) stretch-over-wrap. This product has a shelf life of 2-3 days.
- Thermoformed trays usually a nylon/polyethylene structure for top and bottom web which gives barrier properties and strengths.
- Modified atmosphere packaging (MAP) consisting of
    - a thermoformed or pre-made semi rigid tray made from polypropylene (PP) (major volume), polyethylene terephthalate (PET) (small volume), high impact polystyrene (HIPS) (smallest volume) with a barrier layer typically ethylene vinyl alcohol (EVOH)
    - co-extrusion or laminate lidding film with high oxygen barrier typically made from EVOH.
    - an absorbent pad
    - atmosphere usually consisting of 80% oxygen (for redness) and 20% carbon dioxide (bacteriostatic - inhibit microbes)
- Skin packs consisting of PVC semi-rigid board with barrier sealant, and a top film made from ethylene based materials with sealants
- Vacuum bags consisting of polyethylene/ EVOH type barrier layers.

EPS tray[9] | Skin packs[10] | Vacuum[11]

Figure 2-10 Examples of packaging formats for red meat

[8] Information provided during interview B
[9] Image source (8 August 2014) from http://www.linpacpackaging.com/en/eps-trays
[10] Image source (8 August 2014) from http://www.cryovac.com/EU/EN/PackagingSolutions/thermoforming_vacuum_skin_darfreshbloom.aspx
[11] Image source (8 August 2014) from http://www.cryovac.com/EU/EN/PackagingSolutions/multipurpose_vacuum_shrink_bag_packaging.aspx

2.4 Current supply chain challenges

> *"International. Cost; haven't been able to take advantage of this. Even though we are closer. Cost. Labour is one of the major reasons. In terms of transport, the problem is the lack of adequate ports, air freight systems that optimise for food manufacturing in general. Compare it to Singapore – cold chain solutions are integrated. We don't have that in Australia"* (Interviewee F).

The 'clean and green' (ie. safe and sustainable) image of Australian food products is recognised globally as a market differentiator, as identified by a study of international markets in regards to the potential for an Australian food brand [26]. This was echoed by an industry player:

> *"In Australia food safety is a limited issue as the food supply chain is highly controlled. In Asia this could be seen as a competitive advantage. There is strong growth in the visibility of food safety as an issue" (Interviewee I).*

Austrade [26] identified Meat and Livestock Australia (MLA) as doing particularly well in promoting this and other attributes of their product internationally, and as such red meat is perceived in international markets as a high quality product. This in turn can provide premium pricing and margins, though there are structural challenges and infrastructure capacity which needs to be put in place to ensure efficient flow of packed product through the supply chain. During a panel discussion at the 47th Annual Australian Institute of Food Science and Technology Convention[12] the following challenges were identified [27]:

- Australia has capacity to supply food to the growing middle class in Asia, but not the infrastructure to support it (e.g., rail, roads, ports) enabling to get product off the farm and into the export supply chain
- Australia is not the food bowl of Asia, but more like the deli of Asia supplying value added niche products that attract premium pricing and margins. Industry players agree on this:

> *"Exporting case-ready; definitely a demand and potential for case-ready formats that can be sea freighted. Processors would like to do this, but shelf-life technology is holding this back. Exporting primal cuts; significant trends to have final cutting in Asia – driven by high labour costs in Australia. We'll see our efforts in packing more product (mass). This will potentially drive increases in carcass weight. For the same amount of cutting, you get more product out. A lot of things will be driven by improved processing margins. This will also flow through to bone-in packs. Now seeing more carcass pieces going into bags for exports"* (Interviewee B).

- Added value products will take advantage of Australia's food safety, reliability, quality, perception of quality and innovation of new products not currently on the market
- Australia's advantage is not going to be price, but advantages through science, technology and innovation that is going to make us competitive. As one stakeholder put it, this includes logistics innovation:

> *"One of the ways to optimise the chain (coming out of sustainable farming systems). Understanding demand, and optimising for demand. Demand driven supply chains. Alternative farming won't kill an animal until they know that all of the animal is sold, a minimum % of animal is pre-sold. Only will work for extremely high value product (e.g. wagyu). If this can be scaled down, this is more about truly understanding the demand and utilisation. IT systems could resolve this problem, predicting etc. Use data to generate insights into demand. Data systems could do this in the future"* (Interviewee F).

- Currently, there are limited butchers in China, for example, and limited infrastructure to support meat processing in Asia
- Distribution costs are high particularly into Asia. Australia cannot compete in these markets

[12] http://www.aifst.asn.au/convention.htm

unless we value add, niche markets and different distribution channels e.g., e-commerce.

- Indonesia, Philippines and Malaysia are other countries that we should be looking at, not just China
- Population growth, different age sectors, ageing population, health and dietary requirements are other factors that need to be considered

These trends and drivers should be assessed against "technical trade barriers" and "market access" and also "eating quality". Mapping packaging technology platforms e.g. active packaging or freezing, against regulatory requirements and also available infrastructure in the importing country, (e.g., the importing country requires x days from slaughter or x days remaining to clear customs) should be addressed, rather than just simply "adopting" a technology that allows sea over air freight. The impact these technologies and infrastructure have also on the eating quality of the meat, besides just microbial/appearance defining shelf life should also be investigated.

According to MLA, beef and sheep meat exports generated $6.7 billion with China, the Middle East and Indonesia as the three fastest growing markets [14]. Food safety and a national livestock identification and traceability program are continual priorities for MLA. While food safety is becoming more important, it is becoming more complex at the same time [28].

With this context on the domestic and export red meat supply chain, the review now turns to a discussion in the following section of current and emerging packaging technologies and trends that may assist in containing, protecting and promoting red meat.

3 Emerging food packaging technologies

3.1 Introduction

This section reviews current and emerging packaging technologies, which are being used and developed to address the different and related functionalities on packaging for red-meat. Consumer perceptions of these developments are discussed, focussing on variations in customer's quality cues and attributes.

3.2 Current and emerging packaging technologies

This section reviews a suite of current and emerging packaging technologies (Figure 3-1). Brief descriptions of these are provided below, with further details provided in subsequent sections.

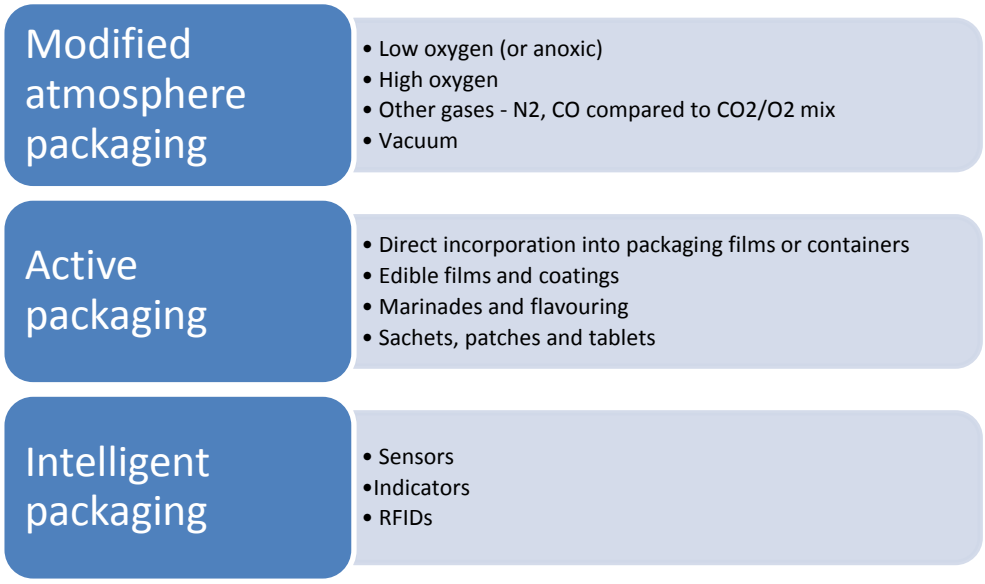

Figure 3-1 Emerging packaging technologies, a summary

- *Modified atmosphere (MAP) and vacuum packaging* (Section 3.2.1)

  In MAP, air within packaging is partially or wholly substituted with other gases, including carbon dioxide, nitrogen and oxygen [29]. In vacuum packaging, air is removed (vacuumed) from the package, and may or may not be substituted with other gases. The packaging material typically has a low gas permeability [29]. This technology includes vacuum-skin packaging.

- *Active packaging* (Section 3.2.2)

  The incorporation of specific compounds into a packaging material itself, on to the surface of packaging material, onto the product directly, or as a separate co-packaged component (e.g. satchel) [11, 29] to extend shelf life and maintain safety, quality and sensory characteristics of the product [30]. "*Moisture absorbers, antimicrobial packaging, carbon dioxide emitters, oxygen scavengers,antioxidant packaging, steam valves, colour formers, and microwave susceptors*" [30, p 405] have been identified as the most important active packaging for meat. Active packaging technology can include the use of essential oils, extracts from herbs [31] and edible films.

- *Intelligent packaging* (Section 3.2.3)

  This packaging monitors food properties and/or environment, which can be interrogated and then communicated to the processor, retailer and/or consumer [29]. These technologies include time temperature indicators, radio frequency identification tags (RFIDs), and integrity or

freshness indicators/ sensors.

In addition to these primary packaging innovations, nanotechnology (Section 3.2.4), high hydrostatic pressure processing (Section 3.2.5), and emerging secondary and tertiary packaging technologies (Section 3.2.6) will be reviewed in the context of both local and export consumption.

> *"The challenge will be to make technologies cost effective. If it's expensive, then there must be a point of difference. If you can add value, e.g. improved freshness or make it environmentally friendly, as well as doing its job, then you can probably charge the consumers more for it. ….. Getting high value properties is particularly applicable to high-value product, e.g. beef. Shelf-life extension is likely to be particularly important for value-adding" (Interviewee A).*

3.2.1 Modified atmosphere packaging (MAP) and vacuum packaging

Modified atmosphere packaging (MAP) can be sub-classified into three broad categories; low oxygen (or anoxic), high oxygen MAP and vacuum-packaging.

Low-oxygen MAP involves the exclusion and replacement of oxygen from within the packaging. Vacuum packaging is sometimes classified as low-oxygen MAP, but for the purposes of this study, it is designated as a separate technology. The most common gases used for low-oxygen MAP are nitrogen (N_2) and carbon dioxide (CO_2).

High oxygen MAP involves the use of high oxygen atmosphere (typically 80% by volume) for packaging [11]. High-oxygen MAP promotes bright red colour (oxymyoglobin) when raw [32], although this is sensitive to the type of cut and storage conditions [33]. Disadvantages include potential for grey colouring and early browning [32] and reduced tenderness, juiciness, and flavour [34].

Vacuum skin packaging (VSP), is a subset of vacuum packaging technology. In VSP, meat is placed in trays, covered in a film, then heat-shrinked and vacuumed [32]. Relative to MAP, advantages of vacuum packaging include low cost, extended shelf life and reduced off-odours [32] [11]. Thoughts expressed by stakeholders include:

> *"The other packaging that I think will become more important is vacuum skin packaging. Can incorporate marinades into these. Also allows for small serving sizes. It looks attractive because if looks like there is no packaging (as it sticks to the product); equipment and infrastructure available now for this"* (Interviewee A).
>
> *"Skin packaging growing" (Interviewee B).*
>
> *"Vacuum* [packaging] *growing for on shelf product" (Interviewee B).*
>
> *"Thermoform will continue to grow, driven by consumers demand for cheap product, particularly for mince in MAP packs" (Interviewee B).*

Disadvantages of vacuum packaging include pigment loss (i.e., deoxymyglobin = purple coloured meat) [32]. There are also questions being asked about structural integrity such as puncture and ease of access issues:

> *"For exports, shrink bags are king and will remain king. Features might be added to the barrier bags, including built-in puncture protection, ease of access. This will facilitate higher levels of automation. Anything to eliminate labour" (Interviewee B).*
>
> *Major hurdle for vacuum is colour – still myglobin state. 2-3 years ago there was consumer reluctance. Originally in MAP/vacuum were kept in separate fridges at supermarket, but now they are side by side. Vacuum denotes a quality product" (Interviewee B).*

Future and recent developments in MAP are and will largely be associated with its use in combination with other technologies, e.g. active packaging [35, 36]. This combination of technologies is sometimes

referred to as hurdle technology, and is aimed at utilising the advantages of each technology. For example, anoxic MAP (80% CO_2/20%N_2 and 60%CO_2/40%N_2) has been trialled in combination with oregano and thyme essential oils, for packaging of lamb. Thyme oil was found to be more effective than the oregano oil, and it was suggested that using thyme oil could result in a one day extension in shelf life, relative to a baseline 80%CO_2/20%N_2 MAP-packaged product [31]. The evidence for combined efficacy is limited [35], and further research is needed to demonstrate whether or not the use of multiple technologies results in synergistic benefits. It has been suggested that the future focus of MAP will be on low-oxygen applications, because the red-colour advantages of high oxygen MAP are offset by oxidation and the need for longer shelf-life [36].

Research into MAP largely focuses on the use of different gas combinations and concentrations. The addition of 0.4-1.0% carbon monoxide in MAP can promote red-colour stability. [37]. Regional regulations on the use of different gases vary. For example, carbon monoxide is not permitted as a food additive in Canada, whereas it is acceptable in New Zealand and Australia [37]. The restrictions on substances are underpinned by toxicity evidence and concerns [36]

3.2.2 Active packaging

Active packaging can be defined as the addition of bioactive substance(s) incorporated into packaging material itself, or within the package, to positively affect shelf-life or quality [30, 38]. Active packaging can be further classified into four different technologies:

- Direct incorporation into packaging films (Section 3.2.2.1)
- Edible films and coatings (Section 3.2.2.2 and 3.2.2.3)
- Marinades and flavouring (Section 3.2.2.4)
- Sachets, patches or tables (Section 3.2.2.5)

3.2.2.1 Direct incorporation into packaging films or containers

Additives can be inserted into packaging films or containers, which act by migrating onto the surface of the meat, or by remaining within (or on) the packaging [38]. Two classes of direct-incorporation active packaging additives exist; anti-microbial and anti-oxidant.

Antimicrobial additives react with microorganisms, causing a count reduction or inhibition [38]. The additives used can be broadly classified into organic (carbon containing) compounds and inorganic compounds (not containing carbon). Organic additives used for direct incorporation into packaging films include organic acids and their salts (e.g. acetic acid, benzoic acid, potassium sorbate), fatty acids, plant extracts (including essential oils from herbs), peptides and antibiotics. Inorganic additives include metals (e.g. silver, zirconium), nitrites and sulphites and salts.

> *"Essential oils can give a flavour/ aroma to meat. We are working on some anti-oxidant materials which don't have an aroma. Some industries (e.g. seafood) don't want aromas to take away from seafood aroma. When you use these anti-oxidants, there can be positive or negative aspects to taste"* (interviewee A).

Table 3-1 provides examples of laboratory use of some of these technologies used for red-meat packaging, and their efficacy on the control of specific micro-organisms.

Table 3-1 Examples of laboratory-tested antimicrobial substances

Antimicrobial substance	Film type	Effect
Bacteriocins, nisin	PE	Reduction of *B. thermosphacta*
Nisin, lacticin	LDPE, PA	Inhibition of total aerobes and coliform bacteria
Nisin, EDTA	PE	Inhibition of *B. thermosphacta*
Organic acid (not further specified)	Alginate	Reduction of *L. monocytogenes*, *S. typhimurium* and *E. coli* O157:H7

Tocopherol	LDPE	Inhibition of *L. monocytogenes*
Horseradish extract, probiotics	PE/EVOH/PET	Inhibition of *E. coli* O157:H7
Grape fruit seed extract	Multilayered PE films	Inhibition of spoilage bacteria
Notes: From [38] and references therein.		

Although there are a number of existing antimicrobial products (both organic and inorganic) on the market, the commercial viability for these products is limited and dependant on a number of factors, including efficacy, interaction with the packaging film, regulations and cost [38]. Of these, cost is the major barrier (Lee, 2010).

The other class of directly-incorporated active packaging additives are antioxidants. These include substances such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), rosemary extract and α-tocopherol [38, 39]. These additives act by reacting with free-radicals, including oxides, which can detrimentally affect colour and odour [39]. The incorporation of anti-oxidants has been found to be more effective than if the same substance is applied to the surface of the meat [39].

> *"In terms of active packaging – anti-oxidants can absorb off-odour/rancid notes. Can give beautiful fresh note to the beef. A lot of these have both antimicrobial and anti-oxidants. Having these two components will be very big in the future" (Interviewee A).*

With both classes of directly-incorporated substances, concerns remain regarding potential human-health hazards associated with substances which migrate onto the meat surface [38, 40, 41]. The use of natural-based additives has been identified as a potential way of mitigating regulatory requirements, by classifying the use of these as flavour enhancers [39].

3.2.2.2 Edible films

Edible coatings can be directly applied to the meat surface to improve permeability and perceived quality properties, such as tenderness [38]. These coatings can include anti-oxidants, anti-microbial substances, preservatives, seasonings (e.g. spices and essential oils) and gelatin [29, 38, 42]. Indeed, these substances are often similar to those used in direct-incorporation technologies. Edible films act through microbial or anti-oxidant reactions, or by affecting gas permeability [43].

Bovine gelatin coatings have been found to extend the shelf life of beef tenderloins, without adversely affecting sensory perceptions, including colour, flavour and aroma [42]. Thyme essential oil increased the shelf-life of air-packed lamb from 7 days to 9-10 days [31]. Consumer perception of gelatin coatings for beef is strong, due to it being derived from the same source as the product itself [43].

Chitosan, a by-product which can be produced through the reaction of crustacean shells with sodium hydroxide, has been cited as one coating with strong commercial potential, due to its ability to extend shelf life of meat [44, 45], biodegradability and non-toxicity [46]. However, the applicability of chitosan in maintaining such quality cues are dependent on the type of packaging used for the meat [47]. For example, for the ground beef-patties, chitosan coatings are more effective in maintaining colour when used in combination with carbon-monoxide flushed PVC packaging, compared with a vacuum-packaged system [47]. Chitosan can also adversely affect mechanical properties. In this respect, the development of active packaging must take into account interaction with the packaging material. A promising advantage of edible films is that they have the potential to remove the need for other materials within the packaging [42], such as soaker pads.

3.2.2.3 Film coatings

Coatings can be applied to films to serve as a gas-barrier, or to act in a similar way to other active packaging by providing scavenging, gas emitting, anti-microbial, and/or anti-oxidant properties.

Natural extracts, such as those from oregano and rosemary, can increase shelf life of beef and lamb [48, 49]. For example, the shelf life of high-oxygen MAP packaged fresh beef steaks increased from 14 to 23 days by coating packaging films with oregano extract [49].

A limitation of using natural oil extracts for coatings is that efficacy is needed, while also taking to account taste and/or smell perceptions [48, 49]. For example, Camo *et al.* [49] report that oregano concentrations of between 1% and 2% are needed to maintain effectiveness, without compromising consumer perceptions. The regulatory framework for the use of natural oil extracts has been cited as an area that needs to be addressed [48]. Finally, there is a lack of understanding into the mechanisms which cause improvements [50].

Metalised films (e.g. PET film coated with aluminium) act by controlling or stopping gas permeability, or by oxygen scavenging [38]. However, the incorporation of metals limits transparency and the ability for the pack to be microwaved [38]. In contrast, it has been suggested that metalised films could be used to allow for microwave crisping [40]. Transparency is cited as a requirement for retailing, but the use of this technology for within the supply chain and the service sector (where the end-customer does not interact with the packaging) should not be ruled out.

3.2.2.4 Marinades and flavouring

Marinades, such as red wine and soy, can increase shelf-life by controlling microbial activity, limiting oxidation [51]. The incorporation of essential oils (e.g. oregano, refer Section 4.3.2.2) into marinades can improve the efficacy of marinades [51]. However, the presumption that marinades always improve shelf life is not necessarily true [52] and can promote growth of certain bacteria, so they must be judged on a case by case basis.

3.2.2.5 Sachets, patches or tablets

Sachets, patches or tablets (for this study, collectively termed as '*packaging inserts*') principally act to modify or control the atmosphere or moisture within packaging [38]. Substances used in packaging inserts include oxygen scavengers (e.g. iron powder, ascorbic acid) [35], generators of carbon dioxide (e.g. bicarbonate), or desiccants (e.g. silica gel) [38]. Anti-microbial substances can also be included. The use of oxygen scavenging packaging inserts is more effective in eliminating oxygen than for vacuum or MAP systems alone [29], and can serve as an additional measure to reduce oxygen in both vacuum and MAP-packed meat [35, 38].

> *"Active packaging – the only thing that I see being played with at the moment are things that facilitate shelf-life and removal of confinement odour. Odour scavenging, oxygen scavenging, all aimed at shelf-life extension". (Interviewee B).*

There remains uncertainty as to the reproducibility of iron based oxygen-scavenging systems, with suggestions that multiple scavengers may be needed to improve reproducibility of results [35]. Carbon dioxide generators are limited in applicability as they can lead to rupture of the containing film, meaning that carbon dioxide scavengers or perforations are needed to limit the likelihood of rupture [29].

Cost, leakage of active substances, toxicity, time taken to insert into the packaging, interference with metal-detection systems and accidental ingestion of packaging inserts are cited as limitations to this technology [35, 38]. As for technology advancements in edible films, the efficacy of differential packaging inserts can be sensitive to the type of film (e.g. PVOH, PVC etc.) [29, 38].

3.2.3 Intelligent packaging

Intelligent packaging is about communication and information [53]. It can be defined as "*systems that monitor the condition of packaged foods to give information about the quality of the packaged food during transport and storage*" [29, 40]. The use of intelligent packaging systems in meat supply chains has in the past been limited [40], but this should not discount future potential. As some of the interviewees put it:

"Communication of packaging on pack still has a lot of work to do. Intelligent packaging could change from use-by to some type of eating quality. A great example of an opportunity is vacuum pack. Consumers see that as product closes in on use by date, it becomes less desirable. Under vacuum, this is less true" (Interviewee B).

"Multi-functional packaging (e.g interactive/intelligent packaging that tells consumers that product is fresh). E.g. systems developed for horticulture (e.g. Ripsense, used for stone fruits and avocado). Could be in the label, or embedded in material. Problem is in the chemistry – it needs to be product specific. Each product has its own biochemistry, e.g. pork not the same as lamb. Fattiness, shape can change. Not there yet. This technology could be used as a platform for quality assurance for the consumer" (Interviewee F).

Three categories of intelligent packaging are available; sensors (for integrity and freshness), time-temperature indicators and information-based RFIDs [37].

3.2.3.1 Sensors

A sensor is a device which can provide signal(s) relating to the detection or measurement of a physical or chemical property [40]. Most sensor systems require a receptor, which translates a detection or measurement into a signal, and a transducer, which reads this signal, which can then be analysed to produce a quantitative value, which can be stored in some instances. Types of sensors include gas sensors, fluoresence-based oxygen sensors and biosensors.

Gas sensors are often used to detect gas levels (either ambient or generated) in MAP systems. Recent advances in gas sensor technologies include non-destructive optical systems, used to detect gases produced from microbial activity (e.g. hydrogen sulphide, amines) [40]. Other research has focussed on utilising nanomaterials within packaging to enable gas detection [54]. The use of non-invasive gas sensors is limited to medical applications, and uptake in packaging is reported as being 'somewhat distant' [40].

"We will most likely explore the use of nano-sensors to explore how to predict (and extend) storage life, e.g. detection of volatiles and pathogens (e.g. listeria, campylobacter). Focus is on food safety, but this will also [possibly lead to extended shelf life" (Interviewee A).

Fluorescence-based oxygen sensors provide a visual indication of the presence of oxygen. They are typically dies, incorporated into a polymer film matrix [40]. There are a number of limitations relating to the implementation of fluorescence-based oxygen, including the ability to work consistently over typical temperature ranges experienced in cold-chains, the ability to withstand other environmental conditions (e.g. light), and toxicity [40].

Biosensors are bio-receptor devices that interact with contact with specific compounds (e.g. specific bacteria or acids produced in the presence of bacteria), sending a response signal, which can be electronic [29, 37]. This interaction can occur through the use of antibodies. An example of a biosensor was the Food Sentinel system, which rendered a barcode unreadable by the presence of certain bacteria [40]. Projections for increased uptake of biosensors [29] have yet been realised and few are commercially viable [40], in fact some that were developed, including the Food Sentinel system, are not commercially available This may be due to anything from cost, scale, robustness, legislation, safety, or the nature of the communication of such devices (directly related to the freshness of the food item, as opposed to other less direct product indicators such as time, temperature, integrity, etc), however developments in flexible/ printed electronics, carbon nanotechnology, silicon photonics and biotechnology may provide breakthroughs that render sensors commercially viable in the future [55].

3.2.3.2 Indicators

Indicators are a form of qualitative intelligent packaging that communicates the quality and/ or state of a product during the food chain [56]. These can include time-temperature indicators (TTIs), integrity indicators and freshness indicators. Indicators are often communicated through a colour range for ease of consumer understanding, however even this presents issues for users that have visual or

colour detection deficiencies (See Section 4.8 on accessibility).

TTIs are typically labels which affix to the outside of a food pack, but indicators can also be applied directly to the food. TTI's serve as a proxy for an indication of bacterial activity [37], and thus can provide indirect information relating to product quality [29]. TTI's work through mechanical, chemical, electrochemical, enzymatic or microbiological changes with time and temperature. These changes are typically indicated visually through deformation of a material, or a change/movement in colour [29]. A key advantage of TTI's is that it allows products to be managed based on remaining shelf life, rather than first-in first-out, thereby reducing waste [29]. In addition, TTI's are low cost, rendering them suitable for individual retail packs [29]. In addition, the technology must be robust and the ability to withstand tampering and other environmental exposure (e.g. sunlight, gases) [29, 57]. In 2006, Kerry *et al.* [40] reported that the potential for TTI's to improve distribution, quality and safety had yet been realised, and that cost, reliability, legislative restrictions [58] and applicability are contributing factors to this. The main limitation to TTI's is that extensive kinetic studies must be undertaken on both the product and TTI in order to demonstrate that bacterial activity is indicated [57]; the TTI response must match the behaviour of the food [40] and the predicative (microbial) shelf life. This matching of behaviour is complicated due to the number of variables associated with meat products, such as the type of cut, processing conditions etc. [40]. Migration of active substances to the product remains a regulatory concern in most jurisdictions, including Europe, Australia and the United States.

Integrity indicators range in complexity from simply communicating how long a product has been opened, detecting leaks over the supply chain, to indicating the amount of ingress of a particular gas into a product at a point in time [30]. Stakeholder needs determines the level of sophistication of the indicator and the nature of the communication. For instance if a consumer only needs to know how long an item has been open, a colour label activated on breaking of a product seal suffices. If the nature of the gas interactions after opening or in the case of a leak are required, a range of colour indicators such as redox dyes or tablets, convey these interactions most often in regard to oxygen content [59], Integrity indicators can often compliment other packaging technologies such as MAP or oxygen scavengers, however one drawback is that many indicators are reversible so that when a reaction such as microbial growth on product occurs, the indicator may change back to a former state [60]. Recent innovations have sought to rectify this problem with non-reversible indicator labels [61].

It is suggested that if TTI's were to be explored that they be on a business to business (B2B) level and not business to consumer (B2C). This relates to the limited understanding of consumer's understanding and perceptions of such technology. To ensure that this technology is accepted and implemented into the market, it is important to know the level of consumers' understanding and trust of such technology. A recent study by Pennanen et al's [62] involving French, Greek, German and Finnish consumers identified both positive and negative perceptions of TTIs for packaged meat/poultry and fish. Positive perceptions such as safety and security with respect to cold-chain management before and after purchase; and an additional selection criterion when purchasing food items need to be weighed against the negative perceptions. Negative perceptions included concern related to the potential for an increase in food waste caused by TTIs where consumers may not use their own judgement to determine freshness and reply upon the labels to indicate freshness; the reliability of the technology; misinterpretation of the TTI message (e.g., slight colour change does that mean throw product out?) or relationship with other freshness indicators (e.g if TTI was in contradiction with best before or expiration date label).

Much like biosensors described previously, freshness indicators monitor microbial growth or metabolism of a product such as changes in anything from glucose, organic acids, ethanol, carbon dioxide, biogenic amines, volatile nitrogen compounds or sulphuric compounds. As such these changes can indicate a measure of direct quality [63]. Various freshness indicator technologies have been developed in the past however as reported by Realini et al [30], in most cases these have not been commercialised. Like biosensors, the reason for this needs more investigation.

3.2.3.3 Radio frequency identification

Information-based intelligent packaging includes radio frequency identification (RFID) and wireless sensor networks (WSN) technologies. RFID tags consist of storage and processing module, and an antenna. An RFID can be used to activate and obtain information from the RFID tag.

RFID can improve the movement of existing and new information associated with the product and its supply chain, from farming through to distribution, storage and retail [29]. In addition, RFID tags have the potential to include consumer-specific information, such as cooking instructions [40]. RFID systems are subject to compatibility throughout the supply chain, and are higher in cost than bar code systems [29]. Advantages of RFID systems include [29]:

- Increased quality control [37]
- Reduced labour
- Better oversight of inventory
- Improved inventory management (e.g. through stock rotation and shelf life algorithms) [54, 57]
- Reduced product recalls
- Line of sight scanning not required
- Security and anti-counterfeiting [40, 54]

The use of RFID for individual retail products (e.g. sliced pork) has been demonstrated [29, 37], although the cost of tagging and tracing individual products is cited as a limitation to this application scope [57].

> RFID and tracking. *"MLA have worked with people developing monitoring devices at the carton and pallet level used to monitor temperatures through the supply chain. Monitoring of temperature is an important area. Things go wrong, and they go wrong at a fairly low percentage. The problem is tracking the problems that go horrendously wrong. There is a chicken before the egg situation. A lot of people don't think there is any value in temperature monitoring, but the truth is they don't have any data on this. The idea of monitoring and knowing what your shipments are doing is a good one, but this needs to be cost-effective. ..[product]… lacks money to commercialise. Credit card-sized which does light, temperature monitoring communicable via the mobile network, downloadable real-time. Ability to set warnings. We started a trial with them with a company that did frozen meat /chilled produce. The trial went for 6 months. In one instance, they found the truck driver hadn't switched the trailer onto frozen. Most of the problems are hidden and there is no data"* (Interviewee J).

RFID tags rely on silicon semiconductor technologies, and applicability of cheaper, alternative materials is being researched [54]. RFID tags have the potential to be combined with temperature, moisture and/or chemical sensors [54, 57], thereby giving the ability to trace environmental conditions within the supply chain [29]. Nanotechnology could act as a mechanism to facilitate the uptake of these technologies in RFID systems [54]. The development of alternative packaging materials (e.g. metallised films) should account for potential interference with RFID systems [57].

The uptake of RFID technology in meat supply chains has been identified as occurring in the near future [37, 64], with projections that the technology will replace barcode systems [54]. Although RFID systems have been used for tracing of food by 7-eleven, and Marks & Spencer [40], there has been a move away from the technology by some retailers, including Wal-Mart [65]. In Wal-Mart's experience, this was driven by poor scanning reliability, with 15-18% of RFID tags being unreadable [65]. In Australia, RFID tags are unlikely to gain use to the supermarket level due to Australia's robust barcode system [65]; scan-rates of greater than 99.3% are reported [66].

> *"RFID won't come into Australia. Barcode quality in Australia/New Zealand will surpass other countries. Enforcement of specifications by Coles, Woolworths and Metcash. 99.5% successful scan rates – lessens the business case to move to other technologies, such as RFID"* (Interviewee C).

A major barrier for implementation of RFID technology is consistent international standards [40]. The

use of RFID for auditing and tracing, particularly in combination with time and temperature monitoring, such as done for a venison supply-chain case study in New Zealand [67], has been identified by one of the interview participants as an opportunity for the future:

> *"With respect to meat - move towards event tracking, such as time temperature tracking. Smart tags could be used in conjunction with this. This would probably fit into quality standards/HACCP processes rather than rolling out"* (Interviewee C).

> *"[Retailers] know what happens up to DC. Big challenge is from the DC to the individual stores. Issue is traceability of time-temperature from receiving dock at supermarket to shelf"* (Interviewee C).

3.2.4 Nanotechnology

Nanotechnology refers to the use of nanomaterials. Nanomaterials can be defined as nanometer (1 x 10^{-9} m; one thousand times smaller than 1 micron) scale materials and can include metals (e.g. silver) [68] and either synthetic or engineered ceramic clays [37]. The incorporation of nanomaterials into existing materials (such as polymer films) is sometimes referred to as nanocomposites. The use of nanotechnology has the potential to improve barrier, mechanical, heat-resistance, and biodegradation properties of packaging materials [38], but also to facilitate enhanced intelligent packaging, including tracking systems [37, 41] and bio sensors [54].

The two most promising applications for nanotechnology in packaging are in barrier films and active packaging [11, 38]. For example, embedding nanomaterials into films can lead to an increase in the length of the diffusion pathway for gas, which limits gas permeability. At the same time, the size of nanomaterials means that improved permeability properties do not come at the expense of lost transparency [38]. Although nanomaterials have potential application in active packaging, their effectiveness depends on a number of factors, including the polymer matrix, nanomaterial type and microbial species being targeted [11].

Although nanotechnology is projected to be taken up by the packaging sector [41], practical applications are currently limited and concerns remain regarding cost [54], health concerns regarding ingestion of nanomaterials [38, 69], and applications. Industry players often simply don't know where the technology fits:

> *"Nanotechnology is an emerging area. This is a little unclear to us as to what extent nanotech is being used in packaging. Nanotechnology. Looking particularly at insoluble and bio-accumulating nanomaterials"* (Interviewee H).

Consumer perceptions of nanotechnologies are dependent on the description or information of these technologies provided to the consumer [70]. Consumer acceptance of new technologies varies across cultures, and understanding these variations in acceptance should be addressed early in any nanotechnology development project [70]. For example, Consumer Affairs Victoria [71] suggest that Victorian consumers are reluctant to accept the use of nanotechnologies. For packaging applications, this could be due to a lack of awareness of nanotechnology [72]. Literature on consumer perceptions of the use of nanotechnology in packaging in Asia is limited. Industry is also still learning about this emerging area:

> *"Our knowledge of insoluble nanotechnology particles is still emerging, and there is not the level of predictability that we have with chemicals. The lack of predictability is an issue. The opportunity is that nanotech could offer some other benefits. The real safety risk of nano is nuclease, and it's not clear when this will be resolved. The FDA and EU are not seeing extensive commercial applications as yet. Again, whether or not it's happening under the radar is a bit of an unknown."* (Interviewee H).

3.2.5 High hydrostatic pressure processing

Packaging and processing are the main mechanisms used to preserve meat. One continual focal point for processing is the use of high hydrostatic pressure (HHP) processing [11].

HHP processing can inactivate micro-organisms and enzymes with the potential to not deleteriously affect sensory characteristics [11]. Indeed, some sensory attributes can be enhanced using this technology [11]. On the contrary, HHP processing can reduce red pigments, resulting in a cooked appearance [37]. HHP processing is currently used for some ready-to-eat meat and deli meat products [73, 74].

In HHP processing, the product is placed within a flexible packaging system, then placed in a liquid (usually water) contained within a pressure vessel. The vessel is then pressurised (typically 200 to 800 MPa) for a period of time (typically 1 to 20 min), before being returned to atmospheric pressure, when the product can be removed [11, 73]. The ongoing cost of HHP technology has been cited as being approximately €0.14/kg [11], or in the order of US$0.08-0.22/kg for ready-to-eat meats [73]. The optimisation of process conditions (e.g. time, temperature, pressure, cycles) remains an area for further research [75].

Research into the use of HHP processing with other packaging technologies, another example of hurdle technology, is an emerging theme. For example, the use of carbon dioxide with HHP processing can reduce pressures required to inactive microbes, thereby reducing cost [76]. In another example, food additives (including those used in active packaging) were also found to have a synergistic effect with HHP processing [77]. Synergistic benefits have been found for the combined use of oregano and HHP processing with raw chicken meat [78]. Research on potential synergy effects on final red-meat products (e.g. retail cuts) is limited. The use of other technologies in combination with HHP processing could also be a means of overcoming degradation of some properties associated with HHP processing (e.g. pigment loss), an issue highlighted by industry:

> *"Hydrostatic pressure processing – won't have a big impact, mainly because it discolours the meat"* (Interviewee B).

In contrast to these advantages, the use of HHP processing with existing packaging materials faces a number of issues. The properties of materials can be compromised when subjected to HHP processing [73, 79], putting at-risk the effectiveness of the packaging material as fit-for-purpose post-HHP. Transfer of packaging compounds to the product has also been observed, presenting an unacceptable risk to food safety [73]. In this respect, materials research into suitable materials for HHP processing is needed [73]. Finally, the commercial application of HHP processing is limited by international agreements on processing standards, limiting its ability to integrate into HACCP food safety plans [75].

3.2.6 Secondary and tertiary packaging

Secondary and tertiary packaging is the additional packaging materials used to protect and contain retail or consumer packs during distribution [6]. Examples of secondary packing include corrugated cardboard product shippers and plastic reusable crates and totes. Tertiary packaging is the packaging used for distributing secondary packaging, e.g. pallets and pallet-wrap. It is important to design the secondary and tertiary packaging in combination with the primary packaging [6] to ensure that it is fit-for-purpose and all support and complement each other.

Retail-ready, or shelf-ready packaging (SRP) is growing in Australia [65, 80]. This growth is attributed to advantages of this packaging format, including [80]:

- Product availability
- Stock rotation
- Reduced product waste
- Increase blockage
- Branding
- Reduced labour

On pack communication and instructions to the shelf packer of how to open and merchandise SRP still remains an issue [80]. The colour combinations of labelling and barcodes on distribution packaging are also important as the barcodes carry important information from manufacturer through to retailer [81]. If the barcode is not able to be read, then the total pallet load could be rejected.

While the meat supply chain into Asia is growing, it is predicted that it will continue to be distributed in corrugated material because the long supply chain would not be cost effective for a returnable packaging supply chain [82].

4 Sustainability, global supply chains and consumer drivers and trends

Globally, there are many drivers and trends that are influencing the food and packaging supply chain. These include demographic and lifestyle trends such as smaller households, ageing population, more convenience and on-the-go / prepared meals, increasing emphasis on quality and organic products; increasing efficiency through the value chain through appropriate primary, secondary and tertiary packaging, adequate distribution and logistics systems through the cold chain, e-commerce; and environmental and sustainability issues such as traceability, food safety, regulations and identifying and reducing food waste through the supply chain [6, 15, 83-88] [89, 90].

Food packaging and the growth in Asian countries is driving global packaging material demand [89]. An increase in consumption of packaging [91] is a result of, for example, increased propensity including impulse buying, convenience, luxury experiences; longer and more complex supply chains; desire for more natural foods; and improvements in the functionality of the package. On the flip side, reducing the packaging, material and distribution costs through the supply chain along with addressing the environmental impacts and regulations is important [91]. As illustrated in Section 1.2, packaging materials and packaging formats play a critical role in containing, protecting and moving food through the supply chain. What is critical is to achieve a balance in selecting and designing packaging to protect the product, while meeting all other economic, social and environmental challenges. This tension is captured beautifully in one stakeholder's comments:

> *"The sustainability challenge in relation to supply chains are for us:*
>
> *a. Creating a culture of zero waste.*
> *At a manufacturing level, there is a lot of discussion about lean manufacturing, and how this can be used to decrease waste. This is a great start. Lean won't necessarily be the solution, but the culture of no or zero waste will help a lot. We have to start with the culture; otherwise any other technical solution won't really work. Optimise the bottlenecks, find solutions, and then create new solutions if needed.*
>
> *b. Financial sustainability*
> *Schizophrenic consumers are looking for vegetarianism. They stop looking at red meat as mass-production and start looking at high-value options. MLA hasn't been successful at the end of the chain, the value-added products. Chilled and frozen is not enough. MLA has a role at looking at other value options, e.g. food services, ready serve meals. There is a change happening now in retail. Opening up retail to the style in UK"* (Interviewee F).

The following sections summarise key sustainability, supply chain and consumer drivers and trends that should be considered in conjunction with the discussion on packaging technologies. As will be illustrated, there are multiple drivers, trends and issues impacting upon the food supply chain. Success in the market will be a result of careful consideration and balancing of the multiple issues.

4.1 Renewable thermoplastics

There is a growing interest in the replacement of polymers made from (fossil-based) non-renewable based resources with those from renewable based materials. While using a renewable based resource can reduce reliance upon non-renewable materials and their associated environmental impacts (extraction of fossil-based materials), materials from renewable resources also have environmental impacts (e.g., land and water use, fertiliser run-off) [92]. For these two types of materials environmental impacts occur at differing degrees and different stages of the supply chain. The key is understanding these differences and using this in the decision making process [2]. The potential environmental impact stemming from displaced agriculture remains a concern for brand-owners [93]. Therefore, understanding the different functional properties and amount of material necessary to perform in a packaging format is important, along with understanding the environmental impacts generated across the supply chain [94]. The Plastic and Chemical Industry Association

(PACIA) has developed guidelines to assist in designing with biopolymers[13].

Previous biopolymer research has focussed on replicating material properties of fossil-based polymers. More recently, it has been suggested that research should focus on utilising the unique properties of biopolymers, and using these in combination with other, existing polymers [93, 95]. This type of application of biopolymers was also identified as a research area of interest by one of the interview participants:

> *"Biomaterials now - what is this packaging going to be useful for? Tailored packaging based on unique properties of biomaterials, including multi-layer films incorporating biopolymers (e.g. for oxygen barriers)"* (Interviewee G).

It is possible to replace fossil-based polymers with renewable based biopolymers without largely compromising shelf life [96], however environmental claims stemming from the use of biopolymers should be subject to scrutiny, due to uncertainty in assumptions that underpin these environmental claims. A survey of consumers in China found that 95% said they had no dealings with bioplastics, and ranked biomaterials as being less important than recycling, energy efficiency and hazard-free material. Poor uptake of biopolymers within China is attributed to a lack of information [97]. Consumer perception of packaging are covered in more detail in Section 4.4.

4.2 End of life of packaging materials

It is important to understanding the available end of life (EOL) waste collection, reprocessing and recycling technologies available to manage packaging material waste. When designing packaging systems it is also important to understand what materials are compatible in the recycling stream and what is actually recycled (e.g., http://recyclingnearyou.com.au/) [98]. Here in Australia, households are serviced by local council collection systems that collect key packaging materials that are sorted through a Material Recovery Facility (MRF) before being sent on for further reprocessing. This also occurs in the commercial and industrial (C&I) sector (e.g., retailers) where corrugated board and plastic pallet films are sorted and collected for reprocessing.

The EOL waste management technologies and processes available in overseas markets may be different to those used in Australia. Investigating what technologies and processes are available and also understanding how consumers interact with recycling will be important when designing packaging formats for exported product. This is particularly important with advances in packaging technology such as the increase in packaging applications in biopolymer, multi-layer laminate and nano scale materials, and whether the systems receiving these applications post use have adapted, or not.

In both the domestic and export markets, providing appropriate on-pack communication to help the consumer identify what packaging materials can be recycled will help assist the consumer in completing the cycle.

[13] PACIA guidelines download from http://www.pacia.org.au/programs/quickstartpublications

4.3 Food loss and waste

Food security and environmental concerns have led to the growing interest of food waste, Figure 4-1.

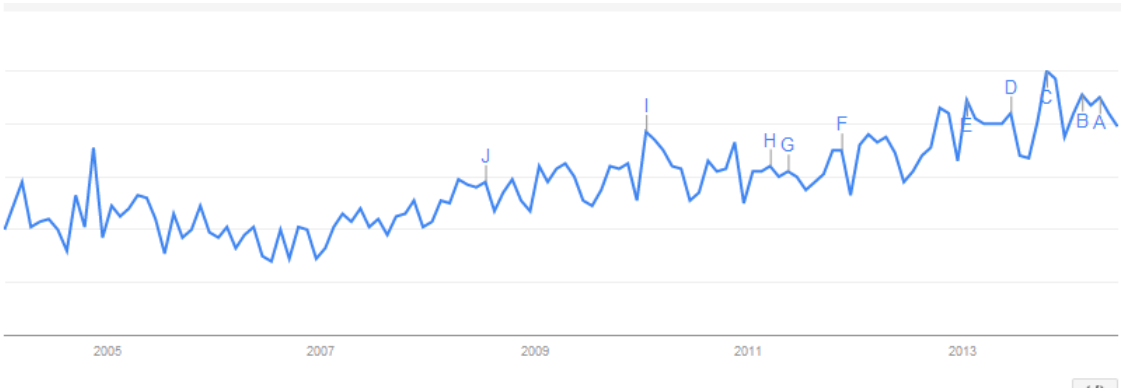

Figure 4-1 Google Trends interest over time for the search term "Food Waste". The vertical scale is a percentage of the highest search count, with the highest (100%) search occurring in October 2013

According to the United Nations Food and Agricultural Organization (FAO)[14], food loss occurs during agricultural production, post-harvest handling and/or processing, whereas food waste occurs during distribution, wholesale and retail sale and final consumption (e.g. in the home, restaurants etc.) [6] (see Figure 4-2).

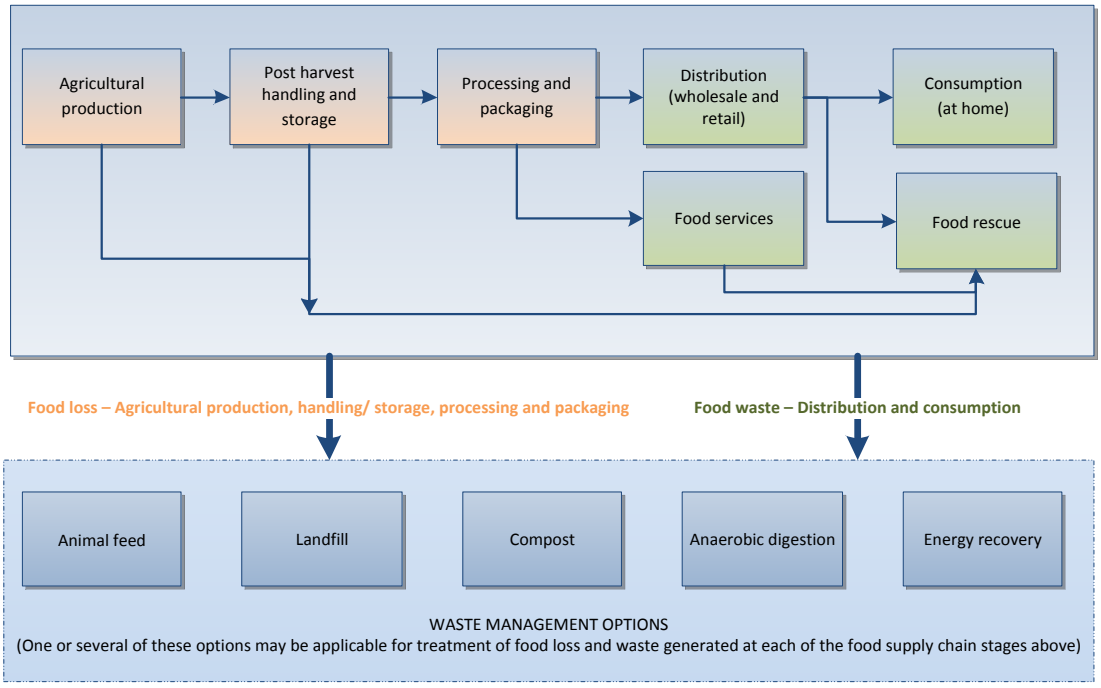

Figure 4-2 Food loss and waste across the food supply chain with waste management options

Source: [6]

The FAO approximate that 10% of meat is wasted at final consumption, while this is estimated to be in the order of 4% for south and Southeast Asia, Figure 4-3 [99]. Combined processing losses and

[14] http://www.fao.org/save-food/savefood/en/. There is also work underway developing a global protocol on food loss and waste (http://www.wri.org/our-work/project/global-food-loss-and-waste-measurement-protocol)

distribution waste are higher in south and Southeast Asia than for Oceania.

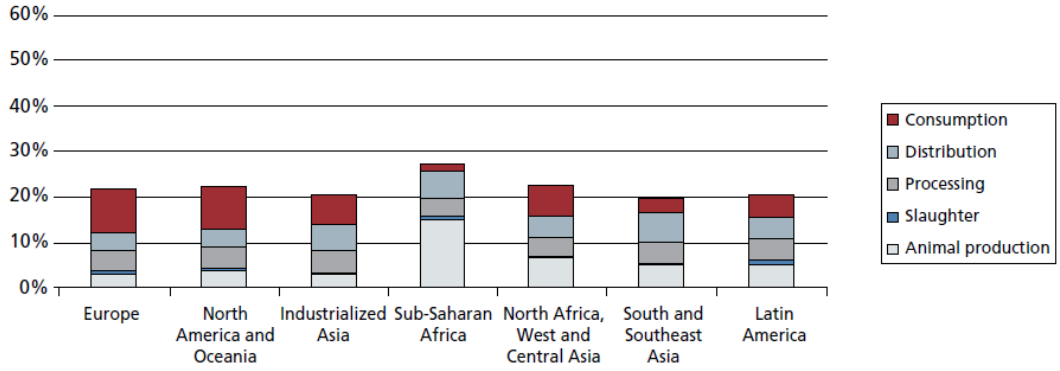

Figure 4-3 Food loss and waste across the meat supply chain

Source: [99]

The reasons for food loss/waste are complex and vary with each stage of the supply chain [6, 86, 100]. The cost and lost value associated with food loss/waste is often undervalued and underreported [101]. In addition to this lost economic value, food loss/waste has implications in terms of the accumulated resource losses and environmental emissions associated with the food loss/waste.

Packaging can play a role in minimising this loss/waste, by protecting products from damage and extending shelf life [6, 101] through the processing, distribution and consumption supply chain stages. However, increased packaging can lead to environmental burden shifting towards increased packaging waste. This trade-off relationship has been the focus of recent packaging research [5, 102-104]. Another reason to consider is the role that 'use-by' and 'best-before' dates play in food waste at the retail and household level. While use-by dates are linked to product safety, best-before dates are linked to product quality. There is evidence to suggest that there is confusion around what these terms mean and as such are a contributing factor to the generation of waste [105]. On the flip side, more research is required to investigate the degree to which promotional activity such as buy one get one free (BOGOF) and bulk buys contribute to food loss and waste at the consumer level (see Sections 4.5, 4.6 and 4.7).

In the case of meat waste, research in the UK found various causes for waste of meat products (Table 4-1). The investigation of loss and waste in the Australian (domestic and export) red meat markets would be a valuable addition to understanding the degree of and reasons for loss / waste and developing strategies and processes to reduce these.

Table 4-1 Causes for meat waste (slaughter, process, pack and at retail)

Stage	Causes of waste	Waste as a % of total weight
Slaughter and initial processing	Legislation (Category 1 and 2) Contamination / pathology Poor recovery from cutting rooms Poor process controls (e.g., floor waste, over trimming)	Category 1 – 12.5% Category 2 – 1.9% Category 3 – 9.2% Blood – 3.8% Total – 27.4%
Processing and cutting	Processing operations (e.g., maturations, giveaways) Weather variations Forecasting Inventory management Promotions Quality / sub-standard product Damage in transit	Category 1 – 0% Category 2 – 0.1% Category 3 – 10.5% Blood – NA Total – 10.6%
Packing	Wrong labelling Changeovers (short product runs) Use of interim trays Damages in storage Damages in transit Re-bagging Defective packaging	
Retail	Weather changes (impact on consumption) Forecasting accuracy Promotions Stock rotation policy (adherence) Temperature control Merchandising standards Quality control (appearance, usually discolouration)	Total – 3.9%
Source: [106, p 151] **Notes**: Category 1 – very high risk includes specified risk material like brain and spinal cord Category 2 high risk includes diseased animals, manure and digestive tract content and material from wastewater treatment Category 3 – low risk is material that is fit, but not intended, for human consumption		

If increased packaging leads to food waste avoidance, better environmental outcomes can result, even if the environmental impacts of the packaging increase [102]. The outcome of any potential environmental improvement depends on a number of factors, including the food and packaging types, percentage of food loss, end-of-life assumptions (e.g. landfill, composting) and the environmental indicator of concern (e.g. fossil fuel depletion, water scarcity, greenhouse gas emissions etc.). Wikström and Williams [103] suggest that a key indicator is the ratio between the environmental profile of the food waste to that of the packaging. When this ratio is high, increases in the environmental impacts of the packaging (e.g. due to more material being added to avoid food loss/waste) will be offset by the environmental benefits of avoiding the food waste. How these parameters relate to red meat require further investigation.

The notion that additional packaging can lead to better environmental outcomes is at-odds with current design practices, underpinned by regional agreements such as the Australian Packaging Covenant (APC) [98, 102], which promote the minimal use of packaging materials for food. Research into this issue is ongoing and the outcomes of this research are anticipated to influence agreements such as the APC.

Consumers typically have a negative association with “too much packaging” [107, 108]. Over-packaging is a concern for consumers, and it should also be for food producers/ manufacturers and retailers. Consumers’ negative perceptions of packaging (see Section 4.4) can influence their purchasing behaviours. There is a growing trend for some cuts of meat to be over-packaged. The ‘branding and marketing’ of the product is obviously having an influencing factor upon the packaging material and format design, but needs to be balanced (see Photo 4-1).

Photo 4-1 Examples of various retail ready packaging formats for lamb roast

Source: Woolworths online (http://www2.woolworthsonline.com.au/) accessed 11 August 2014. While these three images show slightly different lamb cuts, they do illustrate the differing range of packaging materials and technologies used, and in some cases the ‘over’ use of packaging.

Research by the Waste and Resources Action Programme (WRAP) in the United Kingdom indicates that although consumers acknowledge the role of packaging in protecting the product within the supply chain, they do not necessarily recognise the role of packaging in minimising food waste in the home [107]. This is an area where the food and packaging supply chain can do more in promoting the benefits that packaging plays in moving food through supply chains and also reducing environmental impact through containment and protection of product and reducing food waste.

4.4 Consumer perceptions and acceptance

Consumer perceptions regarding food quality relate to the visual, smell and taste senses, as well as beliefs which are informed through experience [12]. Packaging technologies can adversely or positively influence these quality cues. In this respect, packaging technologies play a key role in maintaining and promoting the quality cues and attributes which end-consumers value.

The success of new packaging technologies in maintaining and promoting product quality cues centres upon consumer acceptance [36, 109]. Risk perceptions and food safety concerns are major barriers to consumer acceptance [109]. For example, a 2011 European study found that MAP and vacuum packaging are familiar technologies for beef consumers, while active packaging (including those with additives, protective bacteria or natural agents) are non-familiar and were rejected as being acceptable [110]. Consumer acceptance for technology can vary with and within regions [111]; acceptance for a new packaging technology in Australia may not necessarily translate to acceptance in overseas markets. Willingness to pay is an additional factor contributing to consumer acceptance [109].

Although consumer acceptance is cited as being of critical importance, publically available studies relating to the consumers' acceptance of emerging packaging technologies are limited, particularly for Australia and south-east Asia. In addition, much of the cited literature on emerging packaging technologies do not address consumer acceptance as it often takes a more technology based perspective. Addressing consumer acceptance should be an integral part of research and commercialisation of new packaging technologies [111, 112]:

> "*Education on benefits of new packaging technology is needed*" (Interviewee D).

A critical part of the understanding and then success of existing and new technologies is consumer education and information [107, 109]. Testing and research prior to commericalisation is critical. Messages should highlight the benefits of the new technology, whilst at the same time providing advice on how to avoid potential negative aspects of the technology or debunk negative perceptions that may not exist [109]. An example of a consumer message for vacuum-packed beef is provided in Photo 4-2. The choice of language has been cited as an important issue when communicating possible benefits of packaging to consumers [110]. More generally according to recent Australian research, valid product information and credible information delivery are paramount to winning the trust of consumers [113]. The example below also illustrates the challenges still existing regarding packaging innovation and consumer accessibility[15] (see Section 4.8) – "*new style of packaging may be a little more difficult to open but this improved sealing process is your guarantee that the freshness is locked in*".

Photo 4-2 Example of consumer message (highlighted in red box, expanded on right hand side), communicating the benefits of vacuum packaging, along with addressing potential negative aspects of the packaging

Image taken by Enda Crossin

4.5 Consumer trends

To have market success, it is critical that sufficient research and testing has been undertaken in the design phase [114] into understanding and meeting the needs and expectations of the consumer. According to Hallak, 'we invent things first, [and] then develop a strategy as to why consumers want this' [115]. Maybe it should be the other way. Knowing your product and knowing your consumer is paramount [95], as business needs to 'see through the eyes of the consumer' [115].

[15] See Annette's story, a 63 year old who was diagnosed at 16 with rheumatoid arthritis http://www.userfriendlypackaging.com/wp-content/uploads/2012/07/End-user-portrait-ANNETTE.pdf for story on accessibility – "especially cold cuts types of packaging. Firstly the flap to tear is too small and kind of ripped off already and then it actually sucks. It is this kind of troublesome nitty-gritty that can drive me absolutely crazy".

A number of global mega-trends have been identified in recent consumer research [115], being:

1. Consumers want to experience lots of things
2. Status seekers are on the increase, particularly in China/India
3. Better business is starting to happen in emerging markets
4. Consumers want more information.

In regards to status this may be in making a consumer feel special, e.g. 'Share a Coke' campaign. Status can, however, be delivered to a range of consumer motives, indeed the traditional notion of status as 'having more' is being challenged by the market segment of 'green' consumers, who regard 'doing without' as increasing their status [116]. This highlights the importance of knowing the consumer for any proposed market.

Consumer access to information has never been greater, both in terms of volume and speed. New forms of information access such as online, social media and other technologies mean that consumers do not only gather information, but are also actively contributing and sharing information (see Section 4.9). For example, McDonald's received high volume social media backlash this year from a seemingly positive campaign incorporating a children's character [117]. This can directly affect businesses, as highlighted by industry:

> *"In the past five years, there has been an explosion of consumers demanding more information. More also consumers have devices (e.g. smart phones) and can contribute information."* (Interviewee C).

The design of red meat product-packaging systems must meet consumer needs and expectations and it is important to determine criteria for validation and minimum standards related to packaging and the supply chain [4] (refer Section 1). Packaging systems must be optimised to ensure that the value is created and captured so that the value add to the product is supported and ensures consumer acceptance and continual purchasing [118]. This is mirrored in some of the observations of industry stakeholders:

> *"What I have seen recently – GM from Woolworths; enhancing consumer offerings (e.g. dry-ageing, high-value, grass fed, corn fed etc.), hormone free statements - statements trying to promote the quality of the meet"* (Interviewee C).

On the topic of retailers, the opposite has also been observed in some areas, relating to the choices made available to increasingly complex consumer requirements:

> *"Currently the Australian landscape is led by retailers. It is a 'push' rather than a 'pull' environment. Their demands are on driving efficiency, not catering to what the consumer wants. This includes increased packaging without regard for the sustainable packaging option. Consumers want a reduction in packaging i.e. cryovac film meat rather than a tray and a film. The black tray is all about aesthetics, masking the red blood run off and accentuating the red flesh. These issues could be solved with a far more lightweight pack. A cryovac shrink film is more light weight, stackable, keeps blood in the flesh, reduces food waste, and facilitates portioning…surely a better solution"* (Interviewee I).

These complex consumer requirements also need to consider the finite retailer infrastructure and processes related to warehousing, stock rotation and replenishment, planograms and merchandising.

With this in mind questions regarding whether packaging meets consumer expectations of sustainability, or even what consumer expectations of sustainability are is important [90]. As previously mentioned (Section 4.3), whether a reduction in packaging is indeed a good environmental choice is contextual in relation to the product-packaging relationship, particularly regarding food waste. However, the rise in consumer awareness of sustainability issues has been noted previously [119]. One industry player thinks that how the sector reacts to this as having a direct relationship to the power dynamics currently at play:

> *"The Australian system will increasingly be a 'hub and spoke' supply model. This will be at the expense of individual suppliers. Climate change issues require strategy, however*

this will fall to the big retailers, where as a good opportunity is for a distributed supply chain to deal with the issues. This will likely not occur, and retailers, agribusiness and peak bodies will gain more of the power base going forward" (Interviewee I).

If this indeed does become the case locally, the importance of key stakeholders, such as marketers, in understanding ecological information has been identified as key to supporting successful environmental decisions and consumer communications [120], which in this case would fall to the retailers locally. In other words, it is not just about understanding the consumer and how to communicate with them, but also understanding the environmental problems industry is addressing. The same interviewee volunteered a scenario where this may also affect a perceived opportunity for the meat industry:

"With climate change, the use of food safety as a competitive advantage to Asia could be offset by the ability to deliver with drought and reduced arable land. Predictive models for long term effects of climate change and policy to match these issues are required i.e. moving stock to regions where affects are not happening, mitigation actions, etc. Again the power issue is at play here, where the issue is not addressed by agribusiness focused on prices, where as they should be because price will be affected when they cannot deliver" (Interviewee I).

At a consumer level, a survey commissioned by the Australian Food and Grocery Council (AFGC) in 2010 concluded that 'there's a green shopper somewhere in all of us' [121]. Of those surveyed, 80% said that they think about environmental issues when shopping and 50% 'often' or 'sometimes' knew the reputation of companies that produce their products. Only 13% had purchased a 'green' product in their previous shopping trip.

When asked about the most important green or environmental attribute of products, the most common answer was 'recyclable' (78% of respondents) (see Table 4-2).

Table 4-2 Consumer interest in the environmental attributes of products

Green/environmental attribute	Percentage of respondents (%)
Recyclable	78
Locally grown/produced	59
Biodegradable	59
Reproduced (??) packaging	59
Low environmental impact	56
Sustainable agriculture	50
Organic	45
Fair trade	43
Low carbon	39
Source: Net Balance [121, p. 4]	

Several of the attributes above apply to either product or packaging, areas that relate directly to the red meat industry.

4.6 Population, demographics, ageing and the middle class

The world population reached 7.2 billion in July 2013[16]. By 2050, it is expected to be 9.5 billion and 10.8 billion by 2100 with most of the growth in developing nations (Figure 4-4).

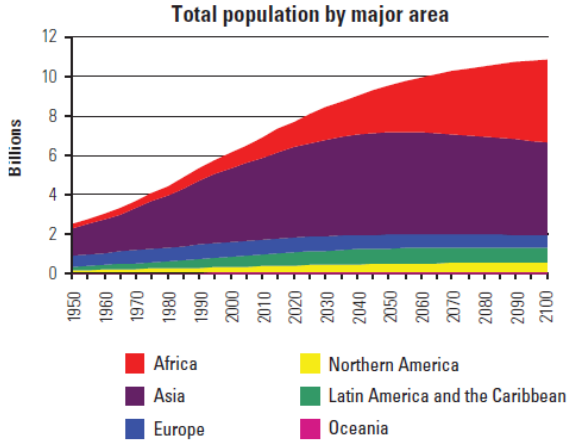

Figure 4-4 Total population by major area

Source: http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf

The global population is also ageing (Figure 4-5). According to the United Nations, '*the number of persons aged 60 or over is expected to more than triple by 2100, increasing from 841 million in 2013 to 2 billion in 2050 and close to 3 billion in 2100. Furthermore, already 66 per cent of the world's older persons live in the less developed regions and by 2050, 79 per cent will do so. By 2100, this figure will reach 85 per cent*'[17].

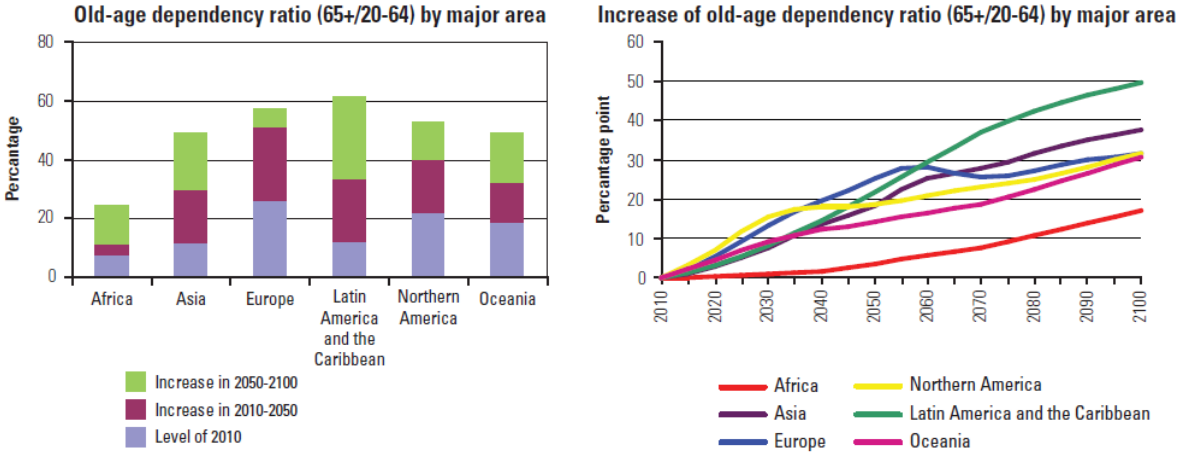

Figure 4-5 Global ageing population

Source: http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf

[16] http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf
[17] (http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf)

Locally, growth in the elderly is also projected with those aged over 65 is expected to increase from 13.5% of the population in 2010 to 22.7% in 2050 [122]. Industry acknowledges this emerging consumer trend, as well as the global significance;

> *"Firstly, ageing population. A popular perception is that the ageing population is a developed country issue, but this is not the whole story. The majority of the ageing population is in developing countries, e.g. Asia, China India. A huge percentage of the ageing population growth is in these developing countries"* (Interviewee E).

The process of ageing results in loss of strength, dexterity and cognition [87, 123]. From 60 years onwards, dexterity decreases by approximately 1.6% per year [123]. The ability to read labels and open packages is termed 'accessibility' and while this will be covered in more detail in Section 4.8, the following interviewee quote puts accessibility into context with an ageing population;

> "*Ageing health results in more barriers to purchase, such as arthritis, eyesight etc. are on the rise. There are more challenges. A lot of the factors such as making packaging shelf stable, fresher for longer, child resistance, structural integrity etc. all tend to increase barriers for open-ability, due to a failure to consider openability in the design process*" (Interviewee E).

Understanding the demographics of targeted markets, their shopping and purchasing behaviours, their accessibility levels and packaging formats they accept need to be taken into consideration when designing and selecting packaging (as illustrated below in these interviewee quotes):

> *"You can't make generalisations about what Asian consumer want and it changes from country to country and even within a country"* (Interviewee D).
>
> *and*
>
> *"One of the things that is interesting is that Australians and Americans are quite use to seeing meat in different packaging formats. In other regions, they aren't necessarily use to meat packaging and there is some resistance in other regions. What works in Australia won't necessarily translate to Asia. There could be some resistance to packaging"* (Interviewee D).
>
> *and*
>
> *"*[In Australia] *Mid 70's – The nuclear family, two parents and one or more children made up around 50% of the population. Now it's less than 30%. Now there are more couples without children, single parents and singles. The traditional view of targeting the housewife of 30-50 will only target a third of the market. You are ignoring the 2/3. In addition to who is buying, the majority of meals are prepared and consumed by one to two people. This has impacts on who is buying the food and who is preparing/cooking. To a large degree, there is an over emphasis on housewives 30-50. When you over emphasis one factor, you ignore others at your peril"* (Interviewee E).
>
> *and*
>
> *"South East Asian meat consumption revolves around the daily shop with small portion sizes (i.e.100 g of protein). Freshness and packaging is not a concern. This is at odds with the Australian model of the weekly shop and bulk buy. A rethink is required by suppliers who want to supply Asia regarding portion sizes, and 'value add'"* (Interviewee I).

Another consideration is the rise in what is known as the 'middle class'[18]. It is estimated that over the next two decades, the middle class will expand. Food is the number one thing that middle-class people will spend their disposable income on [124]. Of this middle class growth, projections are that 50% of world's middle class population will be in Asia by 2020 [124]. This presents an area that the red meat industry can exploit, where there is a surge in the real value of global food demand expected to rise by around 35 per cent by 2025 from 2007 levels, close to 60 per cent of this from China and India [125]. The red meat industry could exploit the advantages of Australia's global recognition of high-quality and safe food products [26], proximity to Asia, skilled labour, complementarity production systems, strong biosecurity measures, and supply chain innovation to supply value added food products into key markets in the Asian century [126]. The Australian food manufacturing sector has a very limited understanding on Asian consumers [124] and their in-shop purchasing behaviours which is very different compared with Australians. A program of research to rectify this deficiency would be beneficial in order to produce products that will resonate with Asian consumers.

> *"Premium packaging in developing countries is an opportunity to separate yourself from the competition"* (Interviewee E).

4.7 Convenience, Ready-to-eat, Portion Control and Sizing

Certainly one of the strong themes coming out of the 2014 Foodservice Suppliers Association of Australia "Foodservice Today and Tomorrow Conference" in Sydney was increase in demands on industry for the combination of high quality, convenience and efficiency of delivery of ingredients and end product. This was echoed in anything from the value proposition of Unilever globally [127], the demands of retailers on suppliers generally to solve problems in ordering, preparation, cooking and delivery [128], the changing demands of aged care catering [129], the expectations of airline diners [130], and the seismic shifts befalling commercial caterers [131]. This aligns with previous discussions regarding food services as a sector for the red meat supply chain to explore further (see Section 2)

That said both domestically and in export markets, convenience in the food supply is on the rise [85]. As an example food behaviour trends in the US changed significantly from 1978 to 2008, towards more snacking, high energy content foods [97]. Ready-to-eat meat products have been developed rapidly in recent years in growth markets such as China, yet the low quality and the short shelf-life still limit their further growth in the Chinese market [132]. With the rise of urbanisation in China, consumers will increasingly demand convenience food [133], and Australian industry is becoming aware of these changes:

> *"In terms of Asia, the consumer studies we do are for high-end products for the rising middle class. The consumers are looking for something new. Similarly for India, new money is looking for new products, including high-value meat products. Emerging markets, particularly Chinese and Indian consumers are looking for products with unique or novel flavours"* (Interviewee A).

Locally, industry has observed trends driven by changing consumer expectations:

> *"Convenience based also emerging. Things like reducing preparation time, e.g. sauce, rubs applied, single portions, freezer-ready, easy-open, half-prepared and cook-in packs. Both cook-in conventional and microwave oven. Conventional cooking in ovens is both a technical and consumer perception challenge. Cooking in microwave further down the track, but not fully accepted. Microwave reheat may be seen as a compromise, as opposed to cooking fresh"* (Interviewee B).
>
> *and*
>
> *"There will be a growth in pre-packaged foods and convenience-based meals. … Also,*

[18] According to the World Bank, middle class are people earning between US$2-US$13 per day. This though will vary depending upon what nation is being considered. Ernst and Young have refined this scale to a more realistic estimation of the number of people being lifted out of poverty and who are entering the targeted market. For most businesses, a much more useful definition of middle class is people earning between US$10 and US$100 per day (http://www.ey.com/Publication/vwLUAssets/Hitting_the_sweet_spot/$FILE/Hitting_the_sweet_spot.pdf).

the traditional family shop of once a week has significantly decreased or largely gone. People are shopping more often with a quicker meal preparation - both at the high and low end" (Interviewee E).

For the red meat industry, the growth in the popularity of commodities such as beef cuts in the retail market channel has included the rise in convenience and value added cuts, aligning with the consumer trend toward convenience [134]. Convenience does not translate to a lack of quality however, as described by one interviewee:

"Consumers are after "natural" wholesome, natural food. Less processes, less synthetic chemicals. Options must be convenient and easy to use. Natural preservatives fit into this perspective….. Packaging innovation plays a role in this, because when the consumer is asking for convenient, ready to eat products that are wholesome, packaging can extend the shelf life" (Interviewee A).

and

"The problem that the red meat industry faces is that there is demand to cut fat and cholesterol, so the industry needs to market high-end products. For example, value added with vegetables "grab and grow" balanced meals that don't need to meal plan. Has to be easy to cook; functional ingredients, for example acidifiers (citrus) which have organic acid, which tenderise meats. Packaging can help deliver these functional materials" (Interviewee A).

The ability of materials to offer flexibility in primary processing as well as reheating at home will be critical [69] as convenience products increase in popularity and distribution. Convenience meals foster other trends as observed by an interviewee:

"There is a major increase in portion control packaging, pre-packaged meals, and packaged food overall. For example, people are buying diced vegetables. Convenience and portion control are both major trends" (Interviewee E).

Portioning and meal sizes are changing with this increase in ready-eat-meals and convenience foods, as well as cost drivers highlighted by industry:

"Locally, [the] *consumer trends we see* [are] *towards portion control and sizing. We think its backed by consumer convenience and the cost of red meat. As we see the cost of red meat increase, portion sizes are reducing to hit price points"* (Interviewee B).

Changes in demographics such as more 'time poor' professionals [135], changes to local ethnicity through migration, smaller households (such as single occupancy households increasing from 1.9 million in 2006 to between 3.0 to 3.6 million in 2031) [136]., the ageing population, and in emerging markets the rise of the middle class and urbanisation also affect meal sizes. As one interviewee put it:

"Portion size is a trend to be considered. The size of protein servings are decreasing. Demographics are changing this issue. If you consider the ageing population (people eat less as they age), smaller households, the growth of the Asian migrant population, and the fastest growing migrant population being Indians, these factors alone mean that a now portioning strategy should drive meat packaging. 400/ 300/ 200 g portions will be less demanded by these groups. For example, lamb chops in a pack of six could be a pack of 4" (Interviewee I).

Portions also decrease as we get older [129], and as such meals in either retail or food services will need to adapt to suit. Indeed the nature of food selection is also influenced by celebrity culture, migrant foods, and as generations such as baby boomers get used to either eating out or cooking with foods from different cultures. As one interviewee put it:

"The cooking shows on TV are leading to changes in demand for food. Not necessarily cheaper cuts, but variety of cuts. Driven by variety of meals across time. Households today like to have more variety than ever before. That trend has plenty of mileage to run

on. As variety accelerates, consumer acceptance will take time to drive it" (Interviewee B).

This is opposed to Anglo-Saxon and rationing traditions of the wartime generations, although these staples can still be the default when cooking at home [137]. Shifts such as these have an influence on the type and size of red meat portions included in meals demanded by current working generations as they age, as observed in both the aged care and hotel industries [129, 138]. Industry is already adapting, one interviewee commenting on a business that has shifted from being solely a weight loss service to cater changing lifestyles:

> *"Light and easy is a perfect example of the 'exact portioning' model, which is something they have been promoting recently (on top of the weight loss message). They still provide 150 g of protein"* (Interviewee I).

4.8 Accessibility

There is increasing attention being placed upon accessibility of packaging, that being how easy packaging is to open, read and understand any labelling. As the population ages and increasing numbers of the population are diagnosed with arthritis, their ability to open or read labelling on packaging causes daily frustrations. According to research in Denmark, 16% of people choose a competing product if they have had a negative experience with packaging [139] – see http://www.userfriendlypackaging.com/ for practical guide for companies and designers. As the saying goes: "If they can't open it, they can't eat it" [114].

According to one stakeholder:

> *"….. It's a physical barrier. You are creating a barrier to purchase and losing a major potential competitive advantage. …. Consumer involvement at the later stage of development typically involves marketing centred approach around do you like it and how much would you pay for it, it's very rare, if ever to focus on accessibility"* (Interviewee E).

Some statistics regarding accessibility include:

- 53% of Australians have suffered an injury when trying to open packaging, leading these consumers to feel largely frustrated [97, 114]
- 9 out of 10 Australian consumers are frustrated by opening packaging [114]
- 5 million plus consumers have had a serious cut when opening a pack [114].

The issue of accessibility here in Australia has gained some traction in recent years following its inclusion as one of the design strategies in the Sustainable Packaging Guidelines (SPG)[19] in the Australian Packaging Covenant. According to the SPG the following key questions should be considered with respect to accessibility of packaging:

> - *Has the consumer's ability to access the product within the packaging been adequately considered in the design process? For example, has a consumer specialist analysed the actions required to interact with the product.*
> - *Have you considered whether the level of information on the packaging ensures the consumer is aware of its contents and how to open the package?*
> - *Have you considered the demographic of the consumer who will use the product? Are there any limiting factors typically associated with these consumers?*
> - *Can changes be made to improve the ability of the consumer to use the product without compromising the safety, security or quality?*
> - *To what extent has your company ever received any complaints in relation to accessibility of packaging?*
> - *Could an alternative design be used efficiently to minimise the requirement for tools such as a knife or scissors?"*

[19] Download from http://www.packagingcovenant.org.au/resources.php/7/sustainable-packaging-guidelines

There is industry evidence that accessibility is being acknowledged as an issue to consider:

> *"Easy open features are available, but not there yet. At the consumer level, this is something that will come. Driving this are safety (no weapon needed), ageing population (ease of access), in general consumers don't like to handle raw meat. For example, ease of open packaging can allow a consumer to place meat on a tray without touching the meat. This will come with time"* (Interviewee B).
>
> *and*
>
> *"At the processor level, having easy-open packaging means that retail cuts won't be damaged and increase speed"* (Interviewee B).
>
> *and*
>
> *"In terms of accessibility, there is a push towards convenience – good design won't be noticed if they can't open it. If you pay for a premium for a product, the contents will be a premium, that they should also be able to open it without risk of injury ….. If you get it right, you create a competitive advantage, if you get it wrong, then you've got a barrier"* (Interviewee E).

As discussed previously, with an ageing population the design of accessible packaging will be an important competitive advantage (see Section 4.6). With the move to new packaging technologies for red meat products, attention to accessibility must be part of the design process.

4.9 Purchasing influences and behaviour

Advances in information and communication technologies such as smart phones are opening up new opportunities to communicate information to consumers at point of purchase. Links through technologies on packaging such as QR (Quick Response) codes provide consumers further information conveniently delivered through their smart phone in order to make a decision. As an example, Nestle is currently developing QR codes that will link consumers to the company website. The site[20] will provide consumers with aspects on nutrition, environment and society [95]. In another example, the 'GoodGuide' smart phone application in the USA attempts to provide "authoritative information about the health, environmental and social performance of products and companies" [140]. With consumer push for extended product information there is an opportunity for the red meat industry to add value through digital media [141], and to engage with consumers on a personal level through a packaging intervention.

Omni-channel purchasing is also being facilitated by technology and information advances, an area that is being exploited to personalise a consumers experience [65, 141]. Data mining of (amongst others) purchase patterns, loyalty programs, social media, etc. could be used to target individuals to cater for their purchasing needs regarding red meat. Retailers in Australia are placing a significant focus on online sales [141]. Established food and grocery companies have established online portals that allow consumers to shop in the comfort of their own homes, serviced by dedicated delivery networks. Even farmer's markets benefit from online forums such as www.efarmersmarket.com.au and www.farmersmarketonline.com. Conway has suggested that online channels could serve as a testing ground for new products and packaging [142]. Pay-Pal estimated online expenditure in Australia to increase from $30.2 billion in 2010 to $37.7 billion by 2013, posting that 'consumers are connecting through local, digital, social and mobile channels that add relevance and convenience to their lives' [143].

PayPal also saw mobile device transaction reach $14 billion globally in 2012, from $750 million as short a period back as 2010 [144].New payment platforms are a purchasing trend the red meat industry must be mindful of in marketing and sales. In the United States, approximately 46% of 'millenials' (people born between 1980 and 2000) have used mobile apps to aid in purchasing

[20] http://www.nestle.com/media/newsandfeatures/global-qr-codes

decisions [65]. Taking mobile shopping model to another level, Tesco opened stores in Korea where shoppers used smart phones to select grocery items represented by pictures laminated to the walls of railway stations, with the final selections delivered by the time they get home [145].This kind of model has now also been trialled in Australia.

Photo 4-3 Screenshots of Tesco laminated grocery items on walls of Korean railway station

Source: www.youtube.com/watch?feature=player_embedded&v=fGaVFRzTTP4

Bulk purchasing is also becoming more common with the arrival in Australia of US (i.e. Costco) models. These have been adapted to the Australian market place, with a focus on volume, efficiency and value. Research by Datamonitor in 2010 found that up to one third of Australians are switching to become frequent buyers of groceries in bulk. They predict that the Costco model may put pressure on Coles and Woolworths to start adopting a bulk packaging and sales strategy [146] ()[147][146][146][146]. Bulk retail provides the red meat industry with new ways to enter the supermarket industry, along with the potential to increase materials efficiency through higher product-packaging ratios. This however needs to be weighed against the risk of increased product wastage, as well as different packaging and logistics – through supply chain and at the household.

Supermarkets are increasing the amount of shelf space allocated to private label products, driving consumers to buy these products more readily. IBISWorld estimates that consumers will purchase $31.8 billion worth of private label grocery items by 2017, up from $9.96 billion in 2007 [148]. Woolworths plan to increase space allocated to their own brand products to reach 35% of total sales outside fresh food. This is still low by international standards – British supermarkets sell three times as many own brand products compared to Australian supermarkets, and US supermarkets twice as many [149, 150]. This trend is increasing the influence of retailers over product choice and packaging which has traditionally been controlled by brand owners, and will require increased dialogue and negotiation between red meat suppliers and retail buyers.

Cost of living is often a hot political topic locally. Consumers change their purchasing behaviour when perceived cost of living rises, such as [85]:

- increased consumption of private label brands
- cheaper variants or portions of the same product
- buying more in bulk.

Economic downturns or cost pressures also start to drive consumers to eat more meals and socialise at home [151, 152].

4.10 Traceability including food safety

Traceability is becoming more important [142] for reasons including economy, safety, efficiency, compliance and consumer demand.

As an example according to Britt [153] the main challenge for sheep and livestock relates to the traceability of exotic diseases e.g., foot and mouth disease. The NLIS ear tag system for beef tracks cattle from birth to slaughter/carcass. Currently, the system does not trace through to individual cuts but this could be possible for high value cuts (may not be commercially viable for cheaper cuts like mince).

Tracking systems can add value back to a supplier, providing them with quality information on their

product [153]. According to Crawford, traceability must extend to all of the product life cycle including packaging, flushing gas, etc. [154]. The food safety risks associated with not having relevant tracing techniques have been highlighted by industry:

> *"We get involved in food recalls or significant food incidents. One of the major issues we face is tracing the product. We can trace the pallet, but not necessarily the ingredients. This is not just seen by us as an issue. We have a one step forward, one step back. We have seen how this plays out in exports, e.g. chlostridium contamination in NZ. It is very difficult tracing, in terms of exports. It jeopordised NZ's trade with China. Tracing needs to be effective and fast"* (Interviewee H).

Consumers' expectations and understanding of traceability is also increasing [154] and if such a system exists for the meat supply chain it can be seen as a competitive advantage [153]. This is echoed in the thoughts of industry stakeholders:

> *"Consumers demand a safe and secure supply chain, but they won't be willing to pay any more for it"* (Interviewee C).

While the global supply chain becomes more complex and consumer 'wants' have changed, food safety needs have not [155]. According to Corbet, "if you can't trace it, you can't protect it" [155]. Food safety is actually a strength of the Australian food industry, as described in Section 2.4. Although strict regulations exist, precautions are evident in the approach industry takes to the issue:

> *"When I think about food-safety, I think about microbiological challenges. Microbioology for meat is a bit of a "weird" area, because from a strict point of view, we say that this is raw food that is intended to be cooked prior to consumption. We aren't really concerned about pathogens in raw meat, however, everybody likes to do it and measure total bacteria. Often this is high – does it matter? Not really, is it an indicator of spoilage? Not necessarily. e.g. for vacuum packing counts can be high. Counts are indicators that care has been taken, or a function of time. Product won't probably spoil if counts are low. High counts are not necessarily a measure of spoilage. People like to do micro testing because its objective. Odour, visual and taste (organoleptic) acceptance is what really determines shelf life. If it's stored under 7°C, pathogens generally don't grow. There aren't food safety challenges. But they are microbiological, so there is always an underpinning concern"* (Interviewee J).

Moving forward, along with an optimal pack design, Asian consumers will want a known, safe supply chain for their food [118]. Existing technologies can be partnered with new technologies to that end. For instance, the humble bar code could facilitate innovation when linked to other platforms:

> *"From a barcode perspective, what you will see is this being included within barcode system. Currently barcoding for meat is typically price or weight-based pricing. New data embedded could include batch numbers and use by dates. Supermarkets have no major barrier to using better systems, utilising scanning hardware and capability of point of sale systems. The benefits include traceability, mark-down systems, and better stock rotation. Australia is behind other countries being a bulk exporter"* (Interviewee C).

The reputation of all suppliers across a supply chain, even if they are not directly involved, can be affected if a negative incident occurs [156]. As a case in point, packaging and product identification has become even more important to instil consumer trust:

> *"For packaging/ product identification internationally, there has been a move from carcass to retail identification. This is driven by the European horse meat example. Major global supermarkets were impacted on this. The consumer is expecting to buy what they have paid for."* (Interviewee C).

5 Regulations and labelling

Regulations' regarding the use of emerging packaging technologies varies. For example, active packaging incorporating oxygen scavenging, are accepted in South Korea and Japan, whereas the use of active packaging in Europe and the United States is somewhat restricted, on the basis of societal concerns or a lack of regulation [38]. The following quote from an interviewee provides some of this context:

> *"In general, some countries have open regulation, while other countries are very, very prescriptive. In regions which are particularly prescriptive, small changes can become unacceptable. E.g. vacuum packs aren't even acknowledged. Regulations are often focussed on aerobic conditions, rather than being developed specifically for packaging technologies, e.g. for MAP/vacuum pack. For developing countries, the way we can assure safety and quality of food is to heavily regulate. They do this in lieu of having the infrastructure to maintain regulations, or expertise to change regulations, or even a system to allow approval*. [It] *becomes very, very difficult. For example, Egypt has a rule that vacuum pack must contain no liquid. Then there are more barriers when a technology is introduced to counter this, e.g. soaker pad. Then after drip, then its microbe count, then pH, then size of piece of meat.*
>
> *Shelf-life and expiry date barriers are seen as the most costly barriers for the export market. Middle East and north Asia are example markets. For example, Egypt sets 49 day shelf life. The only way to get it to market is to air-freight. In Japan, there is an industry guideline which is strongly adhered to. As the industry guideline is expiring, product is sold at a discount. Arbitrary requirements".* (Interviewee J).

There is also the issue of food contact packaging and the use of recycled material content. In recent years issues such as migration of mineral oils from cardboard with recycled content and BPA has highlighted the unknowns with respect to packaging and food contact. Current Australian food-packaging regulations dictate that food must be safe, but do not go into any depth on what food-contact materials are safe [157]. Food Standards Australia and New Zealand (FSANZ) will soon release a proposal (P1034), which aims to address food-contact packaging, but only addressing current packaging systems, and not at emerging technologies such as active packaging. Self-regulation, based on evidence-based research, is likely to be one of the key pillars of the FSANZ framework [157].Testing and understanding of the possible interactions, let alone regulations are lacking. A way to approach this is given in the following quote:

> *"I think direct food contact is the greatest regulatory concern. For example, freezer to oven material, material gets to very high temperature. …..If edibility is considered as a starting point for development, then regulatory approval is less likely to be a problem"* (Interviewee A).

The regulatory environment for meat in China has changed significantly in recent years, with increases in government regulation of meat quality and safety [132]. Most standards relate to the areas of production, detection and processing, while no detailed standards have been established for meat sources and pre-slaughter management. The standards between government and private enterprises are often not consistent leading to difficulties in the meat supervision and inspection for government. The asymmetry of information and communication would be a key factor to limit the sustainable development of the meat industry in China. In recent years, there have been two serious food safety outbreaks in China: one involving milk contaminated by melamine[21], and the second, fresh pork contaminated by clenbuterol[22]. Therefore, more attention should be paid to food-borne pathogens, especially in fresh meat from open markets.

The commercial uptake of nano-materials in the food industry is attributed to a lack of clinical toxicology data and a lack of globally recognised regulation protocols [38]. More clinical research in this area is pivotal to the commercialisation of nano-material technologies [38]. This research is

[21] http://ausfoodnews.com.au/2009/08/25/marketing-milk-one-year-on-from-melamine-in-china.html
[22] http://news.bbc.co.uk/2/hi/7905717.stm

ongoing, some of which was presented at the International Association of Packaging Research Institutes (IAPRI) 19th World Conference on Packaging in Melbourne, 2014.

When applying nanotechnology, there are regulations that state it cannot be used without further assessment, even when direct contact with the packaged food is impossible through the functional barrier (article 5(2)(c)ii of Regulation 450/2009/EC). Nanoparticles should be assessed on a case-by-case basis until more information is known about this new technology. According to one interview, some of the emerging on-pack label themes, relating to both compliance (e.g. legal requirements) and marketing could include:

- "Portion size information, and per person sizing.
- Provenance information (like the UK).
- Nutrition labelling like traffic lights (i.e. N.Z. and Scandinavian model).
- There is a need to sell attributes over the brand, particularly with shifting demographics and increased consumer education" (Interviewee I).

6 Opportunities for further research

This review forms the basis for strategy development related to emerging packaging innovation and trends and can be used by MLA to establish potential pathways to the adoption of packaging innovations that will provide value added benefits to red meat. These insights can also be incorporated into training and development resources that MLA can further develop.

Below are opportunities for further research, listed under key areas of focus from this review.

1. **Modified atmosphere and vacuum packaging**

    a. Refinement of presentation of meat in vacuum packaging and structural integrity of packaging material.
    b. Exploration of modified atmosphere packaging in combination with other technologies (e.g., active, intelligent)
    c. Addressing 'over-packaging' such as all over cardboard sleeve wraps

2. **Active packaging**

    a. Further understand the potential human health hazards of 'additives' (anti-microbial and anti-oxidant) incorporated into packaging.
    b. Further understand how active packaging may have a positive or negative impact upon the eating qualities (e.g., tenderness, taste and aroma) of meat – this may expand the current Meat Standards Australia (MSA) pathways.
    c. If active packaging inserts such as sachets, patches or tablet are to be incorporated into the packaging system, addressing issues such as cost, leakage of active substances, toxicity, time taken to insert into packaging and interference with metal-detections.

3. **Intelligent packaging**

    a. Understanding the drivers for intelligent packaging – e.g., food safety, shelf life extension – and who will benefit.
    b. Understanding the stakeholders and their needs in relation to time-temperature indicators – who will benefit and what needs are to be addressed? Could these have potential negative impacts upon other stakeholders in the supply chain?
    c. The optimal use for RFIDs – is this at retail pack level or pallet level? Where will the most benefit be derived? E.g., retail pack level most likely cost prohibitive. E.g., pallet level to monitor supply chain mechanisms, cold chain, integrity etc.

4. **Nanotechnology**

    a. Explore and analyse the uncertainties associated with this technology (e.g., practical applications, cost, and health concerns regarding ingestion of nanomaterial).
    b. Understand consumer perceptions and acceptance of nanotechnologies and their application to red meat packaging.

5. **Shelf life**

    a. Identify what minimum shelf life is required through the supply chain.
    b. Who is determining this and why are the reasons for this?
    c. Understand what packaging systems and technologies will enable the shelf life to be achieved

6. **Efficiencies through the supply chain**

    a. Map and analyse product and packaging material flows through the supply chain

(domestic and export) and identify where product-packaging loss/waste occurs, how much is generated and the reasons for the waste.

b. With the insights from supply chain mapping of efficiencies, identify areas/strategies and solutions to address these inefficiencies.
c. Explore and understand the role packaging plays in reducing food waste and the optimal product-packaging ratios that can be achieved to reduce loss and waste through the supply chain.
d. Understand the dynamics associated between retail packaging and the secondary and tertiary packaging systems used to protect and deliver product through the supply chain (domestic and export).
e. Map the existence of end of life waste management collection practices, technologies and processes used in export markets, including identification of what materials are collected, destinations (e.g., landfill, recycling, waste to energy) and business and consumer understanding and participation behaviours and practices. This can provide insights into material selection and on-pack communication.

7. Biopolymers

a. Understand the drivers and stakeholder needs associated with the research into biopolymer materials. What are the proposed benefits of these materials? Are any trade-offs being made?
b. Explore and understand the properties of biopolymer materials and how they perform in protecting the product, compared against other packaging materials.

8. Consumer perceptions and acceptance

a. Explore, analyse and understand consumers' perceptions of packaging and its role in the red meat supply chain – undertake within different consumer settings (e.g., household make-up, age groups, cultures, countries). This could be through modes such as surveys, face to face interviews, focus groups to help determine how to educate and deliver messages, design for target markets and identify barriers to entry for example.
b. Explore, analyse and understand consumers' understanding of packaging formats and technologies.
c. Explore, analyse and understand consumers' acceptance of packaging formats and technologies.
d. Explore, analyse and understand consumers' perceptions and understanding of sustainability in the context of product protection, packaging attributes, supply chain efficiencies and packaging material use.

9. Consumer trends and drivers

a. Explore who 'the consumer' is in targeted markets – who is making decisions, who is purchasing, how do they shop, how often do they shop – within different settings (e.g., cultures and nations) and what is the optimal packaging formats for these consumers?
b. Explore what consumer needs and expectations of red meat are in relation to consumer trends such as demographic and lifestyle changes, a growing global population, an ageing population, convenience, accessibility and traceability. Link back to supply chain efficiencies and packaging material selection and design.
c. What are the convenience features that 'the consumer' in targeted marks wants? What packaging formats will help deliver these convenience features?
d. What are the trends in cooking / heating methods (e.g., stove top, oven, and microwave) of 'the consumer' and how best can packaging formats help?
e. Review the accessibility features of current packaging formats? How easily can consumers open the pack and read the text on labels? What improvements can be made to make it more accessible? Disseminate insights to the supply chain to improve accessibility.
f. What are the likely consumer trends with respect to portioning and serving sizes? What size cuts will 'the consumer' want to purchase? How does this link to their

demographic and lifestyle? Will they generate ‘waste’ in preparation, cooking and eating?

g. Determine purchasing changes such as bulk, online, mobile and private labels that present opportunities and can be exploited to increase red meat distribution locally and globally.
h. Identify the right information mix with traditional and new sources such as omni channelling, scanning (QR or bar code links) and mobile applications that engage and personalise purchasing decisions regarding red meat, and measure the success of such strategies.
i. Explore technology platforms such as online environments, smart devices, and data mining that are relevant and can be used to enhance the profile and distribution of red meat.
j. Analyse whether the cost of living question is a positive or negative issue for the red meat industry, based on the behaviour changes that occur in such conditions.

10. Traceability and food safety

a. Identify the key areas of traceability that are of relevance to the red meat supply chain (e.g., food safety, efficiency, compliance, consumer demand).
b. What are stakeholder expectations and needs in relation to traceability?
c. What systems and technologies will stakeholders use to access traceability information?
d. What are the systems and technologies that are necessary to address these key areas? How are they to be developed? What are the current cost and technical challenges? What benefits will be achieved and which stakeholders will benefit?

11. Food service

a. Exploit opportunities in the food service category to expand the red meat product offerings and design packaging systems that will cater for, e.g., convenience, through this supply chain channel.

12. Regulations and labelling

a. Continue to actively engage and scan discussion with packaging material suppliers, red meat producers and processors, the research and science community and regulators with respect to food contact packaging issues.
b. Maintain focus on developments domestically and internationally with respect to food contact packaging regulations.

7 Conclusions

Many opportunities exist for the Australian red meat supply chain to remain competitive both domestically and in the export market. Understanding and maximising the opportunities that information, packaging and technology can provide in effectively and efficiently containing, protecting and moving red meat product through the supply chain will be a core component. Many technologies exist or are being developed, but further research is needed to understand the benefits and challenges and how they can best meet the needs of the red meat supply chain is getting product to market. Mapping stakeholder needs and expectations against these packaging and technology interactions can also provide for valuable information.

While selecting and designing packaging materials, formats and technologies that will support red meat products will be paramount, what will also be critical is understanding who the consumer is, how their changing lifestyle and demographics, their needs and wants, their perceptions of, their expectations of and their understanding of these packaging materials, formats and technologies will influence their purchasing behaviours. Actively engaging with consumers, understanding who they are across different settings, cultures and markets, both domestically and internationally, can position the Australian red meat supply chain to capitalise on the premium, clean and green image of Australian produce. Optimising packaging so that it supports and adds value to the red meat supply chain, both in the domestic and export market, with the consumer in mind, will help deliver this mission.

8 List of packaging experts

First name	Last Name	Title	Organisation	E-mail	Phone	Area of expertise
Joseph	Kerry	Head of the Food Packaging Research Group	School of Food & Nutritional Sciences, University College Cork, Ireland	joe.kerry@ucc.ie	+35 3 214 903 798	MAP, sensors, edible coatings, shelf-life stability, food composition
Lynn Van	Wezemael	Postdoctoral Researcher	Department of Agricultural Economics, Ghent University	lynn.vanwezemael@UGent.be	+32 9 264 59 25	Consumer preferences and sensory perceptions
Karli	Verghese	Associate Professor, Principle Research Fellow	Centre for Design and Society, RMIT University	karli.verghese@rmit.edu.au	0 3 9925 9080	Sustainability, food waste
Damian	Frank	Researcher in Flavour and Sensory Science	CSIRO	damian.frank@csiro.au		Consumer preferences and sensory perceptions
Vincent	Rouillard	Associate Professor	Head of Engineered Packaging and Distribution Research Group, Victoria University	vincent.rouillard@vu.edu.au	0 3 9919 4609	Packaging testing
Silvia	Estrada-Flores	Program Manager	Competitive Foods, Food SA	silvia@foodsa.com.au	08 8303 9457	Food innovation
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Linda	Brennan	Professor of Marketing, School of Media and Communication	RMIT University	linda.brennan@rmit.edu.au	03 9925 2842	Marketing and social side of supply chains
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Robyn	Warner	Meat Scientist and Research Team Leader	CSIRO	robyn.warner@csiro.au	03 9731 3268	Colour, flavour and texture contributors to meat quality

First name	Last Name	Title	Organisation	E-mail	Phone	Area of expertise
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First name	Last Name	Title	Organisation	E-mail	Phone	Area of expertise
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First name	Last Name	Title	Organisation	E-mail	Phone	Area of expertise
						statistical analysis
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9 Available technologies

Table 9-1 Available packaging technologies

Tradename / trademark	Developer	Type of technology	Description	References
FreshPax®	Multisorb Technologies Inc. USA	Active packaging	Oxygen scavenging / CO2 generating sachet	http://www.multisorb.com [40]
Ageless®	Mitsubishi Gas Chemical Co. Japan	Active packaging	Oxygen scavenging / CO2 generating sachet	http://www.mgc.co.jp/eng/products/abc/ageless/ [40]
OxyGuard®	Clariant Ltd. Switzerland	Active packaging	Oxygen scavenging Sachet	http://www.desiccants.clariant.com/fileadmin/pages/clariant/user/cdp-pdf/Oxy-Guard_Eng_ProdSheet.pdf [30]
OxyCatch®	Kyodo Printing Company Ltd. Japan	Active packaging	Oxygen scavenging sachet	http://landi.kyodoprinting.co.jp/cn/oxycatch.html [30]
ATCO®	Emco Packaging Systems, UK and Standa Industrie, France	Active packaging	Oxygen scavenging sachet	http://www.standa-fr.com/eng/laboratoires-standa/atco/ [40]
Oxysorb	Pillsbury Co., USA	Active packaging	Oxygen scavenging sachet	http://oxygenabsorbers.com/ [40]
Cryovac® OS2000	Sealed Air Corporation, USA	Active packaging	UV-activated oxygen scavenging film	http://www.cryovac.com/na/en/food-packaging-products/oxygen-scavenging-active-barriers.aspx [40]
Enzyme-based	Bioka Ltd. Finland	Active packaging	Oxygen scavenging film	http://www.bioka.fi/products/index.htm [30]
Shelfplus® O_2	Albis Plastic GmbH, Germany	Active packaging	Oxygen scavenging masterbatch	http://www.albis.com/en/products-solutions/standard-plastic/shelfplus/

Tradename / trademark	Developer	Type of technology	Description	References
				[30]
OxyRx®	Mullinix Packages Inc. USA	Active packaging	Oxygen scavenging container for high temperatures	http://www.mullinixpackages.com/Libraries/Brochures/OxyRx_Press_Release_9_23.sflb.ashx [30]
OMAC®	Mitsubishi Gas Chemical Co. Japan	Active packaging	Oxygen scavenging film for high temperatures	http://www.mgc-a.com/AGELESS/OmacFeatures.html [30]
Linpac	Linpac Packaging Ltd. UK	Active packaging	Moisture tray	http://www.linpacpackaging.com/ [30]
TenderPac®	SEALPAC,	Active packaging	Dual compartment system	http://www.sealpac.de/index.php?id=173&L=1 [30]
Dri-Loc®	Sealed Air Corporation, USA	Active packaging	Moisture pad	http://www.cryovac.com/na/en/food-packaging-products/premier-driloc.aspx [40]
MeatGuard	McAirlaid Inc. Germany	Active packaging	Moisture pad	http://www.meatpads.info/en/ [30]
CO_2® Fresh pads	CO_2 Technologies, USA	Active packaging	CO_2 emitting pads	http://www.co2technologies.com/meat.html [30]
UltraZap® Xtenda Pak pads	Paper Pak Industries, USA	Active packaging	CO_2 emitting and antimicrobial pads	http://paperpakindustries.com/products/ultrazap_xtendapak.php [30]
SUPERFRESH	Vartdal Plastindustri AS	Active packaging	Box system with CO_2 emitter	http://paperpakindustries.com/products/ultrazap_xtendapak.php [30]
Nor® Absorbit	Mondi Group, UK	Active packaging	Microwavable film	http://www.mondigroup.com/desktopdefault.aspx/tabid-2179/472_read-22564/

Tradename / trademark	Developer	Type of technology	Description	References
				[30]
MoistCatch	Kyodo Printing Co., Ltd. Japan	Active packaging	Moisture and outgassing scavenger film	http://landi.kyodoprinting.co.jp/en/moist.html [30]
AgIon®	AgION Technologies LLC, USA	Active packaging	Antimicrobial substances	http://www.agion-tech.com/ [40]
Biomaster®	Addmaster Limited, UK	Active packaging	Antimicrobial substances trays and films	http://www.biomastertechnology.com/ [30]
Irgaguard®	BASF, Germany	Active packaging	Antimicrobial substances	https://www.basf.com/group/corporate/en/brand/IRGAGUARD [30]
Surfacine®	Surfacine Development Company LLC, USA	Active packaging	Antimicrobial substances	http://www.renextra.com/surfacine/ [30]
IonPure®	Solid Spot LLC, USA	Active packaging	Antimicrobial substances	http://solidspot.com/antimicrobial.html [30]
Bactiblock®	NanoBioMatters, Spain	Active packaging	Antimicrobial substances	http://www.nanobiomatters.com/wordpress/products/bactiblock%C2%AE-antimicrobial-additives [30]
Nisaplin and Novasin	Integrated Ingredients, USA	Active packaging	Antimicrobial	http://www.gillco.com/pr_antim-nisaplin.php [40]
Food-touch®	Microbeguard Corp. USA	Active packaging	Interleavers	http://www.microbeguard.com/ [30]
Sanic Films	Nanopack, Spain	Active packaging	Interleavers	http://www.nanopack.es/en/sanic-films/ [30]
SANICO®	Laboritories STANDA, France	Active packaging	Antifungal coating	http://www.standa-fr.com/eng/laboratoires-standa/sanico/

Tradename / trademark	Developer	Type of technology	Description	References
				[30]
Wasaouro®	Mitsubishi-Kagaku Foods Corp. Japan	Active packaging	Antifungal/ bacterial sheets, labels and films	http://www.mfc.co.jp/wasaouro/e/about/index.html [30]
OxySense	OxySense, USA	Intelligent packaging	Biosensor	http://www.oxysense.com/ [30]
FreshCase®	Bemis Company Inc. USA	Active packaging	Film that activates red colour in meat	http://www.bemis.com/news/press/article/id/274/ [30]
Sira-Crisp®	Sirane Ltd. UK	Active packaging	Microwave susceptor	http://www.sirane.com/food-packaging-products/microwave-susceptors-crisp-it-range/sira-crisp-crisp-it-films.html [30]
SmarthPouch®	VacPac Inc.USA	Active packaging	Microwave susceptor	http://www.vacpacinc.com/smartpouch.html [30]
Flexis®	Avery Dennison Corp. USA	Active packaging	Steam Valve	http://www.averydennison.com/en/home/technologies/core-capabilities.html [30]
MicVac®	SEALPAC GmbH, Germany	Active packaging	Steam Valve	http://www.sealpac.de/index.php?id=176&L=1 [30]
Ageless Eye®	Mitsubishi Gas Chemical Co. Japan	Intelligent packaging	Integrity indicator (gas)	http://www.mgc.co.jp/eng/products/abc/ageless/eye.html [40]
Tell-Tab	IMPAK, USA	Intelligent packaging	Integrity indicator (gas)	http://www.sorbentsystems.com/tell-tab.html [30]
O_2Sense	Freshpoint, Switzerland	Intelligent packaging	Integrity indicator (gas)	http://www.freshpoint-tti.com/technology/default.aspx [30]
Timestrip®	Timestrip Ltd. USA	Intelligent packaging	Integrity indicator (time)	http://timestrip.com/products/food-range/

Tradename / trademark	Developer	Type of technology	Description	References
				[30]
Novas®	Insignia Technologies Ltd. Scotland	Intelligent packaging	Integrity indicator (time)	http://insignia.mtcserver11.com/portfolio-view/novas-embedded-label/ [30]
Best-by®	Freshpoint, Switzerland	Intelligent packaging	Integrity indicator (time)	http://www.freshpoint-tti.com/product/BestBy.aspx [30]
3M Monitor Mark®	3M, USA	Intelligent packaging	Time-temperature indicator (fatty acid ester)	http://solutions.3m.com.au [40]
VITSAB® TTI	VITSAB, Sweden	Intelligent packaging	Time-temperature indicator (enzymatic)	http://vitsab.com/ [40]
Fresh-Check®	Lifelines Technology Inc., USA	Intelligent packaging	Time-temperature indicator (polymerization)	http://www.fresh-check.com [40]
Keep-it®	Keep-it Technologies, Norway	Intelligent packaging	Time-temperature indicator (chemical)	http://keep-it.no/en/about-us/ [30]
OnVu®	Freshpoint and Ciba, Switzerland	Intelligent packaging	Time-temperature indicator (photochemical)	http://www.freshpoint-tti.com/technology/default.aspx [30]
TopCryo®	TRACEO, France	Intelligent packaging	Time-temperature indicator (microbiological)	http://www.traceo.com/en/food/catering/benefits.html#content [30]
FreshCode®	Varcode Ltd. Israel	Intelligent packaging	Time-temperature indicator (barcode)	http://www.varcode.com/?CategoryID=158&ArticleID=78 [30]
Tempix®	Tempix AB, Sweden	Intelligent packaging	Time-temperature indicator (barcode)	http://tempix.com/ [30]

Tradename / trademark	Developer	Type of technology	Description	References
Raflatac	VIT and UPM, UK	Intelligent packaging	Freshness indicator (colorimetric)	http://www.upmraflatac.com/emea/en [30]
Easy2log®	CAEN RFID Srl, Italy	Intelligent packaging	RFID	http://www.caenrfid.com/en/CaenProd.jsp?idmod=780&parent=65 [30]
CS8304	Convergence Systems Ltd. Hong Kong	Intelligent packaging	RFID	http://www.csl-rfid.com/ [30]
TempTRIP	TempTRIP LLC, USA	Intelligent packaging	RFID	http://www.temptrip.com/ [30]
Intelligent box	Mondi PLC, Austria	Intelligent packaging	RFID	http://www.mondigroup.com/products/desktopdefault.aspx/tabid-1784/ [30]
Note: All websites reviewed 6th August 2014				

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