Final report

Project code: **P.PSH.0765**

Prepared by: Scott Needham, Yilan Chen & Russel Rankin
Xinova Australasia Pty Ltd

Date published: 20th March 2018

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Xinova Smart Packaging open innovation

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

P.PSH.0765 Xinova Smart Packaging open innovation RnD4profit (insights2innovation)

March 2018

Project Leader: Dr Scott Needham,
President AUS & NZ
Xinova Australia
0439 135 268
sneedham@xinova.com

Purpose: Using Xinova's open innovation and technology review process, develop insights and solutions related to 'smart packaging' technologies that can assist the Australian red meat industry to gain greater competitive advantage and price premiums over the next 3-5 years because of an increased capacity to deliver products to exports markets that deliver on food safety, provenance, shelf life, traceability, and integrity. Also assist MLA and the industry to identify and overcome commercial impediments and barriers for Australian producers and brand owners in developing and adopting "Smart" packaging solutions.

Acknowledgment of funding sources:

Xinova acknowledge the financial support for this project from Meat & Livestock Australia (MLA) and Meat Donor Company (MDC).

Abstract

Food producers need a deep understanding of market and technology trends to be able to evaluate and prioritise new product and packaging technologies that may open up new export markets. The domestic market alone will not generate the necessary type or quantity of innovations required for Asian markets in key areas like packaging, preservation, tamper evidence and provenance. In addition, the size and variety of international markets means that those technologies need to be viewed through a lens of consumer demand, changing needs and age-based considerations.

Current food preservation and packaging technologies have generally performed well for the delivery of fresh food to domestic markets and some international markets for certain food products and food commodities, but there are still major deficiencies in their performance. While polymers are the most common packaging material due to a range of desirable properties such as transparency, low cost, good mechanical properties and controllable permeability, unfortunately these packaging materials are not totally recyclable or biodegradable. They do not add significantly to shelf life preservation and they are not able to indicate in a smart way whether the contents have been tampered with.

Equally, we know that the source and food supply chain 'credentials' are of significant interest to consumers. The interest derives from unreliable supply chains in some Asian markets, a number of well publicised food adulteration scandals and a demand for clean and green foods with traceable production history can become valuable attributes for Australian agrifood.

Australia's red meat industry exports approximately 75-80% of its production. However, the current quality state of fresh packaged meat is also often hard to measure as it is not visible from the outside with prescribed use by dates used. Remaining shelf life cannot be measured directly, yet it may be predicted by biological models calculating the effect of accumulated temperature and other influences.

There is also the opportunity for the labelling associated with the packaging to produce a transformational market effect. Currently labelling and marketing materials are mostly static with limited consumer interaction. Near Field Communication (NFC) has the potential to provide information to a consumer but also glean information from a consumer about their interests and tastes; cheap and flexible screens on the package could be used to change presentation based on the data provided from consumers; augmented reality using a smart phone will allow for overlay of best use of the product as well as recipe ideas, for example.

"Smart Packaging" can inform the status of the packaging and product integrity (breaking of the seal, quality, and security) and can demonstrate the authenticity of Australian agrifood products, anti-theft, traceability of handling and distribution. In addition to intelligent packaging functions where "extra production and consumer information" is added to the pack, packaging innovations can be embedded in the material to interact with the product. For example, pack materials can "actively" control the oxygen levels and thereby growth of bacteria or fungi or confinement odour can also represent advancements and market development to previous sachets and modified atmosphere gas technologies

The objectives of the project were to;

i. Develop technology insights and solutions related to 'smart packaging' technologies that can assist the Australian red meat industry to gain greater competitive advantage and price premiums over the next 3-5 years as a result of an increased capacity to deliver products to exports markets that deliver on food safety, provenance, shelf life, traceability, and integrity.

ii. Identify and develop strategies to overcome commercial impediments and barriers for Australian producers and brand owners in adopting "Smart" packaging solutions to add value to Australian red meat products in both domestic and export markets.

Xinova has been commissioned by Meat and Livestock Australia (MLA) to develop technology insights and solutions related to smart packaging technology. The intention of this work was to assist the Australian red meat industry to differentiate their product in the rapidly expanding Asian markets, with a particular focus on China, and to protect Australia's brand of a high quality and consistent red meat product.

In parallel to this project, MLA commissioned a series of reports exploring issues pertaining to Smart Packaging, including Chinese consumer profiling, competitor analysis, and market trends. These reports provided an incredibly detailed analysis of the opportunities and challenges as they pertain to smart packaging of Australian red meat for a Chinese market.

Executive summary

Food producers need a deep understanding of market and technology trends to be able to evaluate and prioritize new opportunities to maintain or grow new export markets. Food packaging is one such area of opportunity that may provide Australian red meat producers with a competitive advantage over international competitors.

Conventional food packaging serves to protect, preserve, and present the food. It has performed well in the domestic market and in some international markets, but there remain major deficiencies in their performance, such as improving shelf life, providing source and supply chain credentials, and providing consumers with additional valuable information on issues like ideal preparation and cooking.

The Smart Packaging project (P.PSH.0765) was established with the objectives;

- To develop technology insights and solutions related to 'smart packaging' technologies that can assist the Australian red meat industry to gain greater competitive advantage and price premiums over the next 3-5 years as a result of an increased capacity to deliver products to export markets that deliver on food safety, provenance, shelf life, traceability, and integrity. The technology insights and solutions developed within this project will be informed by consumer, customer, competitor and general market insights being developed via complementary projects managed by MLA.
- To assist MLA and the industry to identify and overcome commercial impediments and barriers for Australian producers and brand owners in developing and adopting "Smart" packaging solutions to add value to Australian red meat products in both domestic and defined export markets.

Table of Contents

1 Background

Food producers need a deep understanding of market and technology trends to be able to evaluate and prioritise new product and packaging technologies that may open up new export markets. The domestic market alone will not generate the necessary type or quantity of innovations required for Asian markets in key areas like packaging, preservation, tamper evidence and provenance. In addition, the size and variety of international markets means that those technologies need to be viewed through a lens of consumer demand, changing needs and age-based considerations.

Current food preservation and packaging technologies have generally performed well for the delivery of fresh food to domestic markets and some international markets for certain food products and food commodities, but there are still major deficiencies in their performance. While polymers are the most common packaging material due to a range of desirable properties such as transparency, low cost, good mechanical properties and controllable permeability, unfortunately these packaging materials are not totally recyclable or biodegradable. They do not add significantly to shelf life preservation and they are not able to indicate in a smart way whether the contents have been tampered with.

Equally, we know that the source and food supply chain 'credentials' are of significant interest to consumers. The interest derives from unreliable supply chains in some Asian markets, a number of well publicised food adulteration scandals and a demand for clean and green foods with traceable production history can become valuable attributes for Australian agrifood.

Australia's red meat industry exports approximately 75-80% of its production. However, the current quality state of fresh packaged meat is also often hard to measure as it is not visible from the outside with prescribed use by dates used. Remaining shelf life cannot be measured directly, yet it may be predicted by biological models calculating the effect of accumulated temperature and other influences.

There is also the opportunity for the labelling associated with the packaging to produce a transformational market effect. Currently labelling and marketing materials are mostly static with limited consumer interaction. Near Field Communication (NFC) has the potential to provide information to a consumer but also glean information from a consumer about their interests and tastes; cheap and flexible screens on the package could be used to change presentation based on the data provided from consumers; augmented reality using a smart phone will allow for overlay of best use of the product as well as recipe ideas, for example.

"Smart Packaging" can inform the status of the packaging and product integrity (breaking of the seal, quality, and security) and can demonstrate the authenticity of Australian agrifood products, anti-theft, traceability of handling and distribution. In addition to intelligent packaging functions where "extra production and consumer information" is added to the pack, packaging innovations can be embedded in the material to interact with the product. For example, pack materials can "actively" control the oxygen levels and thereby growth of bacteria or fungi or confinement odour can also represent advancements and market development to previous sachets and modified atmosphere gas technologies.

The objectives of the project were to;

i. Develop technology insights and solutions related to 'smart packaging' technologies that can assist the Australian red meat industry to gain greater competitive advantage and price premiums over the next 3-5 years as a result of an increased capacity to deliver products to exports markets that deliver on food safety, provenance, shelf life, traceability, and integrity. The technology insights and solutions developed within this project will be informed by consumer, customer, competitor and general market insights being developed via complementary projects managed by MLA.
ii. Assist MLA and the industry to identify and overcome commercial impediments and barriers for Australian producers and brand owners in developing and adopting "Smart" packaging solutions to add value to Australian red meat products in both domestic and defined export markets.

Specifically, the project will address the need to develop 'Smart' packaging systems for red meat that;

- Extend product shelf life
- Measure surrounding conditions along the supply chain to assure and protect authenticity, origin and enable traceability
- Measure and control conditions to maximise shelf life
- Deliver sustainable packaging formats that quantifiably reduce environmental impacts
- Present consumers with product information that clearly delivers against attributes that they are willing to pay for.

Xinova has been commissioned by Meat and Livestock Australia (MLA) to develop technology insights and solutions related to smart packaging technology. The intention of this work is to assist the Australian red meat industry to differentiate their product in the rapidly expanding Asian markets, with a particular focus on China, and to protect Australia’s brand of a high quality and consistent red meat product.

2 Methodology

This project was undertaken using the following methodology;

2.1 Technology Insights

The project undertook technology and product scanning in the area of food packaging as well as some adjacent sectors such as pharmaceutical, as well as a literature and patent review. Also included will be a curation and review of global packaging technical trade shows, conferences and events, to identify technology trends and new products as well as existing solutions in the area of 'smart packaging'. 'Smart packaging' will address challenges for export markets around, food safety, shelf-life, integrity, traceability and provenance. The scanning methodology will cover literature, research activities, products and companies.

This activity was overlaid with Thomson Reuters' (Clarivate Analytics) IP landscape analysis (MLA project V.RDP.1003). The scanning process utilised Xinova's existing global capability, through its Asian offices in India, Singapore, China, Korea, Japan and Australia. This report will assist the red meat sector to understand and assess the best of what is available now to capture opportunities by better meeting emerging consumer and market trends (initially in the China market).

MLA provided Xinova reports of the outcomes of previous packaging and traceability technology scanning activities such as A.RHC.004 emerging packaging trends report (2014) and regularly updated Xinova of the outcomes of other relevant consumer and market insight projects.

2.2 Smart Packaging Invention Sourcing

RFI Topic identification:

Potential RFI topics were then assessed against a series of criteria; IP landscape, technical solutions available, commercial viability, areas of opportunity for technical advancement and others in order to select one problem topic for development into RFIs.

Based on the identified gaps in available technologies, Xinova undertake an initial Request for Innovation (RFI) focused specifically on seeking solutions to the 'Food without Fear" theme which has been identified as a key consumer trend in the China market. In this stage of the project the following activities will be conducted:

Problem Definition Workshop:

A 'Problem Definition Workshop' was conducted involving key thinkers from the food and packaging industry in Australia and Internationally, commercial value chain participants from the red meat industry, Xinova, participants in the RnD4profit project and a number of selected domain experts. Input into the Problem Definition Workshop was used to inform Xinova’s own desk research and country-based intelligence and networks as well as the IP Landscape Mapping report undertaken by Clarivate Analytics (formerly known as Thomson Reuters) along with other MLA projects conducted within the 'Food without Fear' theme related to: consumers; customers; supply chain issues

Request for Invention Development:

Identify 2 Request for Invention (RFI) topics: Based upon the outcomes from the Problem Definition Workshop. Final topic selection will involve feedback from the RnD4profit Project Steering Committee that will be established from industry, domain experts, other agrifood sectors where applicable and MLA.

Invention sourcing:

Two RFIs identified as having the greatest potential to deliver on the 'Smart packaging' objectives will be released to Intellectual Ventures' Inventor Network for solution sourcing. The project targets a minimum of 5 novel inventions per RFI.

Facilitated 'All-star' Inventor Workshops.

Participants involved will be global Platinum Inventors, cross disciplinary, MLA and industry representatives with extensive industry knowledge.

Review of Xinova patent assets:

Xinova has 3,500 existing IP assets that have resulted from its invention sourcing activities. There is a strong and curated portfolio of packaging and food related assets amongst many others. The project will undertake a systematic review of those assets to identify if any had application to the selected problem topics. Should relevant IP assets be identified then commercial packaging companies that are potential commercialiser will be engaged.

Proof of Concept:

Xinova and MLA will select at least 2 inventions to undergo proof of concept development. Xinova will utilise its Laboratory at UNSW and its Development Centre based in Singapore.

In addition, Xinova with MLA input will provide stakeholders and advisory committee members the progress of the project and developments.

3 Results and Discussion

3.1 Technology Insights

This phase of the project represented the gathering of technology insights around smart packaging. The work involved an assessment of field, by reviewing and assessing the technical landscape and looking for opportunities to provide new solutions in areas that have either not been considered, or not adequately addressed.

The technology insights task considered smart packaging technologies in the context of the following five key attributes:

- Food safety
- Shelf-life
- Anti-counterfeit
- Traceability
- Provenance

Within each key area, existing technologies, solutions and products were reviewed, as well as challenges and barriers for market adoption. Technology and market trends are also presented to help the Australian red meat industry to identify further research opportunities. Key stakeholders and potential commercial partners are also listed based on their activities involved in research and development within the smart packaging technologies field.

Existing Technologies: several technologies were identified, at various stages of development, which we believe are worthy of further consideration. These include:

- Next generation QR Codes - Next generation QR codes which are more secure and more visually appealing, incorporating with product pictures and company logos. These Next generation QR Codes are also being used to allow the consumer access to real-time video of product origination.
- Unique ID traceability systems –Authenticateit Pty Ltd, an Australian company which has developed an app-based traceability system which allows tracking and tracing at any point along the entire supply chain, with geolocation authentication ability.
- Invisible tracers – Rare earth tracers as an authenticating identifier, coupled with a hand-held scanner

Future technologies: Xinova's searching and analysis has identified technical areas that could be considered for future inventive effort and consideration. These areas are as follows:

- Mobile-engaged intelligent packaging technologies

- Next generation RFID technologies
- Smart components incorporating modified atmosphere and vacuum packaging
- Brand differentiation (through use of new technologies)

3.2 Smart Packaging Invention Sourcing

This Final Report also includes *Milestone 8 Invention Sourcing & Portfolio development* and *Milestone 10 Report on the Young Food Innovator.*

Two RFIs were identified, developed and released to the Xinova innovator network. Below is a summary of invention sourcing and portfolio development, including invention numbers, selected inventions, stand-out inventions, as well as outcomes from the Inventor Workshop.

RFI-170106 Tracking Exported Meat Products from Farm to Fork

Invention ID	Country	Title	Submission Date	Status
US-927268	United States	Supply Chain Packaging Tracking System	8/4/2017	New
AU-927132	Australia	Laser Meat Branding with QR-codes	6/7/2017	Failed Pre-Screening
JP-927185	Japan	Tracking trace of meat	6/21/2017	Under Review
CN-927204	China	Meat Product Tracking Based on a Distributed Ledger System	6/5/2017	Under Review
US-927212	United States	Providing Transparency and Trust through an Extremely Fast X-ray Screening of Bulk Meat, Cloud Available Database + Simple Inexpensive Genetic Testing for Tracking and Verifying Exported Meat Products from Farm to Fork	7/5/2017	New
US-927319	United States	Tracking Meat Products with Laser Grill Marks	9/5/2017	New
US-927341	United States	Meat Identifying and Labelling Probiotics (M.I.L.P.)	9/20/2017	New
CH-927377	Switzerland	Passive time and temperature logging labels for data collection and user interaction	10/13/2017	New

RFI-170115 Intelligent Interactive Packaging

Invention ID	Country	Title	Submission Date	Status
JP-927281	Japan	RFID that manages temperature history	8/5/2017	Under Review
IL-927282	Israel	NFC based intelligent sticker	8/6/2017	Not Selected for Patenting
IL-927286	Israel	Ultra-Low Cost Time Temperature Capillary Indicator	8/11/2017	Under Review
IL-927362	Israel	Authentication and Visualization System and Method	10/3/2017	New
KR-927415	Korea	Smart label using ultrasound for information transmission	10/31/2017	New

Overall invention sourcing was slow with 8 invention solutions submitted from Xinova's inventor network in Australia, United States, Japan, China, Switzerland and the US for RFI-170106 "Tracking Exported Meat Products from Farm to Fork". For Request for Invention RFI-170115 "Intelligent Interactive Packaging" there were 4 strong submitted solutions from Japan, Korea and Israel.

An All-star Inventor Workshop was held in Sydney on 17th July 2017. This workshop included Xinova Platinum & Gold Inventors, working together with Xinova staff and several MLA staff, including Michael Lee and Duncan Veal. The presentations from the All-Star Inventor Workshop are included as an attachment, along with the concept inventions (confidential) from the All-star Inventor Workshop.

3.3 Young Food Innovator

A member of MLA's Young Food Innovator Program (YFI) was included in this project, as a dedicated team resource. Following a recruitment process in partnership with MLA, Dr Xin SUN was selected and appointed to the role. Xin's position is co-funded by Meat and Livestock Australia's Donor Company (MDC) as part of their "Young Food Innovator Program", which is similar to a cadetship, but at the post-graduate level. Xin was based in Xinova's Sydney office, but also undertaking a number of 1-week off-site training modules with MLA.

Xin joined Xinova from the University of NSW, where she worked in the Food Science & Technology Department of the School of Chemical Engineering after completing her PhD in Food Science at UNSW. In her PhD, she researched "Allergenic potential effects of major peanut allergens and whey allergens induced by hydrostatic high-pressure processing". She had 6 years wet lab chemistry experience at UNSW and worked on food related projects such as analyzing bio-active peptides in beef, and hypoallergenic milk formula processing. Her Chinese background and food experience had been valuable in assisting with this project which has a strong emphasis of differentiating Australian red meat in China.

The specific aim of the traineeship was to assist a new young professional to build strategic value chain thinking and capabilities and to explicitly support the integration of this smart packaging project within the broader Insights2Innovation initiatives, including the 'Food Without Fear' theme. Xin also participated in MLA's YFI program's development and mentoring activities.

4 Recommendations

Food producers need a deep understanding of market and technology trends to be able to evaluate and prioritize new opportunities to maintain or grow new export markets. Food packaging is one such area of opportunity that may provide Australian red meat producers with a competitive advantage over international competitors.

Conventional food packaging serves to protect, preserve, and present the food. It has performed well in the domestic market and in some international markets, but there remain major deficiencies in their performance, such as improving shelf life, providing source and supply chain credentials, and providing consumers with additional valuable information on issues like ideal preparation and cooking.

The Smart Packaging project (P.PSH.0765) was established in March 2016 with the objectives;

i. To develop technology insights and solutions related to 'smart packaging' technologies that can assist the Australian red meat industry to gain greater competitive advantage and price premiums over the next 3-5 years as a result of an increased capacity to deliver products to exports markets that deliver on food safety, provenance, shelf life, traceability, and integrity. The technology insights and solutions developed within this project will be informed by consumer, customer, competitor and general market insights being developed via complementary projects managed by MLA.

ii. To assist MLA and the industry to identify and overcome commercial impediments and barriers for Australian producers and brand owners in developing and adopting "Smart" packaging solutions to add value to Australian red meat products in both domestic and defined export markets.

Since then, the following milestones have been completed, including:

1. Execution of agreement
2. Report detailing technologies and products relevant to 'smart packaging' theme
3. Identification of RFI topics
4. Scoping report
5. RFI specification distributed to inventors
6. Progress report on invention sourcing and portfolio development
7. Report on all-star inventor's workshop

And partial completion of Milestone 8. Report on selected invention solutions and final portfolio.

The final component of Milestone 8. Results from proof of concept development testing of at least two selected inventions, has not be undertaken.

In parallel to this project, MLA commissioned a series of reports exploring issues pertaining to Smart Packaging, including Chinese consumer profiling, competitor analysis, and market trends. These reports provided an incredibly detailed analysis of the opportunities and challenges as they pertain to smart packaging of Australian red meat for a Chinese market.

To ensure that the partnership focuses the smart packaging project on the right opportunities and challenges, it was decided to bring these two pieces of work together. To do this, the commissioned reports were analysed and synthesised into an insights report, attached. The report summaries the key findings of the commissioned reports and identifies criteria deemed essential for a smart packaging product to successfully build market share for Australian red meat producers competing in the Chinese market.

The insights report also brings the Smart Packaging project in line with the new project governance process developed by Xinova and MLA. Endorsement of this report marks the conclusion of Phase 2, Explore, and represents endorsement of problem and invention requirements. This insight report was discussed with MLA project Manager, Mr Michael Lee in the Brisbane meeting held on 1st March 2018. At that meeting it was decide the project should be halted and a Final Report prepared and submitted as the inventions that have been sourced to date don't reflect the current context around smart packaging.

	Phase 1 **Articulate**	Phase 2 **Explore**	Phase 3 **Ideate**	Phase 4 **Validate**	Phase 5 **Launch**
OVERVIEW	• Clarifying and re-framing the challenge or opportunity space • The project is defined and scoped • The intent of the project is identified to unlock the potential for impactful change	• Research with real people who are affected by the challenge, including technical and business experts • Generate deep insights	• Generating new ideas from the insights and opportunities identified • Ideas are developed into draft concepts and prototypes to test	• Test concepts and prototypes with users • Prototypes should be rapid and low fidelity at first • With each successive iteration, the concepts become more refined and more detailed	• Converge on a complete solution and look to implement a pilot
GOALS	*Blue sky thinking and not jumping to solutions. Setting the direction and goals of the project.*	*Being empathetic and listening to stakeholders. Being open to new ways of thinking and not jumping to solutions.*	*More blue sky thinking. Coming up with new ideas. Having courage to try, fail and learn.*	*Critical thinking and being open to changes. Discovering insights from user testing to improve the design.*	*Clear direction informed by research, experimentation and user testing.*

Insights Review

The meat industry in China has become a market of interest for the biggest exporters of meat in the world. Current red meat consumption remains low with pork (64%) and poultry (23%) continuing to dominate the Chinese market. However, red meat consumption is forecast to grow at 2.4% p.a. for beef and 2.5% p.a. for sheep over the coming years. This consumption will largely be supplied by access to increasing imports, with beef imports forecast to increase 11.8% p.a. between 2016 and 2019 (KPMG 2016).

China is full of opportunities for the Australian red meat industry. With a growing middle class, who are increasingly willing and able to pay for premium imported products, whether for an aspirational need to maintain face or for the more practical need of addressing food safety concerns (KPMG 2016), Australia red meat exporters are faced with an exciting prospect.

The demand for food safety in China during the last years has awakened a great appetite in the Australian meat industry to serve this market. However, research has demonstrated that in order to target and compete in the Chinese market, the certainty of the quality and safety of Australian meat is not sufficient to succeed. Rather, there are numerous factors to consider that impact on consumer's buying behaviours such as fresh and natural meat, shelf life and information of the product through packaging formats among others. These factors are closely related with packaging, which is the focus of this report.

Exporting products requires extensive research to understand the target market, its behaviour, requirements, challenges and opportunities that it can offer. In that sense, Meat and Livestock Australia (MLA), which is the marketing, research and development body for Australia's red meat and livestock industry, has commissioned a number of red meat specific consumer research, value chain, supply chain, regulations and technologies researches to understand trends driving consumer choices in China across different geographies, identify the different stakeholders of the supply and value chain, legislation that needs to be complied and innovation available within the industry. The results of these researches will be the input to design strategies to efficiently and effectively serve the Chinese meat market.

This report summarises those reports to obtain insights into the challenges and opportunities that Australia meat industry can leverage in order to be successful in China.

Challenges

One of the most important decision factors for Chinese customers when choosing meat is **Fresh and Natural**. How fresh meat looks visually in terms of colour and the use-by date will determine a purchase decision. This is applicable not only in store, but also in online sales, a distribution channel which is expected to have high growth in the future (Canadean 2016b). For this reason, **shelf life** is a critical issue and must continually be improved in order to fulfil the Chinese market demand of fresh meat. The impact of shelf life is so important that issues with it can have a negative impact on Australia's rates trade (Solomon 2016). This leads to another challenge: it may be difficult to **measure the quality state of fresh packaged food**. This is not visible from the outside with prescribed 'use-by dates' (Solomon 2016). **Packaging needs to interact more with the consumer** to provide them with the information that can assure the quality of the product. Currently most of the labeling and marketing materials are static, with not enough consumer interaction (Solomon 2016).

Adopting technology to better inform consumers

Packaging also needs to be **more attractive** as some Chinese consumers stated that they are more attracted by the packaging of US beef (Australian Trade Commission 2011).

The Chinese market has also raised complaints about **the handling of the product** along the supply chain such as distributors combining low grade meat into a high-grade meat order (Solomon 2016) (Australian Trade Commission 2011). **Counterfeit**, grey import, bribery and corruption along the value chain pose real risks to foreign imports (KPMG, 2016). This is a challenge that the Australia red meat industry must solve if it is to maintain or grow its market share in China.

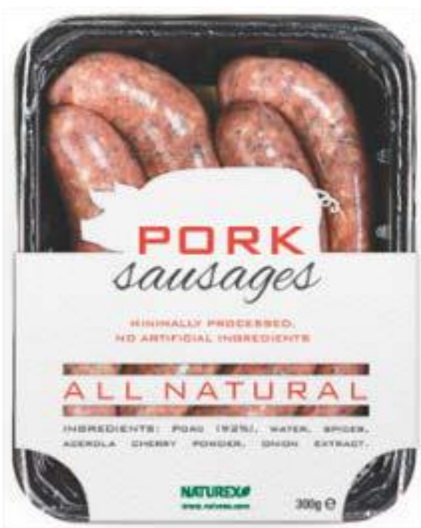
Therefore, the opportunity arises for Smart Packaging, defined as a combination of active, intelligent, and modified atmosphere packaging techniques, specifically designed to increase and monitor shelf life (Thompson Reuters 2016). This technology can provide status and information of the packaging and product integrity (security, quality, breaking of the seal etc); it can demonstrate the authenticity of Australian agri-food products and provide anti-theft capabilities and traceability of handling and distribution. In addition to intelligent packaging functions where extra production and consumer information is added to the pack, packaging innovations which are embedded in the material and interact with the product will be developed (Solomon 2016).

Active packaging

For example, pack materials actively control the oxygen levels and thereby growth of bacteria or fungi or confinement odour can also represent advancements and market development to previous sachets and modified atmosphere gas technologies (Solomon 2016).

Another example of Smart Packaging which is able to provide feedback on food freshness is the “Living labels”, which inform in real-time, by touch, when meat is no longer safe for consumption (Canadean 2016b).

On-pack freshness indicators



Ensuring meat looks visually appealing

Naturex Xtrablend OA, in its turn, is a natural ingredient inside the packaging that helps to keep the chilled meat fresh and visually appealing with a “healthy red” colour for longer (Canadean 2016b).

A report of Thomson Reuters on patent and published literature data within the Smart Packaging technology field concludes that there is a gap which has not yet been covered by Smart Packaging. This gap is the **interaction between product and shelf/environment, environmental sensing and reporting and near field communication enabled features**. An example of this is that currently the most common packaging material used in meat exports to China is composed of polymers, which are not completely recyclable or biodegradable (Solomon 2016).

Insights across key consumer segments (Canadean 2016b)

One of the research studies commissioned by MLA aimed to identify the top five cities in China that offer the best opportunities for Australian red meat producers. These cities are: Shanghai, Hangzhou, Beijing, Shenzhen and Chengdu (Canadean 2016a). In a later phase of this project, insights into consumer behaviour and attitudes were collected in those cities, among different customer segments: affluent singles, dual income with no kids, families with young children, families with older children, empty nesters and multi-generational households. Some of the challenges mentioned in the previous section are supported by these insights as shown in the following profiles:

<u>Profile of an Affluent Single from Beijing</u>

"I like to eat healthy food without preservatives. Green and organic."

"I like to eat and travel overseas, exploring culture of other countries."

"I can't do without meat. I need to have meat in every meal."

"I always think imported meats taste better and are safer to consume. Their farming standard is very professional,

City: Beijing
Age: 25 years old
Lives: Alone
Occupation: Manager in Finance
Income: 20,000 RMB
TrendSights Segment(s): Ethically Minded; Health Conscious; Global Giant; Home-Body; Pleasure Seeker

- **Plans to eat more beef** as a source of protein as he's planning to start working out more to lose weight.

- **Busy weekdays**: buys simple healthy dishes for lunch, usually with meat (e.g.. Chinese pastry or Japanese food). Has a simple dinner (e.g.. congee – a dish made with oats) or eats out with friends.
- **Enjoys cooking at the weekend:** weekends are for family time, eating home-cooked meals rather than going out. Uses "Who's Cooking" software to learn recipes.
- **Buys meat from the Supermarket (Carrefour)** rather than closer convenience stores because the choice is better and fresher.
- **Doesn't shop online for meat** because he finds it easy to buy in the store.
- **Chooses chilled meat over frozen** because the quality is better and it tastes better, although he'll sometimes freeze it himself at home if he can't eat it the day he buys it.
- **Opts for packaged over loose** meat because they are branded, more convenient, better quality and safer.
- **Finds steak difficult to cook** so tends to have this when he goes out to restaurants rather than at home.
- **Prefers to buy for pre-sliced raw meats** because he finds it difficult to chop it himself.
- **Japanese and Australian** are his favorite imported meats but says the selection is still limited.
- **Prefers to eat smaller quantities of good quality meat**, over larger quantities of cheap local meat.

What does this mean for the project?

- Prioritise the development of Smart Packaging technologies which preserve the freshness status of the meat.
- Emphasise "freshness" and "purity" in branding and on-pack claims.
- Promote healthy characteristics of the product on-pack
- Promote Australia as a country of origin on-pack
- Offer family pack sizes of meat

Profile of a DINK (Dual Income No Kids) household from Chengdu

"We have popular dishes at home every day, so like to have something new when eating out."

"The price of what I buy is about RMB 40-50 per portion, the price of imported meat cannot be too high. If its like RMB 200 per piece, I won't buy it."

"The price of what I buy is about RMB 40-50 per portion, the price of imported meat cannot be too high. If its like RMB 200 per piece, I

City: Chengdu
Age: 29 years old
Lives: With his wife
Occupation: Real Estate Manager
Income: 30,000 RMB
TrendSights Segment(s): Health Conscious; Global Giant; Pleasure Seeker

- **Cooks at the weekend** while relying on food deliveries and meals at his parents during the week.
- **Favours Western and Mexican** cuisine and enjoys eating them during special occasions and celebrations.
- **Prefers beef** but will also consume lamb more during the winter time.
- **Chooses chilled meat over frozen** because it tastes better.
- **Enjoys experimenting** with new dishes when cooking at home, while having more traditional Chinese dishes at his parents.
- **Shops differently depending what he's buying:** goes to the supermarket for Western-style ingredients (e.g. steaks, lamb chops) and wet market when making Chinese food (e.g. beef brisket).
- **Negative experience buying meat online** from Taobao as the steak was attractively cheap but arrived "mouldy." Would consider buying online again "if they have good quality like the supermarket" and it is delivered chilled not frozen.
- **Avoids processed meats (e.g. burgers, meatballs)** because he's concerned over the quality following negative media reports.
- **Trusts family/friends' recommendations** but not adverts or celebrity endorsement.
- **Price, date, weight and cut** are the priority when buying meat, rather than origin.
- **Thinks imported meat is better but expensive** however would consider buying if the price was lower.
- **Freshness of imported meat:** concerns about added preservatives and storage during transportation need to be alleviated to justify price points.

- **Positive perception of Australian** meat: although unsure if he's tried it before, he believes it is the "best in the world" and would consider paying "10-20% more."

What does this mean for the project?

1. Prioritise the development of Smart Packaging technologies that preserve the freshness status of the meat.
2. Emphasise "freshness" and "purity" in branding and on-pack claims.
3. Promote the ethical advantages of Australian meat over local offerings, using on-pack certification logos to engage consumers at point of sale.
4. Clearly display nutritional information on pack and emphasise naturalness of ingredients used.

Profile of an older family with children from Beijing

"I think imported meat is okay to eat. Those meats are inspected in order to come to China. But why are these goods not branded?"

"I would prefer to go to the supermarket as I can check the meat closely. But if I place an order online you can only have whatever they delivered."

"Most of the time, I would rather cook and eat at home. Just because I feel much safe at home, and the flavor and taste is not so good

City: Beijing
Age: 40 years old
Lives: With her husband and 11 year old son
Occupation: Manager in Hotel industry
Income: 80,000 RMB
TrendSights Segment(s): Health Conscious; Home-Body; Global Giants

- **Travels frequently** and enjoys taking in the culture and trying local foods. Recent vacations include Europe and America.
- **Health drives purchases:** avoids chicken ("too many hormones") and pork ("too fatty"). Eats beef because "it won't make me fat."
- **Will travel to buy good quality meat:** buys meat from Neimeng Building (premium retailer in Beijing) which is "far away from here" because the meat is fresh.
- **Has bought meat online** but has concerns over quality: "you have no way to check the goods. You just received whatever the seller delivered to you."

- **Takes care cooking quality meat:** buys Australian beef because its safer and better quality than domestic and other imports (e.g.. US beef); and takes more care when preparing it because it's expensive to buy.
- **Wants to see Australian meat "brands:"** Would like to see actual Australian brands in-store, not just the origin.
- **Chooses pre-packaged frozen meats** as they are not exposed to the air and are usually stay fresher longer than chilled.
- **Prefers to buy whole cuts** as trusts the quality to be better than pre-cut which may have other meats/ingredients added.
- **Celebrates with Western food:** pizza, chicken nuggets and chips feature on special occasions as it is her son's favorite cuisine.
- **Does not trust packaged processed meats:** "I have no idea what the meatballs are made of. I will make them myself."
- **Uses mobile apps** to learn recipes and news about cooking.
- **Prefers to eat at home than go out:** "Just because I feel much safer at home, and the flavor and taste is not so good outside."

What does this mean for the Project?

1. Prioritise the development of Smart Packaging technologies that preserve the freshness status of the meat.
2. Emphasise "freshness" and "purity" in branding and on-pack claims.
3. Promote the naturalness of Australian meat, by highlighting it is free from preservatives, hormones and other additives.
4. Highlight health/nutritional benefits on-pack (e.g. low fat).
5. Create a brand for the Chinese market, which projects an image and a complete package

Profile of an older couple whose child has left home from Hangzhou

"I prefer beef. It has less fat. Pork has too much fat."

"Local beef does not look good. Australian beef is bright. Looks very fresh. Local one may be frozen too long. Looks grey."

"I'll pay more for better quality."

"It's better to have a brand. I can mention the brand to other people "

City: Hangzhou
Age: 43 years old
Lives: With her husband. Her 20 year old is away during the week studying.
Occupation: Manager in textiles
Income: 40,000 RMB
TrendSights Segment(s): Health Conscious; Home-Body

- **Beef is her favourite meat:** prefers beef because it's less fatty than pork.
- **Has better food when son is home:** cooks simple food during the week, but have "better food" and more variety such as steak when her son is home at weekends.
- **Eats out at upscale restaurants:** only eat out at upscale restaurants (RMB 70-100 per head) because they are clean, and goes to 5* hotel buffets on special occasions because of the variety and quality (e.g.. thinks they serve Australian or NZ beef).
- **Cooks simple dishes at home:** uses recipes passed from her mother, but sometimes learns from TV shows, friends or product packaging information.
- **Prepares convenient Western food for her son:** her son enjoys steak, spaghetti, lamb chops and hot dogs which she claims are "simple and convenient." Happy to buy packaged processed meats like burger patties and meatballs as they are quick.
- **Prefers chilled meat over frozen** because it preserves the quality and texture better.
- **Buys Australian meat from Lianhua Supermarket:** buys from a special counter in-store for Australian beef. Thinks Australian beef is safer and looks better, and is prepared to pay more for it.
- **Rarely buys meat online:** thinks imported beef online seems "too cheap" which raises concerns over the quality. Tried it once but the texture was "too soft."
- **Origin, cut and price are most influential** when buying meat and will spend RMB 70 on quality steak which she considers a premium price.
- **Cleanliness is key:** Does not like buying local meat because the displays are messy and piled up. Prefers to buy meat that's individually packed, priced and very clean.

- **Plans to buy more premium meat:** will buy better quality meat rather than a higher volume in future as “you can only eat so much meat.”

What does this mean for the Project?

1. Offer Australian meat in familiar formats that Chinese consumers are used to.
2. Use on-pack health claims to promote the benefits of Australian red meat.
3. Ensure healthy offerings do not compromise on flavour or taste; and clearly communicate this to the consumer using phrases such as “real,” “fresh” and “pure” to evoke both a tasty and healthy image.
4. Promote the ethical advantages of Australian meat clearly on pack.

Profile of a multi-generational household from Hangzhou

“We all believe that, compared to pork, beef may benefit my child’s growth. Americans look tall and strong, it may have some relation with beef, as they like beef a lot. For us, we do hope our child can grow taller, so we encourage him to eat

“I can roughly tell a bad meat from a good meat, but won’t be able to tell a premium one from a normal one.”

City: Hangzhou
Age: 38 years old
Lives: With his wife, 6 year old son, and his parents (five person household)
Occupation: Office worker
Income: 430,000 RMB
TrendSights Segment(s): Busy Lifestyler; Health Conscious; Home-Body

1. **Consumes meat with every meal:** chicken and pork are consumed most often, has fish most days and beef occasionally, but rarely eats lamb/mutton.
2. **Health is a priority:** he eats prawns often because he perceives them to be healthier than meat. Buys beef because he believes it is good for his son’s health.
3. **Sticks to familiar dishes:** when cooking he makes dishes passed down from his family, rather than following recipes and is not interested in trying something new.
4. **Prefers Chinese cuisine to Western:** they have Western food such as steak occasionally because his son enjoys it and its healthy.
5. **Branding is not important:** claims to have found no difference between branded pork and others, so is not really brand conscious when buying meat. However the overall packaging is important.
6. **Freshness influences meat purchases:** always checks expiry dates and the colour of the meat for freshness (“dark colour indicates the flesh is not so fresh.”)

7. **Prices and promotions are influential:** will buy meat if the price is not too high and will buy more meat when its on promotion. Thinks imported meat can be cheaper than domestic when bought on promotion online.
8. **Food safety is a key driver:** “Once a problem with a product is exposed, we will never buy from the brand again.”
9. **Thinks Australian is better:** Believes Australian beef better than local because the cattle have been raised on grasslands and the meat is safer. The brand is not important, but origin is.
10. **Buys meat online or in the supermarket:** purchases frozen imported meat online from COFCO when on promotion as there’s more choice and its cheaper than the supermarkets.

What does this mean for the Project?

1. Offer Australian meat in familiar formats that Chinese consumers are used to
2. Use on-pack health claims to promote the benefits of Australian red meat
3. Ensure use-by dates are prominently displayed and the product is visible inside the pack to address freshness concerns.
4. Promote Australia as a country of origin on pack

Other relevant insights are (Canadean 2016b):

- **Ensure meat is fresh in colour**
  “To define a beef as a superior quality the colour can not be too scarlet. Too deep a colour may come from dyeing. If it’s too light, it might also have problem. It should be well balanced.” Restaurant manager, Chengdu.

- **Create a brand**
  “I want to see brands rather than just buying “Australian” beef. It’s better to have a brand. I can mention the brand to other people.” Female Empty Nester, aged 43 from Hangzhou.

- **Promote benefits to justify premium**
  “I want to know what the cow eats, how much protein, and nutritional content. I want this on the label of top grade meat.” Male**,** aged 25 from Beijing.

- **Less packaging can be more**
  - *“Chinese are no longer going just for luxury packaging. Now people go for the basic quality packaging with quality goods.”* Innovation Manager, Miandian Food Company Ltd, Shenzhen.
  - *“I judge a good quality meat by simple packaging and just one label. Simple means real.”* Father**,** aged 38 from Shanghai.

- **Safety guarantees are essential**
  "I'm concerned about the quality of imported meat. I'm not sure if the meat will be affected by some kind of bacteria during the transportation. I'm not sure about the safeness of the imported meat." Mother, aged 40 from Beijing.

- **Frozen is not a barrier to freshness**:
  "With imported foods, the chilled meat is not as good as frozen when it comes to freshness." Father, aged 38 from Hangzhou.

- **Individual packaging is better**
  "Meat display must be clean and tidy. It shouldn't look like the local meat display. They pile it up in the middle. Very messy. I like to see meat displayed individually packed and priced, and very clean." Female Empty Nester, aged 43 from Hangzhou.

- **Wrapping is important**
  "I like the vacuum packaging that is used for online meat deliveries. It looks well wrapped. I would like to be able to buy the same packaging from the supermarket." Father, aged 38 from Hangzhou.

In summary, the key insights from the top five cities to target in China are:

- **Reassure the freshness and safety characteristics of meat not only on pack but also through the development of new technology.** Offering innovative products which spark conversation can help build brand awareness from trusted sources and in turn will encourage product trial and raise the profile of Australia and Australian origin meats in China. (Canadean 2016a)

  97% of consumers across the five cities trust family and friends, making them the most trusted information source when shopping for meat (Canadean 2016a)

- **Consider packaging for frozen meat.** Not only on-pack labeling, but also technologies that can improve the preservation and the presentation of the frozen meat, as sales of frozen red meat are forecast strongest growth out of the top five cities over the next five years (Canadean 2016a)

- **Clearly highlight nutritional content on pack as well as the health benefits of red meat** (e.g.: levels of beneficial nutrients such as being high in protein and iron) Approximately 10.7% of meat sales volume in China are influenced by health motivations, which translates to around 99.4k tonnes of red meat in the top five cities combined in 2020 (Canadean 2016a).

Opportunities and Solutions

Chilled counter meat dominates sales, but packaged and frozen meat is the biggest opportunity and is expected to continue to grow away from counter/loose meat. (Canadean 2016a) (Canadean 2016b).

By 2020, fresh counter red meats' sales value will have declined to 67% of total red meat sales. The market for frozen red meat will be 7.6bn CNY and chilled packaged red meat will be 10bn CNY (Canadean 2016a). Solutions to help overcome these challenges are mentioned below.

Freshness

- Active packaging: Solutions that are embedded in the packaging material and interact with the product. For example, a company called Toppan has a freshness preserving agent product. The oxygen absorption properties of this product inhibit oxidization and the formation of bacteria and mold within packages, resulting in improved product freshness and quality (Solomon 2016) (Thompson Reuters 2016).

- Other active packaging solutions are: modified atmosphere, tamper evident packaging, moisture barriers, scavenging technology and self-heating exothermic packaging (Solomon 2016).

It is advisable to complement one of the previous solutions with the implementation of on-pack freshness indicators for reassurance (Canadean 2016a).

Freshness is the top priority for Chinese consumers when shopping for meat. Although it is less of a priority for current imported meat consumers; it will be essential to encourage new consumers to try imported options (Canadean 2016a).

Almost half of consumers in the five cities (44%) consider the “colour of the meat” one of the most influential factors when shopping for meat; in addition to the 64% who are influenced by freshness. Technology such as MAP will help ensure meat looks as fresh as possible in colour and appearance for longer (Canadean 2016a).

Counterfeit

- The use of nanotags® (Honey & Fox 2017b): This system consists of two parts:

    1. A cover protection: a tiny metallic tag attached to the surface of the product and will react when buyers scan the product with an ultraviolet light. In that way buyers can prove that the product is genuine.
    2. Overprotection: High Security stickers, labels, seals and packaging tape applied to the product and/or its packaging which recognises the product as protected by the NanoTag© Brand Protection system. This system has been successfully implemented in the Australian Wild Abalone industry (AWA).

The potential for fraud is an ongoing issue in export markets. Once value is established in a brand it is inevitable for copies to be made (Honey & Fox 2017b).

- Use of QR codes and RFIDs to enable traceability and verification of the products (KPMG 2016).

    86% of consumers in the five cities consider information on brand/manufacturer websites at least somewhat trustworthy when shopping for meat. Given 40% of Chinese meat consumers find interactive packaging exciting or essential in product packaging, interactive packaging can help help build trust and drive purchase (Canadean 2016a)

- Implementation of Blockchain ecosystems to prove the provenance of the product. Blockchain is a distributed database that can mathematically guarantee the existence of a data record at a point of time (KPMG 2016). Due to the decentralised characteristic of the Blockchain, Xinova's use of the technology would provide consumers with product provenance guarantees from a reliable third-party, which is independent of Xinova's systems.

Environmentally friendly

Sealed Air Corporation and Ecovative Design LLC completed an agreement to accelerate the production, sales and distribution of Ecovative's EcoCradle® Mushroom® Packaging, a new technology for environmentally responsible packaging materials made from agricultural byproducts and mycelium, or "mushroom roots" (Thompson Reuters 2016).

Consumers in Beijing are most likely to strongly agree that the meat they buy is environmentally sustainable and are prepared to pay more for this (36%). Although levels of pollution in Beijing are extreme, with CO_2 emissions standing at 11 metric tons per capita, this can be to Australian meat supplier's advantage as consumers become more willing to spend on clean, green products and those stressing environmental friendliness (Canadean 2016a).

Attractiveness

- Use transparent packaging to ensure the product inside is clearly visible (Canadean 2016b).

  The packaging features that Chinese consumers consider most essential or exciting are bright colours, interactive packaging (e.g.: QR codes) and unique shapes. However, with sensory cues such as colour of the meat and visibility of ice/blood in packs also important; it is essential that bold marketing includes an element of transparency (Canadean 2016a)

  Visual cues are extremely important to Chinese meat buyers, with 44% in the five cities considering colour of the meat as one of the most influential factors. Visibility of blood, ice and fat in the pack are also influential for many. Indeed, the lack of product visibility is cited as one of the main barriers to buying meat online (Canadean 2016a).

Transparent pack with eye-catching and informative overlay

- Use innovatively shaped packs and brightly coloured labels, such as with imagery of Australia, to make the transparent packaging stand out (Canadean 2016b).

  Almost half (47%) of Chinese meat consumers find bright colours essential or exciting in product packaging, while 42% feel the same about unique shapes; highlighting the importance of packaging to help sell Australian meat (Canadean 2016a).

  Although less important than freshness cues, many consumers are influenced by country of origin and brand when buying meat. Building a strong brand presence and positive image of Australia will be important in encouraging consumers to choose this over other meat options (Canadean 2016a).

Bright colours offer strong shelf-standout selling point

Using country of origin as a key

- Use on-pack certification logos to build trust (Canadean 2016b).

  The strong influence of use-by dates highlights that freshness is still a concern to imported meat consumers when shopping for meat, but factors like country of origin and animal welfare also hold greater sway compared to the average meat consumer (Canadean 2016a).

  Ethical considerations are said to drive around 5.4% of volume meat consumption in China overall. [1] This will equate to around **50.2k tonnes of red meat** in the five target cities combined in 2020 (Canadean 2016a).

  Almost half of consumers in Beijing consider on-pack certification logos to be completely trustworthy in informing their decision when shopping for meat. (3.2)

Organic food certification

- Offer large pack sizes to cater to large households and families (Canadean 2016b).

Those who are already frequently consuming imported meat are most likely to be from households of at least three or more. Furthermore, consumers from three of the four key TrendSights segments (Pleasure Seekers, Health Conscious and Global Giants) are most likely to be from large households with five or more members (Canadean 2016a)

KEY SUCCESS FACTORS

It was recommended that the associated RFI be reviewed. The following criteria were presented for a successful solution to be identified in Smart Packaging:

1. Must prove the authenticity of a product in terms of their origin. Premium products demand a premium price tamper-proofing technology that provides provenance and prevents counterfeits. This is a key value proposition for customers.

2. Must support consistently high-quality standards of shelf life optimization, quality/grading/safety systems, and in secure, individual packaging (or small portions).

3. Recommended to have a strong country-of-origin premium branding, utilizing premium packaging design elements to emphasize ‘naturalness’ (e.g. free from …), clean, green, health, and satiety qualities (Canadean 2016b).

4. The packaged cut of meat must be carefully selected & well matched to the Chinese palate for repeat purchases. The meat must also be visually attractive and red in colour.

5. The value proposition should include cooking instructions to educate the consumer. A consistent message of the consumer not being able to correctly prepare and cook the cut must be addressed or the likelihood of repeat purchases will be jeopardized.

6. Australian red meat options must be available at convenient locations where people currently shop and provide confidence about a secure cold chain.

Other factors to consider are:

1. Strategic connections are important in China particularly if they aid with the supply chain complexity (Honey & Fox 2017a). Also, if a new technology requires training or education, it is important that the staff in contact with the product along the supply chain understand the packaging system.

2. Australian red meat value chain participants must work closely with Chinese authorities to assist with the introduction of new innovations and to test tolerance and acceptability levels (Solomon 2016).

Desirability criteria	Viability criteria	Feasibility criteria
• Packaging must: ○ Be transparent for consumer to visually check the product inside. ○ Make the meat look fresh and with an appealing colour. ○ Be attractive and engaging. ○ Clearly highlight nutritional content as well as highlighting the health benefits of red meat (e.g.: levels of beneficial nutrients such as being high in protein and iron). ○ Promote ethical credentials of meat products on pack such as being free-	• Competitors are offering significantly more attractive packaging than Australia. (e.g. US). New packaging must clearly differentiate Australian red meat (see desirability criteria) from the rest of the world. • Packaging must be: ○ Protectable from copying by competitors. ○ Protectable from tampering by partners in the supply chain. ○ Cost effective and not add disproportionate costs to the product.	• Adopt modified atmosphere packaging (MAP) to ensure colour is a desirable red to emphasize freshness • Adopt interactive packaging (e.g.: QR codes) to provide greater information on the product, without cluttering packaging labels. •

range, pasture-raised, or grass fed. ○ Highlight natural credentials such as being antibiotic and hormone-free. Organic certification can strengthen these credentials and enhance trust. • Visibility of blood and ice inside packs is kept to a minimum to ensure products are visually appealing.	○ Adoptable into Australian red meat producers current packaging processes (or with very minimal changes).	

Appendix 1: Smart Packaging Technology Overview

This Section first reviews the classification of smart packaging technologies and solutions. Technologies and solutions in each subcategory are briefly defined and introduced. Those recently developed technologies in laboratories and commercial applications in the five key areas (described in Section 4.2) are then introduced and discussed in detail.

Classification of Smart Packaging

"Smart packaging", sometimes referred as "advanced packaging" is more of a colloquial term than a scientific definition in the food and packaging sciences. The classification of smart packaging technologies may have minor discrepancies from different sources, but it can be generally described as in Table 4-1:

Table 1 Classification of Smart Packaging

Type of Smart Packaging	Descriptions
Active Packaging	Packaging systems incorporating of certain components which release or absorb substances from or into the packed food or the surrounding environment so as to prolong shelf life and sustain the quality, safety and sensory characteristics of the food (Realini and Marcos 2014).
Modified Atmosphere Packaging (MAP)	Packaging involving the alteration of the surrounding air/internal atmosphere of a package with gases (e.g., oxygen, carbon dioxide and nitrogen) (BCC Research 2015).
Intelligent Packaging	Packaging capable of detecting, sensing, recording, tracing, or communicating information about the quality and/or the state of the product during the entire supply chain (Realini and Marcos 2014).

Active packaging

Further classification of active packaging technologies is summarised in Table 4-2 (Realini and Marcos 2014; BCC Research 2015; MLA A.RHC.0004 2015):

Table 2 Classification of Active Packaging

Classification of Active Packaging	Descriptions
Moisture Absorber	Packaging which absorbs excess water, in order to prevent bacterial and mould growth; most common systems consist of a super absorbent polymer located between two layers of a

	microporous or non-woven polymer in the form of a drip-absorbing pad in tray-formatted meat products.
Oxygen Scavenger	Packaging which reduces residual oxygen in the package, in order to prevent proliferation of aerobic bacteria and moulds and/or to prevent photo-oxidation processes when exposed to store lighting, leading to changes in flavour, colour, texture, and nutritive values of the meat products; common scavenging mechanisms include iron powder oxidation, ascorbic acid oxidation, photosensitive dye oxidation, enzymatic oxidation, unsaturated fatty acid oxidation, and immobilised yeast oxidation on a solid substrate typically in the form of a sachet, as well as more advanced O_2 scavenging labels.
Antimicrobial Packaging	Packaging which actively controls the growth of microorganisms by extending the lag phase and reducing the growth phase of microorganisms; most common system include silver-based antimicrobial materials in the form of masterbatch.
Carbon Dioxide Emitter	Packaging which increases CO_2 levels which is desirable for red meat and poultry; most common systems are based on absorbing fluids from the packed food and then activating CO_2 emission in the form of a drip pad.
Antioxidant Packaging	Packaging which inhibits oxidation in meat products; generally by incorporating antioxidant agents into sachets, labels, or coatings, or immobilised on the packaging material surface, the polymer matrix, multilayer films, tec.
Colour Formation Packaging	Packaging which enables the formation of a red colour for packed meat products; one commercial product uses a sodium nitrite-containing film which promotes the formation of red colour formation in vacuum packed meat.
Odor Absorber	Packaging which reduces confinement of odours and maintains the desired aroma profile.
Edible Coating	Packaging with improved permeability, which leads to improvements in perceived qualities, such as tenderness, via consumable bio-packaging materials directly applied to the meat surface; common edible coatings are protein-based, whey-based, polysaccharide-based, cellulose-based, pectin-based, or gellan gum-based.
UV Blocking Packaging	Packaging which blocks UV light or rays and thus minimises the adverse effects of the sun on packaged meat products; most

	common systems incorporate UV blockers as an additive in the packaging material or as a coating for packaging materials.

Modified Atmosphere Packaging (MAP)

Further classification of MAP technologies is summarised in Table 3:

Table 3. Classification of MAP types

Classification of MAP	Descriptions
Low Oxygen (or anoxic) MAP and Vacuum Packaging	Packaging that excludes and replace of O_2 from within the packaging to minimize metmyoglobin, which causes meat colour deterioration; the most common gases used to replace O_2 are N_2 and CO_2; poultry and processed meats commonly use low oxygen MAP or vacuum packaging (Ščetar et al 2010).
High Oxygen MAP	Packaging using high O_2 atmosphere (typical 80% by volume) to promote a bright red colour when raw; raw red meat commonly uses high O_2 MAP, although different cuts and storage conditions may be sensitive to the O_2 percentage (MLA A.RHC.0004 2015).

Intelligent Packaging

Further classification of intelligent packaging technologies is summarised in Table 4 (Realini and Marcos 2014; BCC Research 2015; Ghaani et al 2016):

Table 4 Classification of Intelligent Packaging

Classification of intelligence Packaging	Descriptions
Time Temperature Indicators (TTIs)	Indicators which continuously monitor the time and temperature history of chilled and frozen products throughout the supply chain based on various mechanisms, such as physical, chemical, enzymatic or biological processes.
Integrity Indicator	Indicators which provide information on package integrity throughout the supply chain, with gas indicators being most commonly used in meat products; while leakage of various gases can be detected, this technique is most commonly used for O_2.

Freshness Indicator	Indicators which monitor the quality of the packed food via chemical or biological reaction to changes occurring in the fresh food products as a result of microbial growth or metabolism.
Barcodes	A pattern of parallel spaces and bars arranged to represent data that can be read by an optical barcode scanner that sends the information to a system where it is stored and processed; one-dimensional (1D), two-denominational (2D), and quick response (QR) 2D barcodes have been all developed and have found market applications.
Radio-frequency Identification System (RFID)	An RFID system including three main elements: a tag formed by a microchip connected to an antenna; a reader that emits radio signals and receives responses from the tag in return, and middle-ware that bridges the RFID hardware with an enterprise application; current applications of RFID relevant to this project include systems used for pallet identification, product identification and traceability, cold chain monitoring, shelf life prediction, etc.

Smart Packaging Technologies and Solutions Addressing the Five Specific Challenges Faced by Australian Red Meat Producers

Food Safety

Food packaging is traditionally defined as a passive barrier or means of delaying adverse effects of the environment on the packaged food. Resulting from the changing lifestyles, safety, and health consciousness of global consumers, the function of food packaging has evolved from such simple protection and preservation to include a range of advanced solutions in order to address new demands from consumers, although ensuring food safety and product quality remains the top priority for food producers. This is particularly true for Australian red meat exporters since microbiological contamination of red meat is one of the main sources of food borne illnesses (Realini and Marcos 2014). In this section, smart packaging technologies and solutions that can help Australian red meat producers to ensure the safe delivery of meat products to consumers are reviewed and discussed. Both research and industry trends, as well as consumer perceptions are also identified.

Active packaging technologies incorporate subsidiary constituents in the packaging material or packaging headspace to enhance the protection performance of the packaging system, and therefore can theoretically also contribute to food safety and quality assurance. However, for the purposes of this report, active packaging and, for a similar reason, MAP, will be both discussed in the subsequent section pertaining to **Shelf-Life**.

Indicators

Indicators convey information. Based on the types of information they convey, indicators can be generally classified into three categories:

1. Freshness indicators;
2. Integrity indicators; and
3. Time-temperature indicators (TTIs)

The conveyed information, which can relate to the presence or absence of a substance, the extent of a reaction between two or more substances, or the concentration of a specific substance or class of substances most often is displayed by immediate visual changes, for example, by different colour intensities or the diffusion of a dye along the indicator geometry (Ghaani et al 2016). Although there are differences among types of information conveyed and the mechanisms to obtain such information, these three types of indicators can all communicate information regarding food safety to retailers and consumers.

Freshness indicators provide the most direct information on product quality and whether it may be compromised either due to exposure to detrimental conditions or due to exceeded shelf life. Older generation TTIs did not provide any direct information regarding the quality of food; rather, they monitored and recorded detrimental changes in temperature fluctuations (e.g., above or below a reference critical value) over time along the food supply chain. However, current TTIs are more user-friendly devices, with information is readily understood by consumers as being directly related to the quality of the food item through mathematical prediction models that predict and estimate microbial growth.

Integrity indicators can either work as leak indicators, providing information regarding a package's integrity throughout the whole distribution chain or more simply providing information about how long a product has been opened. In either case, stakeholders throughout the supply chain can have access to warnings that the package integrity has been compromised and the packed contents may not be safe to consume anymore. For example, prior studies have established critical leak size and associated meat quality deterioration for MAP meat products (Smolander 1997).

Table 5 outlines commercial applications of indicators that may help retailers, consumers and other stakeholders throughout the supply chain to determine whether food safety has been compromised. Some commercial applications in other food sectors other than the red meat industry are also included, where the mechanism or the format of the indicator itself can be adopted for the red meat industry.

Table 5 List of commercial applications of food indicator technologies.

Trade or Product Name	Supplier	Format/Function
Freshness Indicator		
Fresh Tag®	COX Technologies	Colourimetric indicator
SensorQ™	FQSI Inc.	pH-sensing indicator
Freshness Guard[1]	UPM Raflatac	Colourimetric indicator (silver nanolayers)
RipeSense™	Ripesense Limited	Colourimetric indicator for ripeness
Integrity Indicator		
Timestrip®	Timestrip Ltd.	Time indicator label
Novas®	Insignia Technologies Ltd.	Time indicator label
Best-by®	FreshPoint Lab.	Time indicator label
Ageless Eye®	Mitsubishi Gas Chemical Inc.	Gas indicator tablet
O2Sense	Freshpoint Lab	Gas indicator tablet
Vitalon®*	Toagosei Chemical Inc.	CO_2 gas indicator
Freshilizer*	Toppan Printing Co	CO_2 gas indicator
Tell-Tab	IMPAK, USA	O_2 gas indicator
Time Temperature Indicators (TTIs)		
3M Monitor Mark®	3M Company	Fatty acid ester TTI
Keep-it®	Keep-it Technologies	Chemical TTI

[1] Freshness Guard is not commercially available at present. However, in December, 2014, UPM has announced that UPM and Indicatorium Oy have entered into an agreement for the international commercialization of the food freshness indicator technology developed by UPM. The product of this commercialization collaboration is not commercially available at the time of this project being prepared. http://www.spinverse.com/indicatorium-commercialise-upms-food-freshness-indicator-innovation/

Fresh-Check®	Temptime Corp.	Polymerization reaction TTI
VITSAB®	VITSAB International AB	Enzymatic TTI
OnVu®	Freshpoint and Ciba	Photochemical reaction TTI
TopCryo®	TRACEO	Microbiological TTI
FreshCode®	Varcode Ltd.	Barcode based label TTI
Tempix®	Tempix AB	Barcode based label TTI

Freshness indicators monitor the quality of packed food by reacting to changes taking place in the package leading to changes in the concentration of metabolites such as glucose, organic acids (e.g. L-lactic acid), ethanol, carbon dioxide, biogenic amines, volatile nitrogen compounds or sulphuric compounds (Realini and Marcos 2014). By indirect detection of target metabolites, freshness indicators provide direct visual information, e.g., colour changes indicating the freshness of the product. Most of the freshness indicators reported in the literature are based on the detection of a single compound or parameter. As a result, they may all suffer drawbacks such as lack of specificity with the risk of offering false positives and false negatives (BCC Research 2015). One research project designed to address this issue involved the use of colorimetric sensor arrays to offer information through suitable colour modulations. In this work, the researchers developed an optoelectronic nose composed of seven sensing materials prepared by the incorporation of pH indicators and chromogenic reagents with different chemical recognition properties to monitor the quality of pork sausages (Solar et al 2014).

Commercial applications of freshness indicators have not achieved much success. Fig.1 shows a few product examples. SensorQ™ and Freshness Guard appear not to be commercially available at present time. Despite many research activities, freshness indicators are still not currently widely commercially available. Some previous consumer studies have suggested that consumer interest and the cost of the indicators are likely not the reason. In a study of Belgian consumers' perception and willingness to pay for freshness indicators, 71% consumers perceived the indicator to be useful as a food safety and quality device and they were willing to pay an average of $0.225 more for a product which incorporated an indicator as opposed to one without an indicator; however the cost of the indicator was only $0.025 to $0.035 per package (Fortin & Goodwin 2008).

One reason for the relatively small market penetration of freshness indictors may be that neither the food producers nor the retailers are highly motivated in providing food products for consumers with a means of readily knowing that the content is no longer fresh. Therefore, one solution may be to integrate the freshness indicators into the tracing devices, such as RFID tags and labels to ensure that spoiled food products will be identified and removed before they reach the retailers and consumers.

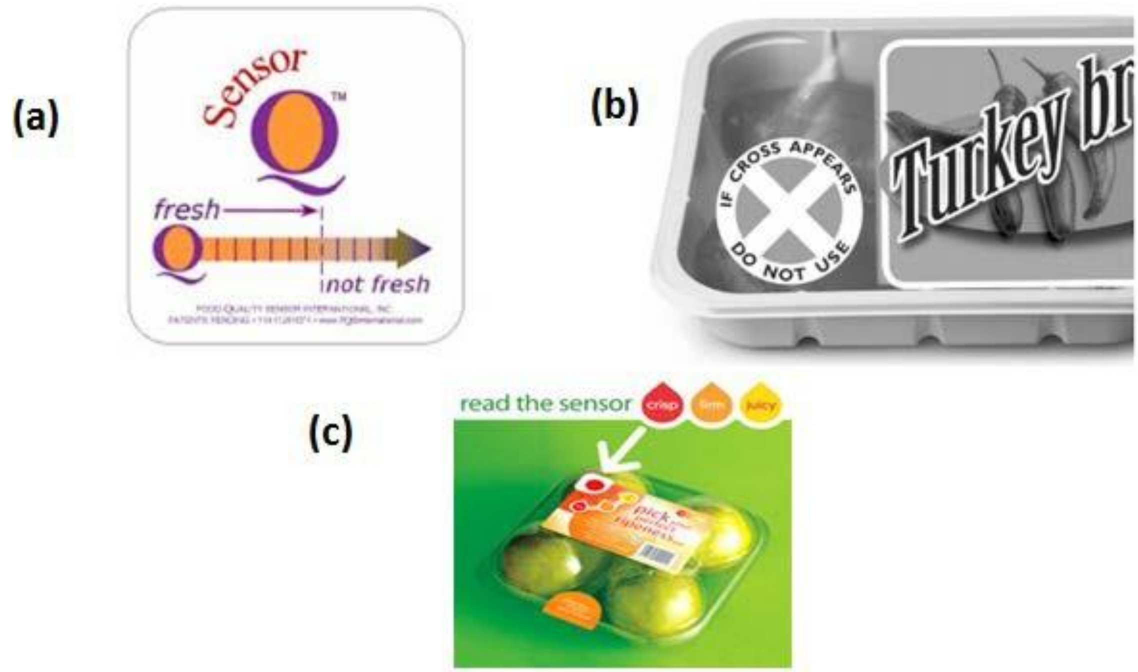


Fig.1. Examples of freshness indicators: (a) SensorQ™, a stick-on sensor label applied by the meat packer to the inside of meat and poultry packages to detect the gaseous by-products of food-borne bacteria growing inside the package; (b) Freshness Guard, a freshness indicator for poultry meat based on a nanolayer of silver that reacts with hydrogen sulphide, a breakdown product of cysteine; (c) RipeSense® changes colour by reacting to the aroma released by fruit as it ripens.

One type of integrity indictor provides information on how long a product has been opened. Such indicators are activated at the moment of breakage of the package and display a colour change with time, which serves to notify consumers of an unintended leak within the packaging or encourage them to use the food product before the expiration date. Fig.2 shows three commercial examples (a-c) of such integrity indicators.

Gas indicators are another type of integrity indicator most commonly used in the meat packaging industry. Of these, the most common type of gas indicators used for MAP packaging applications are oxygen indicators, which typically involve a system consisting of a colourimetric redox dye, a reducing compound and an alkaline compound, which will induce colour change when oxidised by O_2. One problem with this mechanism is that the colour change is reversible, such that the indicator can resume its original form when the O_2 concentration is reduced. Redox-based oxygen indicators are also subject to dye leaching upon contact with moisture in the package's headspace, although researchers have recently explored the use of an alginate polymer to prevent dyes from leaching out of colorimetric oxygen indicator films (Vu and Won 2013). Fig.2 shows two commercial examples of reversible O_2 indicators, namely Ageless Eye and O2Sense indicators. In 2013, EMCO Packaging announced plans that they were going to launch a non-reversible oxygen indicator label based on a unique liquid that changes colour in the absence of oxygen (Emco Active and Intelligent Packaging Technology 2016). This label was not commercially available at the time of this report.

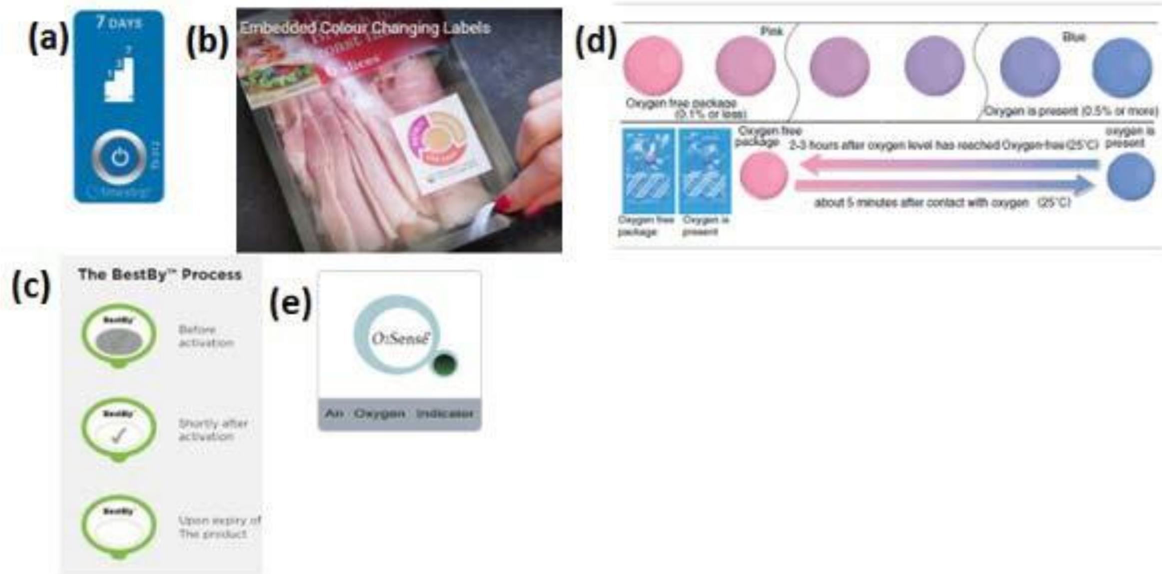


Fig.2. Examples of integrity indicators: (a) The Timestrip® indicator offers a helpful visual reminder of service and maintenance schedules for consumable components; (b) a label can be embedded into a film lid and activated when consumer opens the package, thereby triggering a timer to show a strong colour change as the food loses freshness; (c) The BestBy® visual indicator clearly signals the end of the product's secondary shelf life, encouraging consumers to use the product at its best and to re-purchase when the product is determined to have expired; (d) The Ageless Eye reversible O_2 indicator turns blue or purple when exposed to oxygen then returns to its original pink colour as the oxygen in the container is reduced; (e) The O2Sense oxygen sensing products (patent pending) are aimed at the MAP market and can either be eye-readable or machine readable.

TTIs are indicators that provide a visible response to mechanical, chemical, electrochemical, enzymatic or microbiological changes to the food products throughout the supply chain. Fig.3 shows several commercial applications of TTIs which use time-temperature dependence of various reactions for continuous monitoring of the time and temperature history of the packed food. For example, 3M's Monitor Mark® uses the melting and diffusing reactions of various fatty acid esters. Bizerba's OnVu™ uses benzopyridines, a pigment that changes colour over time at temperature dependent rates. The trend in recent research involves the use of TTIs to predict food quality during shelf life by developing mathematical models to predict microbial growth based on the time-temperature dependence response (Ellouze and Augustin 2010).

Some studies have found that some consumers have negative perceptions of TTIs, including concerns related to the reliability of the technology, misinterpretation of the TTI message, contradicted messages between TTIs and other freshness indicators, and the potential for an increase in food waste in circumstances where consumers rely too much upon the TTI labels rather than their own judgment to determine freshness (Pennanen 2013). As a result, as with other freshness indicators, TTIs may be more effectively deployed on a business to business (B2B), rather than a business to consumer (B2C), level (MLA A.RHC.0004 2015). Furthermore, anecdotal evidence suggests that TTI cost may be a barrier to adoption for many refrigerated grocery goods.

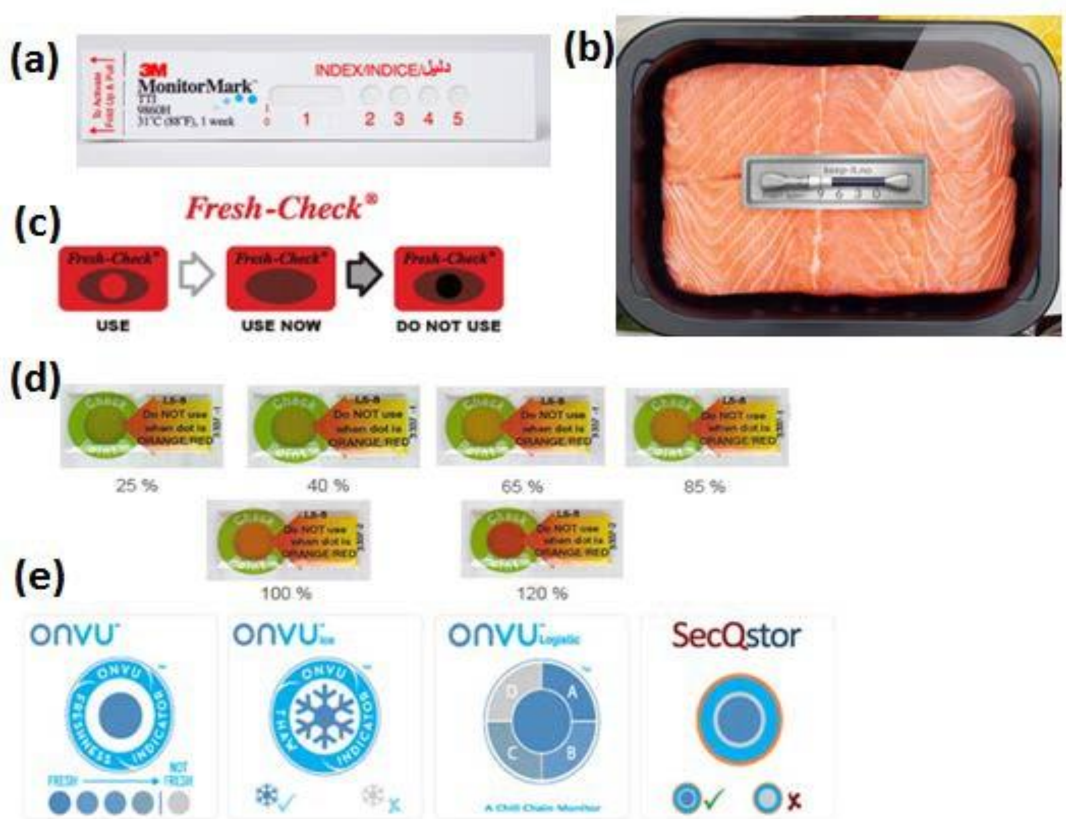


Fig.3. Examples of TTIs: (a) MonitorMark™, a self-adhesive label for monitoring thermal exposure of temperature-sensitive products during transportation and storage; (b) Keep-it, a TTI that predicts remaining shelf-life; (c) Fresh-Check®, a self-adhesive TTI specifically formulated to match the shelf life of the food products to which it is affixed; (d) VITSAB, a customised TTI label, such as the L5-8 Seafood label, which provides consumers with a full history of customised cold chain information; (e) OnVu™, a tailored TTI calibrated for the different spoilage behaviour of various foods and beverages, which is designed to be highly accurate and consistent in recording and displaying the freshness of the products, based on their time and temperature histories.

Sensors

Sensors detect, locate, or quantify energy or matter by proving a signal for the detection or measurement of a physical or chemical property to which the sensing device responds. Most sensors have four components:

(1) Receptor, i.e., the sensing component;

(2) Transducer, i.e., the measuring component;

(3) Signal processing electronics; and

(4) Displaying unit.

In contrast with indicators, sensors comprise receptor and transducer components and communicate information not through direct visual change but by responding to a chemical or physical quantity to produce a quantifiable output that is proportional to the measurement (Ghaani et al 2016). Because sensors and indicators are technically two different intelligent packaging technologies, they are discussed separately in this report. However, in many literature and patent references, such a distinction is somewhat arbitrary and the use of these two terms interchangeably is unavoidable.

Established gas sensor systems include metal oxide semiconductor field-effect transistors (MOSFETs), piezo-electric crystal sensors, amperometric oxygen sensors, organic conducting polymers, and potentiometric carbon dioxide sensors (Ghaani et al 2016). The two main types of gas sensors are O_2 sensors and CO_2 sensors; however, the development of CO_2 sensors for food applications has lagged behind that of O_2 sensors because O_2 plays a far more important role than CO_2 in food deterioration.

Another important type of sensor used in the food packaging industry is the biosensor. The main difference between chemical sensors and biosensors is the receptor material. While chemical sensor receptors are chemical compounds, biosensor receptors are composed of biological materials, such as enzymes, antibodies, antigens, phages, and nucleic acids. One advantage of the biosensor is its capacity to directly detect target metabolites produced during food spoilage

One major challenge for both chemical sensors and biosensors is the means of integrating these devices into the food packaging system. Integration of sensors into food packaging for real-time and continuous quality monitoring involves three important aspects, each facing different challenges. Firstly, nontoxic and food-safe sensing components need to be used in order to prevent cross-examination. Secondly, a deep understanding of microbiology is required to engineer materials which are responsive to chemical or biological targets present in the food. Finally, the transducer system must meet the requirements for both safety and performance durability (Brockgreitens and Abbas 2016).

One promising direction involves the use of printed electronics. This technology is expected to revolutionise the production of electronic devices on flexible substrates (Vanderroost 2014) with the global market for flexible and printed sensors projected to reach $9.6 billion by 2020 (Global Industry Analysts, Inc.2015 In a recent work, researchers have developed a screen-printed analogue-to-digital converter (ADC) with 4-bit resolution, which is a first step toward using near field communication (NFC) to transmit information on food conservation from sensors incorporated in packaging materials; this technology could enable monitoring of food quality using handheld devices (Cantatore 2015). One commercial application of printed electronics is Thin Film Electronics ASA’s “Smart Sensor Label”, which is a stand-alone, integrated printed electronic temperature-tracking label, designed for monitoring of perishable goods (Thinfilm 2013). Another approach to integrate biosensors into food packaging is molecular imprinting, which creates recognition elements for selected analyte molecules. Johns Hopkins Applied Physics Lab has developed molecularly imprinted polymers (MIPs) and has used these polymer materials to detect meat spoilage through colour change (Jacobovitz 2014).

Another research trend involves the use of nanosensor technologies in meat processing technologies and packaging to improve food safety and reduce the frequency of food-borne diseases. Recently, scientists have used nanosensors to detect the presence of gases, aromas, chemical contaminants, and pathogens (Duncan 2011). Due to the unique chemical and electro-optical properties of various nanoscale particles, nanosensors are theoretically able to detect microorganisms or chemical contaminants at extremely low levels. For example, scientists have developed nanosensor technology that can detect picomolar (pM) levels of protein-based bacterial toxins (Warner et al 2009) and parts-per-trillion (ppt) levels of gaseous amines as indicators of fish and meat spoilage (Hernandez-Jovier et al 1996). Recently, researchers from MIT have developed carbon nanotube-based sensors, which can be deployed in food packaging systems to detect sub-ppm levels of gases emitted by rotting meat (Liu et al 2015).

Despite the bright potential of nanosensors in food packaging industry, there have been great challenges as well. For example, there are major concerns with respect to the safety of nanotechnology in general, and some consumers fear that nanoparticles used in food packaging materials could enter into the food itself, posing health risks. Additional issues that need to be addressed include the high costs associated with nanotechnology research and development, as well as stringent regulatory environments (Technavio 2014). Such concerns may reduce the adoption of nano-enabled packaging technologies.

The sensor technologies discussed above are all based on electrical transducers, meaning that the transducer generates an electrical output signal in proportion to the change of an electrical property of the receptor. Recently, transducers that generate optical output signals have attracted considerable interest from the scientific community as well as industry. Compared to sensors based on electrical transducers, sensors based on optical transducers do not require an electrical power supply and can be powered and read out from a distance via UV, visible, or IR light. In addition, such sensors can leverage the existing infrastructure and methodologies that are used to manufacture conventional silicon semiconductors and, therefore, are capable of being produced on a large scale, at low cost (Vanderroost 2014). Recently, a research consortium, ChekPack, has initiated a research project to develop an optical sensor that can be integrated into food packaging in order to detect spoilage of food products (by determining the respective concentrations of various volatile compounds) and to verify the integrity of food packaging (by measuring CO_2 and O_2 concentrations) (CheckPack 2016).

Research and development of sensor technology has historically largely focused on the environmental and biomedical industries. Because sensor technology has huge potential to provide rapid and quantitative detection of food quality, by determining freshness, microbial spoilage, oxidative rancidity, and oxygen/heat induced deterioration, there has been a tremendous amount of sensor research activity in the field of intelligent packaging. However, due to high development and production costs, stringent industry specifications, safety considerations, and relatively limited demand (in comparison to the biomedical sector), very few systems to date have found commercial success in the market (Kerry 2012). Further cross-disciplinary development in materials science, nanotechnology, signal processing, printed electronics, process control, and silicon photonics, along with knowledge transfer from more established environmental and biomedical industries, will likely lead to wider adoption of sensors in the food packaging industry. Table 6 outlines commercial examples of two classifications of sensors that have been used in food safety applications.

Table 6 List of commercial applications of sensor technologies

Trade or Product Name	Supplier	Format/Function
Gas Sensor		
OxyDot - O2xyDot®	Oxysence	fluorescence quenching O_2 sensor
Biosensor		
Food Sentinel System™	SIRA Technologies (USA)	Biosensor (barcode)
Toxinguard®	Toxin Alert Inc.	Monitor *Pseudomonas sp.* growth
Flex-Alert	Flex-Alert (Canada)	

Shelf-Life

The role of packaging to extend food shelf life, particularly for meat products, is increasingly important. Active packaging can extend shelf life and improve product quality by incorporating active components into packaging systems, whereas MAP is used to extend shelf life by using gases to alter the internal atmosphere of a package. In this section, these two packaging solutions were identified as ways that may help Australian red meat producers extend product shelf life and hence realise new business opportunities.

Active Packaging

Active packaging technologies and solutions generally can be classified, according to their various functions, into six categories:

1. Moisture absorbers;
2. Oxygen scavengers;
3. Carbon dioxide emitters;
4. Odour absorbers;
5. Antimicrobial packaging; and
6. Antioxidant packaging.

Table 7 outlines classification of activating packaging technologies and commercial applications of each category (Realini and Marcos 2014).

Table 7 Classification of activating packaging technologies and commercial applications

Trade or Product Name	Supplier	Format/Function
Moisture Absorbers		
Dri-Loc®	Sealed Air Corporation	Absorbent pad
MoistCatch	Kyodo Printing Co., Ltd.	Absorbent pad
MeatGuard	McAirlaid Inc	Absorbent pad
Linpac	Packaging Ltd.	Absorbent tray
Fresh-R-Pax®	Maxwell Chase Technologies	Absorbent tray
TenderPac®	SEALPAC	Dual-compartment system
Nor®Absorbit	Nordenia International AG	Microwavable film
Oxygen Scavengers		
OxyGuard®	Clariant Ltd.	Sachet
OxyCatch®	Kyodo Printing Company, Ltd.	Sachet
FreshPax®	Multisorb Technolgoies, Inc.	Sachet
Oxysorb	Pillsbury Co., USA	Sachet
ATCO®	Laboratories STANDA	Label
Ageless®	Mitsubishi Gas Chemical Inc.	Label
Cryovac® OS2000	Sealed Air	Film
Enzyme-based	Bioka Ltd.	Film
Shelfplus® O2	Albis Plastic GmbH	Masterbatch
OxyRx®	Mullinix Packages Inc.	Container suitable for high temperature

OMAC®	Mitsubishi Gas Chemical Inc.	Film suitable for high temperature
Odor Absorbers		
Dri-Fresh® Fresh-Hold™ OA	Sirane Ltd	Pad
Cryovac®	Sealed Air	Film
Tyvek®	DuPont	Odor-absorbent packages
CO_2 Emitters		
CO2® Fresh Pads	CO2 Technologies	CO_2 emitter pad
UltraZap® Xtenda Pak pads	Paper Pak Industries	CO_2emitter and antimicrobial pad
SUPERFRESH	Vartdal Plastindustri AS	Box system with CO_2 emitter
Anti-microbial Packaging		
Biomaster®	Addmaster Limited	Silver-based masterbatch
AgIon®	Life Materials Technology	Limited Silver-based masterbatch
Irgaguard®	BASF	Silver-based masterbatch
Surfacine®	Surfacine Development Company LLC	Silver-based masterbatch
IonPure®	Solid Spot LLC	Silver-based masterbatch
d2p®	Symphony Environmental Ltd	Silver-based masterbatch
Bactiblock®	NanoBioMatters	Silver-based masterbatch
Biomaster®	Linpac Packaging Ltd.	Silver-based trays and films
Food-touch®	Microbeguard Corp.	Interleavers
Sanic Films	Nanopack	Interleavers
SANICO®	Laboratories STANDA	Antifungal coating

Wasaouro ®	Mitsubishi-Kagaku Foods Corp.	Antibacterial and antifungal sheets, labels and films
Nisaplin® and Novasin™	Integrated Ingredients, USA	Antimicrobial compound
Anti-oxidant Packaging		
ATOX	Artibal SA	Film coating

Moisture absorbers are commonly used in the meat industry to control excess water accumulation inside the package. A moisture absorber usually consists of a super absorbent polymer located between two layers of a microporous or non-woven polymer, commonly in the form of a drip-absorbing pad used in tray-formatted meat products (Realini and Marcos 2014). Fig.4 shows an example of a commercial product with this typical sandwich-like structure, namely Dri-Loc® Meat, Fish and Poultry Pads.

Fig.4 Dri-Loc® Meat, Fish and Poultry Pads

Oxygen scavengers are used to remove, absorb, or neutralise oxygen present in the package, which leads to oxidation of food contents and proliferation of aerobic bacterial and moulds. Oxygen scavengers are typically used with MAPs and typically utilise oxygen scavenging mechanisms such as iron powder oxidation, ascorbic acid oxidation, photosensitive dye oxidation, enzymatic oxidation (e.g. glucose oxidase and alcohol oxidase), oxidation of unsaturated fatty acids (e.g. oleic or linolenic acid), and oxidation of immobilised yeast on a solid substrate (Realini and Marcos 2014). O_2 scavengers are commonly incorporated into packages as adhesive strips, labels, or sachets. In response to the negative perceptions that consumers may have towards the presence of non-edible artefacts in the food package, one technology trend in this area involves directly incorporating the scavenging material into the food packaging. For example, Cryovac® OS2000 from Sealed Air Corporation, USA is a polymer-based oxygen scavenging multilayer flexible film activated by ionizing radiation that can reduce the oxygen levels in the packaging headspace from 0.4% to below 0.1% in about one week. Another research trend in the O_2 scavenging field is the use of nanomaterials. Researchers have developed high barrier oxygen scavenging polyolefin nanocomposite films containing an iron-modified kaolinite; these materials show great potential for active food packaging applications (Busolo and Lagaron 2012).

The development of unpleasant odours can result from thermal degradation of food components, such as proteins, or of reactions such as the Maillard reaction (Han 2005). For meat products, exposure to oxygen will affect lipids and proteins in the meat, resulting in chemical changes that adversely affect the colour, odour, and taste of meat products. Oxidised meat products have a tendency to smell like cardboard and taste rancid (Brooks 2007). Research work is relatively limited for odour absorbing technologies compared to those of other active packaging technologies. One reason may be that many research efforts have been directed to oxygen scavenging and antioxidant packaging technologies, which both function to prevent oxidation from occurring. Commercial examples of odour absorbers include Dri-Fresh® Fresh-Hold™ OA odour-absorbing pads from Sirane, Cryovac® Odor Scavenging Materials from Sealed Air, and Tyvek® odour-absorbent packages from DuPont.

Carbon dioxide emitters are often used in MAP systems to regulate the CO_2 levels within the package in order to reduce microbial growth and thus prolong product shelf life. In a typical mechanism of CO_2 generation, the drip losses from meat products are absorbed by the emitter pad, which then activates the generation of CO_2 resulting from the reaction of active components in the pad, e.g., the reaction of citric acid and sodium bicarbonate with water. As with O_2 scavengers, packaging materials incorporating the CO_2 emitting function are being developed in order to avoid the use of separate emitters inside the package (Kerry and Butler 2008).

Among all categories of active packaging technologies, antimicrobial packaging appears to be that which has received the most interest and attention in academia. According to the patent filing data provided in a BCC report, in the period from 2010 to April, 2015, antimicrobial agents and packaging accounted for the highest number of patents issued within the active packaging category (BCC Research 2015) However, even with the significant amount of work in this area, antimicrobial packaging has achieved only limited commercial success (with the exception of silver-based materials). This is believed to be due to existing technical hurdles and the stringent regulatory regime. The technical hurdles exist because effective antimicrobial solutions require multidisciplinary One such cross-disciplinary approach involves combining antimicrobial films with high pressure processing (HPP); this combined strategy has proved to be effective to reduce *L. monocytogenes* levels and to eliminate *Salmonella spp.* in vacuum packed cooked ham (Jofre et al 2008). Unfortunately, the synergistic antimicrobial effects of this technology did not appear to work well with foods having low water activity (Marcos et al 2012). Another trend in the area of antimicrobial packaging involves the use of natural materials with antimicrobial properties, such as natural extracts, essential oils, and biocompatible materials, such as cellulose. In one example, scientists have developed an antimicrobial cellulose film containing allyl isothiocyanate encapsulated in carbon nanotubes, which was effective in reducing microbial contamination in ready-to-eat (RTE) chicken meat (Dias e al 2013). In another example, researchers developed a sodium alginate film containing zinc oxide nanoparticles capable of eliminating *S. typhimurium* and *Staphylococcus aureus* in RTE poultry meat (Akbar 2013).

Antioxidant packaging is an alternative to oxygen scavenging to prevent food oxidation by incorporating antioxidant agents into food packaging in different forms, such as sachets, labels, coatings, or immobilization on packaging material surfaces. As with antimicrobial packaging, recent trends in this area involve the use of natural extracts, such as rosemary, oregano, and tea, to replace synthetic additives, as many natural essential oils contain ingredients with both antimicrobial and antioxidant properties. Dual antimicrobial and antioxidant functioning films have also received much research interest. For example, dual function films based on cocoa extract (Calatayud et al 2013) and rosemary and oregano (Camo et al 2008) are being developed.

Modified Atmosphere Packaging (MAP)

Modified Atmosphere Packaging (MAP) is a packaging method based on altering a package's internal atmosphere with gases to improve the shelf life of meat products. MAP may be used for bulk or retail ready products or several trays of retail ready products may be placed in a master MAP pack. Individual sealed trays may also contain the modified atmosphere (Scetar et al 2010). MAP is one of the most commonly used methods of controlled packaging in the meat packaging industry due to its ease and ability to combine multiple technologies. Global MAP market revenue is anticipated to be around $6.4 billion after increasing at a CAGR of 2.0% during the forecast period of 2013-2020 (BCC Research 2015).

The gases used in MAP include O_2, CO_2, N_2, and CO. The use of chlorine dioxide has been suggested for its oxidizing power and antimicrobial activity, as well as its activity at high pH and inactivity with organic matter (Byelashov and Sofos 2009). Typically fresh red meats are stored in MAP with 80% O2:20% CO_2 while cooked meats are stored in MAP with 70% N2:30%CO_2 (Scetar et al 2010). Past research on MAP has focused primarily on the use of different gas combinations and concentrations. Many MAP formulas for different types of meat products can be found in reviewed articles (Scetar et al 2010; Arvanitoyannis and Stratakos 2012).

Vacuum skin packaging (VSP), a subset of vacuum packaging technology, is a major mode of packaging used in shipping of meat products. While so-called "shrink bags" are widely used for exports, colour is a major hurdle for vacuum packaging of meat products because low partial oxygen pressure values cause the development of brown colour due to the conversion of myoglobin to metmyoglobin. This may potentially be addressable via technology capable of inducing formation of a red colour. For example, Bemis Company Inc. has devolved FreshCase® packaging, a special packaging solution that allows red colour formation in vacuum-packed meat. This packaging system consists of a multilayer film containing sodium nitrite, which is converted to nitric oxide gas upon contact with meat. The nitric oxide gas combines with myoglobin in the meat to give the typical red colour of fresh beef (Freshcase active vacuum packaging n.d.).

Anti-Counterfeiting

Counterfeiting has become a major concern for all businesses globally. It not only damages brand value and sales revenue for the brand owners and manufacturers, but also poses significant health risks to consumers, especially in the food and beverage and pharmaceutical industries. While Australian red meat producers and exporters are grateful for the new business opportunities presented by emerging nations, many are worried about the enormous counterfeiting activities in these countries and regions as well. Counterfeiting problems call for global solutions in law and enforcement, secure business practices, and consumer awareness and education; however, for the purpose of this report, only packaging technologies and innovations related to anti-counterfeiting have been reviewed and discussed herein.

Anti-counterfeiting packaging technologies can be classified into two categories: authentication, and track and tracing. Authentication is the act of establishing or conforming something as genuine; authentication packaging therefore relates to brand protection, theft-deterrent, anti-counterfeiting, and anti-tampering. In contrast, track and tracing technologies provide solutions for manufacturers to track and trace individual products throughout the supply chain, from production to the end consumer, and hence reduce counterfeiting risks by ensuring that products can be easily located and identified. In practice, authentication and track and trace technologies are used together in industries to fight against counterfeiting. For the purpose of this report, track and trace packaging technologies will be discussed in next section.

Traceability.

Existing authentication packaging technologies can be classified into five categories: inks, materials, holograms, watermarks and taggants. Table 8 outlines existing authentication packaging technologies that are relevant to the meat industry and offers a brief description, protection level, and ability to indicate product tampering (BCC Research 2015(2); Hayes 2015).

Generally, there are three types of protection, namely overt, covert, and forensic protection, as follows (Hayes 2015).

- Overt – Visible features which are directed toward end-users and enable the packaging to be validated quickly and easily.
- Covert – Features which are generally invisible to the naked eye but can be revealed with certain tools or calibrated readers; such features are usually difficult to copy.
- Forensic – Means of protection wherein a sample is obtained and taken to a laboratory for a full analysis.

Table 8 Existing authentication packaging technologies

Type of Authentication Packaging	Description	Protection Level	Tamper evidence?
Inks			
Colour-shifting Ink	Colour shift when viewed at different angles	Overt	No
Holographic Ink	Inks containing coloured metal particles to produce holograms or images with colourful decorative features; when copied, the ink reproduces as black	Overt	Yes
Thermochromic	Inks that change colour with exposure to different temperatures	Overt	No
Photo-chromic ink	Inks that change colour with exposure to UV light/sunlight	Cover/Overt	No
UV fluorescent ink	Either visible or invisible under normal conditions; print stands out under UV or IR light	Over/Covert	No
Electro-optic ink	Particles in ink which are verified by bespoke readers	Covert	Yes
Authentication material			
Fragile labels	Label disintegrates if attempts are made to remove it	Overt	Yes
Chemically reactive paper	Paper darkens if solvent or bleach is used to lift label or remove ink	Covert	No
Magnetic coated fibres	Effectively invisible wires which can be embedded into adhesive, papers or labels and only visible with a reader	Covert	No

Fluorescent fibres	Fibres embedded in papers, which fluoresce under UV light/sunlight	Covert/Overt	No
Colour shift pigment in polymers	Pigments give a colour shift	Overt	No
Holograms	3D image presented on 2D surfaces; can provide multiple layers for authentication - overt for identification for consumers	Overt/Covert/Forensic	Yes
Watermarks			
Physical paper watermark	Embossed image appears different when viewed against light	Overt/Covert	Yes
Digital watermark	Embedded codes within various types of media content that can be detected and read by specially designed readers	Covert	Yes
Taggants			
Taggants (UV or IR)	Chemicals having a discrete UV or IR trace in an analyzer	Covert/Forensic	Yes
Taggants using colour particles	Micro-particles of different colours give a fingerprint pattern	Covert/Forensic	Yes

Many existing authentication technologies, and especially overt authentication technologies, all suffer the problem of being easily duplicated. Nanotechnology research and development has the potential to enable next-generation authentication solutions due to the intrinsic and complex nature of nanoscale materials. For example, NanoVox, a Voxtel Inc. company, has developed a nanocrystal-based security tag, which can replace the organic dyes and metal complexes most often used in security inks and spectrally encoded holograms. The use of nanocrystal quantum dots in the nanotags creates complex and unique spectral "fingerprints", and such nanoscopic materials are uniquely encoded and virtually impossible to duplicate (Williams 2012).

Another trend in authentication packaging involves the use of smartphones for authentication. Traditionally, overt authentication features are directed to consumers but are relatively easy to duplicate, whereas covert and forensic features are mainly beneficial to manufacturers and brand owners, with the help of specialised instruments, and are more difficult to copy as compared to overt features. However, covert, and even forensic, level authentication technologies are increasingly accessible to consumers via smartphone apps and related technologies, and the use of such technologies is expected to increase along with the rapid increase in smartphone ownership. For example, AlpVision SA has developed a digital invisible marking Cryptoglyph® that can be applied to cartons, leaflets, labels, closures, blister packs, and metal using regular visible ink or varnish and standard printing processes. The verification can be accomplished simply in less than three seconds with a regular smartphone, using AlpVision’s custom product authentication application (Cryptoglyph 2016). In addition to the smartphone usage, the increase in mobile internet access offers further solutions for consumers. As another example, Spectra Systems’ TruBrand™ allows consumers to authenticate holograms in a single swipe by authentication of taggants located in the hologram via a cloud-based server (Product authentication and tracking 2016).

Even though the global market size of anti-counterfeiting packaging has been expected to reach $131.1 billion by 2019, growing at a CAGR of 15.21% from $66.1 billion in 2015, the share of the authentication segment is predicted to reduce from 51.96% in 2015 to 48.66% by 2019. In the meantime, the market share of the traceability segment is predicted to increase from 48.04% in 2015 to 51.34% by 2019 (Technavio 2016). The vast majority of key players in the industry have indicated that the ability to enhance the security features and functionality of their technologies remains a top challenge (BCC Research 2015(2)). The advantages of anti-counterfeiting packaging are well-known to end-users, but the exorbitant cost poses a major concern (Technavio 2016). Market research suggested that providing secure on-demand Internet-based and smartphone-capable platforms represents an attractive direction for existing and prospective customers (BCC Research 2015(2)).

Traceability

Authentication packaging technologies enable consumers to authenticate the products they purchase. Track and trace packaging technologies help manufacturers and brand owners to identify and trace the products as they move through supply chain. A complete traceability system not only includes tracing of the end product, but also includes tracing of raw materials, processing steps, and packaging. For the purpose of this report, only the packaging technologies relevant to the tracing of end products are reviewed and discussed.

Barcodes

There are two main track and trace packaging technologies, namely barcodes and radio-frequency identification (RFID) systems. A barcode consists of a series of parallel, adjacent bars and spaces. Predefined bar and space patterns or "symbologies" are used to encode small strings of character data into a printed symbol. The encoded information is read by an optical barcode scanner which sends the information to a system where it is stored and processed. The first generation, i.e., linear or one-dimensional (1D) barcode technology was first developed in 1948 and was commercially available in the 1970s (BCC Research 2015). There are various types of 1D barcodes which have been developed to meet the needs of specific industries and subsequently standardised for use in different areas, such as UPC (Universal Product Code), EAN (International Article Number), Code 39, Code 128, and the Interleaved 2 of 5 (Garcia-Betances and Huerta 2012). The information stored on a 1D barcode is alphanumeric (letters and numbers) and can include information such as product numbers or an address. 1D barcodes are ubiquitous and almost every packaged good has a barcode.

Only a limited amount of information can be stored in 1D barcode. In the early 1990s, a 2D barcode with much higher data storage capacity was invented by combining dots and spaces arranged in an array or a matrix, instead of bars and spaces, enabling 2D barcodes to store many more characters than 1D barcodes, within a smaller footprint. 2D barcodes, especially Quick Response (QR) codes, can hold as much as 7,000 digits or 4,000 characters of text. Fig. 4-5 shows the historic evolution from 1D to 2D barcodes, and Fig. 4-6 shows several common types of 2D barcodes. Not only can manufacturers use 2D barcodes to provide information, such as price, quantity, web address, or images of the products, to the consumer, 2D barcodes are applicable to many other areas. For example, healthcare facilities use 2D barcodes to monitor medications, and even to integrate data with programs like MS Office, MS SQL Servers, and other databases and files (Trujillo 2015). Reading 2D barcodes requires a scanning device capable of simultaneous reading in two-dimensions, vertically and horizontally. Unlike 1D barcode scanners, 2D barcode scanners use an image sensor to capture the image of the barcode.

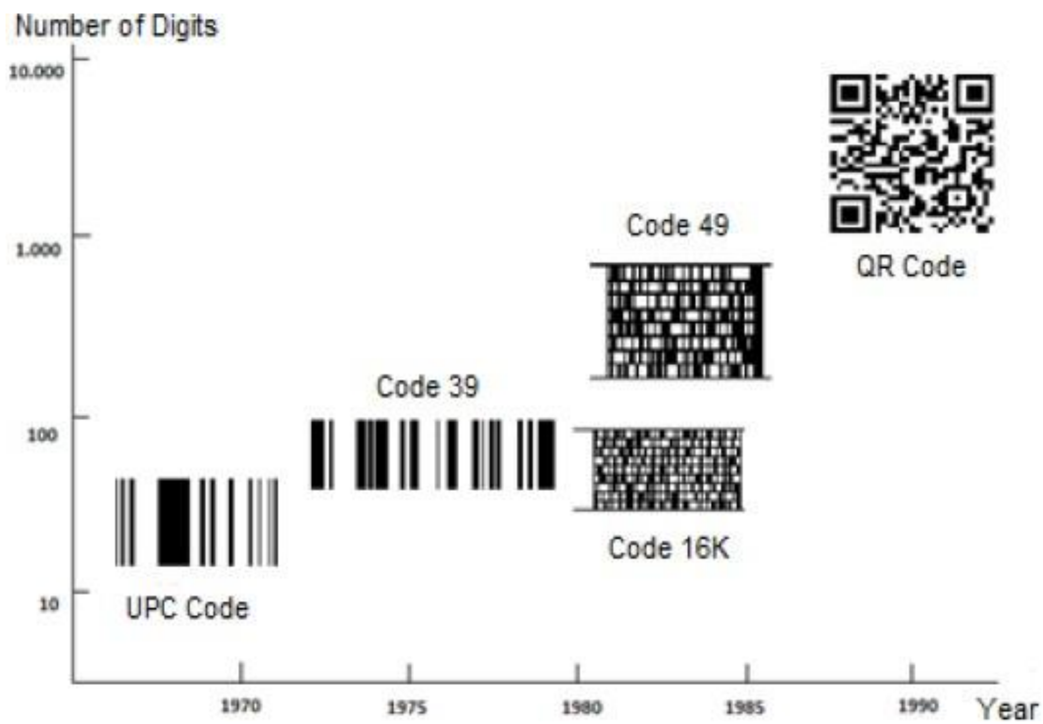


Fig.5 Historic evolution of 1D to 2D barcodes (Garcia-Betances and Huerta 2012)

		QR Code	PDF417	DataMatrix	Maxi Code
Developer(country)		DENSO(Japan)	Symbol Technologies (USA)	RVSI Acuity CiMatrix (USA)	UPS (USA)
Type		Matrix	Stacked Bar Code	Matrix	Matrix
Data capacity	Numeric	7,089	2,710	3,116	138
	Alphanumeric	4,296	1,850	2,355	93
	Binary	2,953	1,018	1,556	
	Kanji	1,817	554	778	
Main features		Large capacity, small printout size High speed scan	Large capacity	Small printout size	High speed scan
Main usages		All categories	OA	FA	Logistics
Standardization		AIM International JIS ISO	AIM International ISO	AIM International ISO	AIM International ISO

Fig. 6 Different types of 2D barcodes (Shihab n.d.)

Barcodes provide a convenient and inexpensive tool to track and trace products throughout the supply chain and consumers can also use information stored in a QR code to authenticate the products they purchase with the help of a smartphone. However, regular QR codes provide no protection against visually identical copies (ScanTrust n.d.). In addition, because QR codes are open-sourced, so that they can be created by anyone, counterfeiters can copy a brand's code and the product's webpage fairly easily (Borison 2013). Scantrust has developed a patent-pending copy-proof QR code. Fig.7 illustrates the differences between a regular QR code and a secured Scantrust code (ScanTrust n.d.). Another example of anti-counterfeiting and secured barcode technology is 3D barcodes. Sofmat, together with scientists from Bradford University, have developed a tiny 3D barcode, with grooves so small that they are barely visible to the naked eye. Fig. 8 shows a printed 3D barcode module. This technology was originally invented to apply to drugs but it may have potential for the food packaging industry as well (Webb 2015).

Fig.7 Differences between a regular QR code and a Scantrust code.

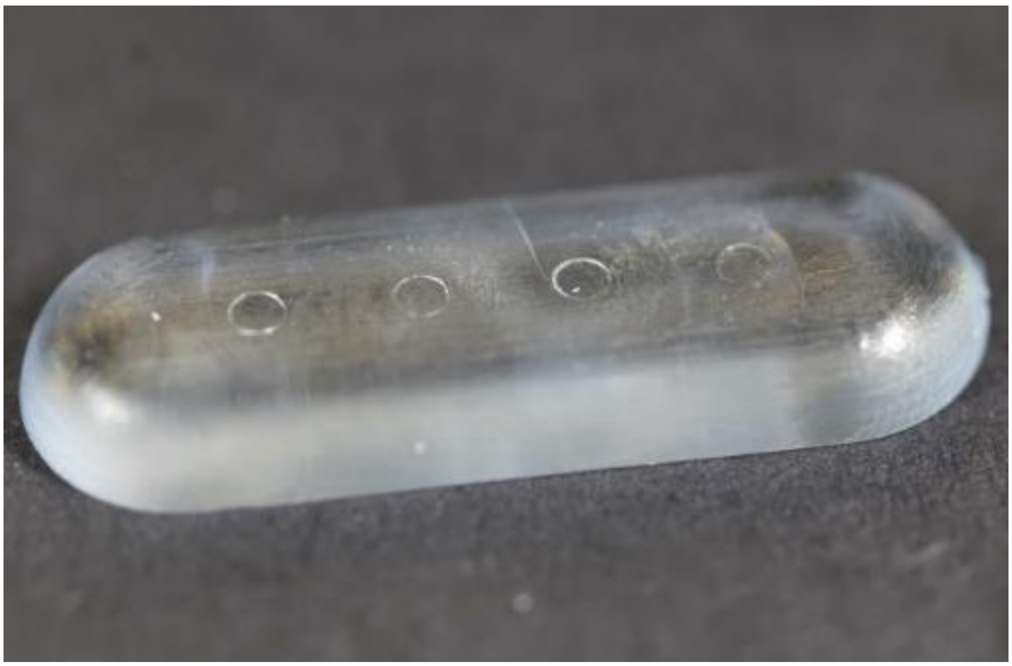


Fig. 8 3D barcode module.

RFID

Radio-frequency identification (RFID) tags use RF electromagnetic fields to store and communicate real-time product information for automatic product identification and traceability. A typical RFID tag consists of an integrated circuit attached to an antenna for the transmission of information stored in the chip to a reader (Realini and Marcos 2014). RFID tags differ in size but are generally small so they can be attached to or incorporated within product packaging. RFID technologies include two types of tags: active and passive tags. The main difference between the two is that active tags use a battery, whereas passive tags do not. Active tags have much larger data storage capacity and typically are used in larger objects which require tracking over long distances, such as container and rail cars. Passive RFID tags do not have a power source, so they depend on a transceiver for activation. Passive tags can be applied in many forms, such as implantation, embedded under skin, mounted on substrates, between layers, and embedded in packages. RFID technologies can also be classified into three groups based on the RF frequency: low-frequency RFID tags, high-frequency RFID tags, and ultra-high-frequency RFID tags (BCC Research 2015(2)).

Although RFID technology has been well known and used for many years, market penetration of RFID tags in the food packaging industry has lagged behind that of barcodes, likely due to some inherent advantages of barcodes over RFID technologies (Ghaani et al 2016). Table 9 lists some important differences between two technologies and advantages of each.

Table 9 Comparison of barcodes and RFID technologies

Features	Barcodes	RFID
Read/Write	Cannot be updated/over-written	Can be updated/over-written
Read range	Several inches up to several feet;	Passive UHF RFID: Up to 20 feet (handheld readers)/40 feet (fixed reader) Active RFID: Up to 100 feet or more;
Line-of sight requirement	Yes	No
Data storage	Low-level of security	High level of security
Type of tracking	Require manual tracking and therefore are susceptible to human error	Can be automatically tracked, therefore removing human error
Integrateability	Not integrateable	Integrateable with other smart components, such as sensors
Price	Ultra-low	High
Application environment	Sensitive to environment, dirt, scratches, and temperature	Customised to resist environmental stress and severe processes
Main advantages	Small, light label with minimal overall cost but offering accurate data; ubiquitous with universal standards and mature infrastructures	More intelligent, efficient and secure and can be used for many applications

Originally, RFID tags were only used to track food products in the supply chain during distribution and storage. Technology development in recent years has enabled RFID systems to become more intelligent by connecting one or more sensors to RFID tags so that, in addition to tracing and tracking the movement of the products, the RFID tags can also provide information about the integrity of the package, the quality status of the food, and the environmental conditions during transport or storage. Current research on sensor-enabled RFID tags is focused on the detection and measurement of one or more of the following properties: temperature, relative humidity, pH, pressure, light exposure, and concentration of volatile compounds and gas molecules (Vanderroost 2014). For example, researchers have developed a handheld, portable RFID system to track the storage and transportation temperatures of perishable products. This system is not only used to detect refrigeration equipment failure along the supply chain, but also to predict remaining product shelf-life (Uysal et al 2011 Sensor-enabled RFID tags that are mountable (i.e., not an integral part of the packaging material), non-integrated (i.e., sensors not integrated in the circuit design of the RFID tags), and non-flexible are already commercially available. Fig. 9 illustrates several commercially available examples of non-integrated and non-flexible sensor-enabled RFID tags.

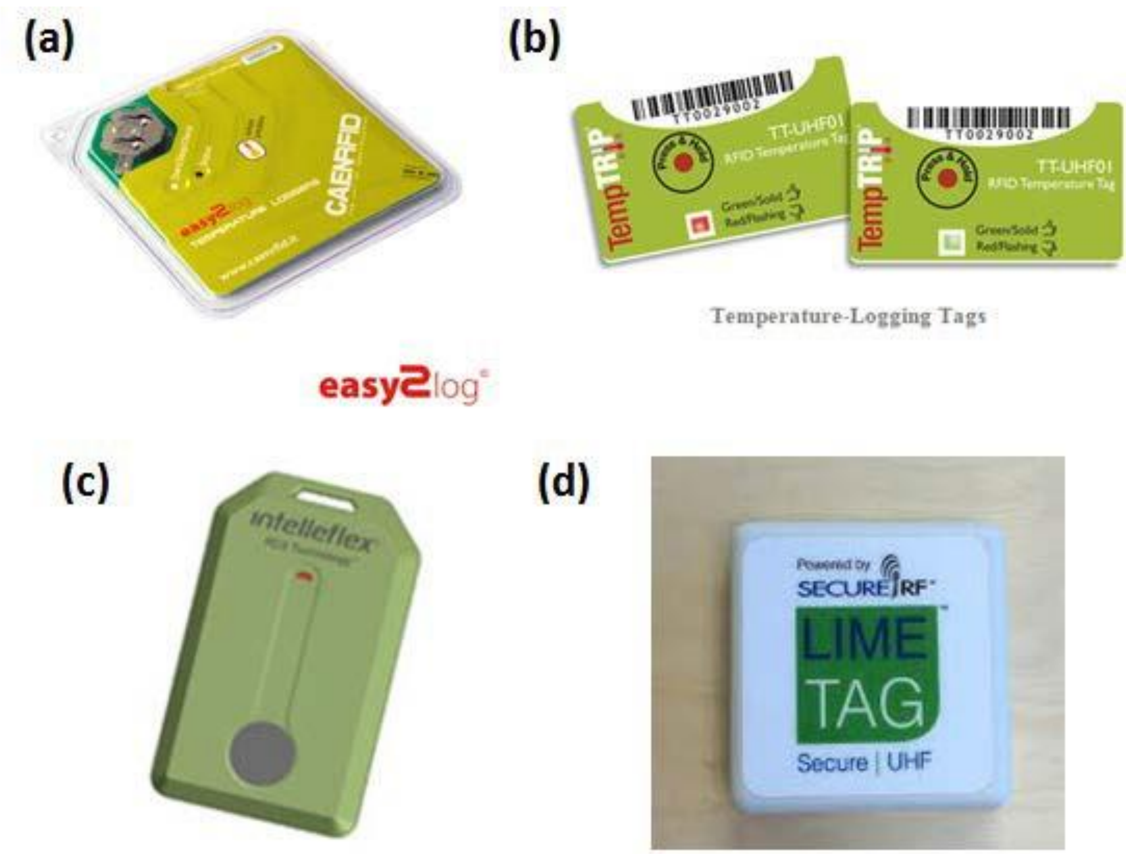


Fig.9 (a) Easy2log© semi-passive UHF temperature RFID tag; (b) TempTRIP® UHF temperature RFID tag; (c) Intelleflex TMT-8500, semi-passive UHF temperature RFID tag; (d) SecureRF Lime Tag™ semi-passive UHF temperature RFID tag

These non-integrated and non-flexible sensor-enabled RFID tags can be mounted on product packaging or put into boxes, pallets, or even product containers to secure supply chains, monitor products, and manage the cold chain. One challenge remaining in the field of sensor-enabled RFID tags is how to integrate one or more sensors in the design of RFID tags and, ultimately, how to integrate the sensor-enabled RFID tags in the packaging materials. New technologies are emerging with the development of printed electronics. For example, scientists have recently designed a single-chip UHF RFID tag with multiple sensor capabilities that can be screen-printed directly on a cardboard package. In addition to temperature sensing, the RFID tag developed in this work can detect whether the package has been opened and the weight change of the package within the range of 1 to 5 kg (Fernandez-Salmeron et al 2015). RR Donnelley recently announced CustomWave, an RFID solution that offers complete smart label solutions beginning with in-house RFID antenna design and performance testing and including printed inlay manufacturing, custom label and tag creation, fully automated quality control, and global distribution and fulfilment services. CustomWave RFID solutions feature the ability to print antennas on a variety of materials, including directly onto a label, which not only drives the product cost down but also provides a more environmentally friendly RFID solution (RR Donnelley 2016). VTT, a Finnish research and technology company, has developed an ethanol sensor that can be printed on a label and detect ethanol in the headspace of a food package. The sensor layer is part of an RFID tag and the sensor data can be read wirelessly using an RFID-reader on a smartphone (VTT 2015).

Silicon chips represent the largest cost for RFID tags. Printable chipless RFID tags have shown great potential in driving production costs down and also offering more diverse applications. Some analysts predict that in ten years, chipless RFID tags will be printed directly on products and packaging for only 0.1 cent each, replacing the ten trillion barcodes used annually with something far more versatile and reliable (Harrop and Das 2010). Researchers from Monash University have developed fully printable chipless RFID tags on paper and plastics, but such tags may require specially designed readers which contain all necessary signal processing and intelligence capabilities (Supply Chain Digest 2015).

Near field communication (NFC) operates at the 13.56 MHz and is therefore a subcategory of high-frequency (HF) RFID technology, since it also uses radio frequency to communicate. NFC takes advantage of the short-read range limitations of radio frequency and allows for short-range peer-to-peer communication, in contrast to the one-way communication of RFID tags. Smartphones enabled with NFC can pass information back and forth to another NFC device and hence provide consumers with a means other than barcodes to retrieve information from NFC chips embedded in product packages. In fact, market research has shown that NFC is more effective in engaging users and customers than QR codes. For example, Kraft has found from its mobile commerce campaigns that shoppers were not only more engaged by NFC tags than QR codes, but they also spent more time with the information communicated by NFC than QR codes (BeQRious 2016). As with RFID technology, scientists have also developed methods to incorporate smart components into NFC tags. For example, scientists from MIT have developed NFC tag-based chemiresistors which are able to detect ammonia, hydrogen peroxide, and cyclohexanone, among other gases (Trafton 2014). In February 2016, Thin Film Electronics ASA announced its collaboration with Constantia Flexibles to develop NFC OpenSense tags, which are thin, flexible labels that can detect both a product’s “factory sealed” and “opened” states and wirelessly communicate contextual content to consumers with the tap of an NFC-enabled smartphone (Thinfilm 2016). Even though the current price of NFC chips may not be as competitive as that of QR codes, it has been predicted that NFC chips will see a price reduction to $0.01 in the near future (Wasserman 2016) and will become an important connecting piece of Internet of Things (IoT).

Provenance

Food packaging not only physically protects the packed contents and extends products shelf life, it also visually communicates information to consumers both at the point of sale and during subsequent use and disposal. Consumers rely on labels to obtain information about the food, e.g., the method of storage, usage, nutritional information, and safety issues, whereas they recognise the brand through other elements of the packaging, for example, the shape, the colour, and the graphic design of the package. As one of the goals of this project, Australian meat producers hope to identify packaging solutions which provide clear and effective communication to consumers about a product's provenance, to tell the story and history of the brand, and to boost the value of "brand Australia" as a premium meat product provider.

For many global consumers, "brand Australia" means a guarantee of high quality, clean, green, and disease-free meat products. However, while brand awareness would appear to be present, the impact of this brand awareness on consumer purchasing decisions is not yet known, at least in key market segments, in comparison with other purchasing decision parameters, such as cost. It will be important to learn how the origin of a product motivates or affects the consumer purchasing decision making process. However, the implication of having a brand awareness of a high quality meat product is that such branding may drive consumption within specific key market groups. Should such implications be confirmed through analysis of market insights, it will likely be important to leverage such associations to build a story around the place of origin and then to communicate to the consumers such associations in a memorable manner.

For the purposes of this report, a few packaging technologies have been highlighted which incorporate smart components to transfer traditional text- and graphics-based packaging communication to a new multi-sensory experience, thereby strengthening the emotional brand connection with consumers.

High penetration of smartphone ownership worldwide enables the use of QR codes as a powerful and easily-implementable communication tool for food packaging. Fig. 10 shows a QR code on the wrapper of the energy bar Zego®; when this code (termed the "Z-Code") is scanned, the consumer is led to a specific webpage showing test results of any measurable amounts of specific allergens for the batch to which this bar product belongs. Whereas other manufactures generally simply place a warning of potential cross contact with allergens, Zego's QR code allows the consumer to learn the exact quantity of a potential allergen which might be in a specific batch, accomplished with a simple scan using smartphones (Colleen 2015 The Z-Code is located on the product wrapper within the sunflower and is fully integrated within the packaging, thereby creating conversational packaging and marketing material because it brings an association to the product's key ingredient, namely sunflower seeds, and hence reinforcing the brand image as a natural and healthy organic snack food provider.

Fig.10 Zego®'s Z-code on the food packaging

Lenticular imaging is a series of images that are interlaced together such that when viewed through an extruded lens presents the viewer with animation, depth, or other effects. Development of high resolution lenticular printing technology allows brand owners to use lenticular labels for a more sophisticated communication with consumers. For example, Lo Tengo® is a Malbec wine from Argentina that uses a photograph of legs of two dancers dancing on a paved street in Argentina on a lenticular label on its wine bottle, as shown in Fig. 11. When consumers view the label from different angles or walk past the bottle, they see the knees and toes of the two dancers flipping back and forth, which suggests something of the passion of old-time Argentina. The website of Lo Tengo® claims: "The world's first lenticular label achieved more PR inches than any other wine." (Stranger and Stranger n.d.)

Fig.11 Lo Tengo's lenticular label, reinforcing the product's provenance.

Häagen-Dazs® has developed an augmented reality smartphone app that allows consumers to watch a two-minute video while waiting for their ice cream to reach the ideal temperature for consumption, as shown in Fig.12. The Häagen-Dazs Concerto Timer app uses 3D Kinect technology to provide consumers with an augmented reality experience, while also playing music. This innovation is functional in two ways. First, it provides great entertainment for impatient consumers who want to consume their ice cream immediately out of the freezer, without proper tempering, and hence not realizing the full flavours of the product. In the meantime, the choice of the music, Bach's Inventions No. 14, is a perfect match for the brand image of the ice-cream, which is best known for classic flavours (Borison 2013).

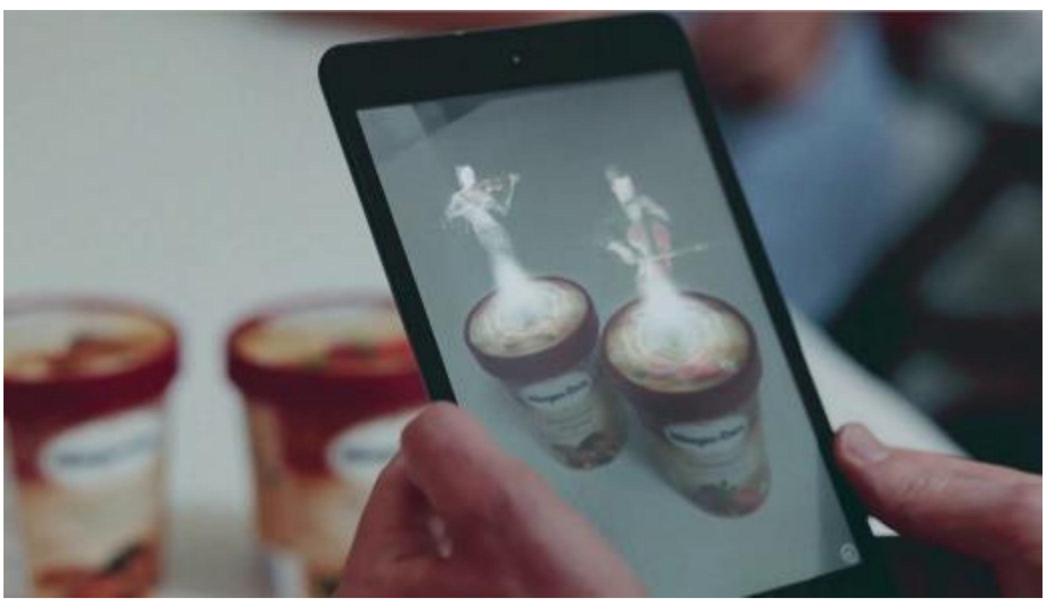


Fig.12 Häagen-Dazs® 's augmented reality smartphone app showing a virtual violin performance.

IP Landscape Analysis

An IP landscape analysis for the Smart Packaging Open Innovation for RnD4profit (insights2innovation) project was independently conducted by Thomson Reuters (MLA project V.RDP.1003). This analysis was reviewed and served as a resource for this report, in particular in section 8 below.

Emerging Technology Trends

After reviewing and discussing the existing packaging technologies and solutions, the following technology trends were identified. Innovation opportunities that can benefit Australian meat producers and exporters may be found in these areas.

Incorporated Multi-Functional Smart Packaging Materials

Previous consumer studies have shown that consumers prefer active compounds to be incorporated into packaging materials, rather than in the form of sachets (Mehmet et al 2015). For example, consumers showed negative perceptions towards oxygen scavengers in the form of sachets inside food packaging due to the presence of non-edible artefacts together with the food and hence the risk of accidental rupture of the sachets and ingestion of their contents (Realini and Marcos 2014). Moreover, studies have shown that incorporation of oxygen scavenging compounds into packaging materials are versatile for food packaging applications due to production efficiency and convenience (Busolo and Lagaron 2012 As a result, both in academia and in industry, there has been a trend to incorporate smart components (active agents or intelligent components) into the packaging materials. Should MLA determine that they want to position meat products as premium products in appropriate market segments, smart packaging components may augment and enhance the premium brand experience to the consumers. Examples include: dual antimicrobial and antioxidant active films, UltraZapXtendaPak (Paper Pak Industries) active absorbent pad that incorporates CO_2 emitters on an antimicrobial substrate (Paper Pak Industries 2016), microwavable moisture-absorbing Nor®Absorbit (Nordenia International AG) (Mondi 2011) and three-phase Activ-Polymer® (CSP Technologies™) with a variety of properties, including absorbing or emitting specific molecules, to meet a range of product stability needs (CSP Technologies 2016).

Nano-Enabled Smart Packaging Technologies

The unique properties of nanoscale and nanostructured materials have led to many novel applications of nanotechnology in the food packaging industry. Previous examples discussed in this report include: antimicrobial nanoparticles, oxygen scavenging nanocomposite films, nanosensors, and nanocrystal-based security tags, such as NanoVox. Recent technology breakthroughs of printable carbon nanotubes on polyethylene terephthalate (PET) and paper via inkjet printing have also opened up opportunities for printable nanosensors (Ammu et al 2012). However, due to the lack of information, particularly with respect to the migration of nanoparticles from the packaging materials into food, there still remain challenges in public acceptance and regulation. Despite the regulatory challenges and unclear consumer acceptance, increased research and development activities in the area of bionanocomposite materials have been observed. Bio-based materials are presumed to be more eco-friendly and biodegradable and hence may be more readily accepted by consumers. Some of the bio-polymers that are being researched in this field include starch, polycaprolactone, derivatives of cellulose and polylactic acid (Technavio 2014(2)).

Biosensors

Biosensors can directly detect target metabolites during food spoilage and therefore can monitor food freshness in a more specific and tailored way than freshness indicators. According to recent market research, the total biosensors market was valued at $11.39 billion and is expected to reach $22.68 billion by 2020, at an estimated CAGR of 10.00% (Rohan n.d.). However, most of the market is driven by medical diagnostics and, in particular, glucose sensors of people with diabetes (Vanderroost 2014). The topic of biosensors has attracted enormous academic interest and tens of thousands of papers have been published in this area. Despite the vast number of papers published, very few biosensor technologies have actually succeeded to become commercially available, particularly in food applications. In the development of commercially viable biosensors for food packaging industry, the following technical challenges remain and need to be addressed (Vanderroost 2014):

- Immobilization of biological components in the receptor;
- Preventing the denaturation or degradation of the biological components due to environmental conditions;
- Identifying rapid, scalable, and cost-effective production processes for biological components; and
- Ignoring the input generated by analytes other than the analyte of interest or actively suppressing all interactions other than those with the targeted analytes.

Printable Chip-less RFID

The Internet of Things (IoT) with the goal of interconnecting a large number of "things" is just beyond the horizon. The US National Intelligence Council predicted that by 2025 not only would mobile phones, tablets, laptops and personal computers be part of the IoT, but also less obvious things such as appliances, food packages, furniture, cars, bikes, etc. (Vanderroost 2014). The use of RFID tags on everyday objects is the plausible approach but the high unit price for conventional RFID tags poses large economic constraints. Accordingly, printable chipless RFID technology provides great potential in replacing barcodes and hence realizing the IoT in the near future. By eliminating the use of silicon IC chips, chipless RFID tags can offer more competitive pricing than normal silicon IC-based tags. Chipless tags also possess a longer communication range since they do not necessitate the use of transistors, unlike silicon-based tags which require a threshold voltage to power up the IC circuit (Botao 2010). Moreover, the printing techniques developed over the years provide a solution for the realization of RFID tags with ultra-low cost for large scale.

Traceable Authentication Packaging Technologies

Most existing authentication packaging technologies cannot be traced. Identifying counterfeited products by consumers is not good enough for winning the anti-counterfeiting war. Industries need to be able to authenticate and trace products throughout the entire supply chain. One traceable authentication packaging technology example is Tesa-Scribos' tesa Holospot®, which takes authentication packaging technology one step further by permitting simultaneous traceability and authentication, thereby enabling products to be uniquely authenticated at the unit-of-use level (BCC Research 2015(2)). Another potential traceable authentication solution is RFID authentication. One example is Verayo, developed by a MIT spinout start-up company, offering "fingerprint" silicon chips used in consumer product RFID tags that can be scanned via mobile device and authenticated (Matheson 2015). An example of an existing business solution is the Dotless Visual Codes developed by the Israeli start-up Visualead; this product was designed to help the Chinese e-commerce giant Alibaba battle counterfeited goods. By scanning the Dotless Visual Codes with Alibaba's Mobile Taobao app, consumers can check with the manufacturer or distributor whether the product they received is genuine. If it isn't, Alibaba can take action against the seller, pursuing legal options or at least removing the offender from its network (Shamah 2015).

Secure QR Codes

QR codes are currently ubiquitous. As discussed in previous sections, QR codes may play important roles in authentication and in providing provenance information about products. However, since QR codes (which are widely underused by consumers despite their ubiquity) are open-sourced, counterfeiters can copy a brand's code and landing product webpage easily. QR codes that can provide anti-counterfeiting features, such as ScanTrust's copy-proof QR codes, are more powerful tools to help brand owners, manufacturers and consumers win the anti-counterfeiting war.

Mobile-Engaged Smart Packaging Technologies

By 2020, it has been predicted that there will be 6.1 billion smartphone users globally (about 70% of the world's population) (Lunden 2015). Mobile network usage has overtaken fixed internet access in 2014, and this usage is continuously climbing worldwide, especially in emerging economies (Chaffrey 2016). Such high penetration of smartphone ownership and mobile network access have fundamentally changed people's way of obtaining information, communicating with each other and ultimately living their day-to-day lives. Development of digital technologies also poses new challenges to brand owners and product producers in winning the current generation of mobile-enabled consumers. Mintel's 2015 US Beverage Packaging report indicated that mobile-enabled packaging is a key way brands are connecting with consumers (Mintel n.d.). The smartphone applications listed in previous sections, such as smartphone authentication applications and smartphone-aided consumer communication are good examples on how packaging can be revolutionised by mobile-engagement in the modern market.

Emerging Market Trends

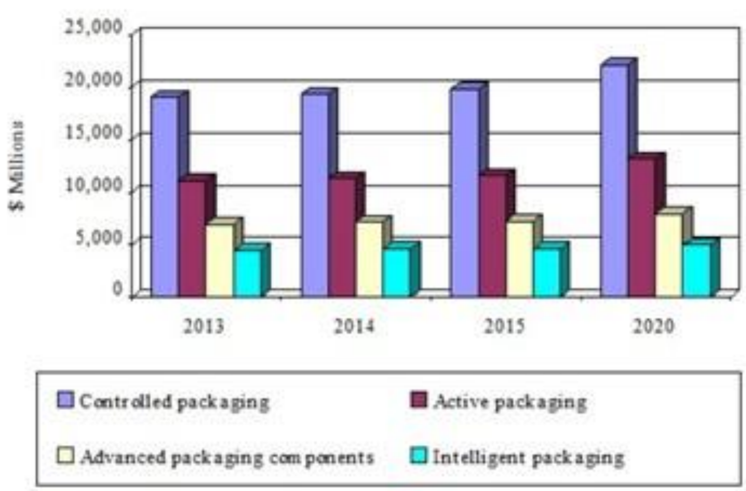
Advanced Packaging Market Data, Market Growth Drivers and Market Challenges

According to a BCC report, global advanced packaging market revenues were about $42.5 billion in 2014, and they are estimated to grow at a five-year compound annual growth rate (CAGR) of 2.2% through 2020 to about 48.3 billion[2]. Globally, controlled packaging accounted for the highest revenue within the advanced packaging market followed by active packaging. Fig. 1 shows the global revenue for advanced packaging by type, through 2020 (BCC Research 2015).

GLOBAL REVENUE FOR ADVANCED PACKAGING BY TYPE, THROUGH 2020 ($ MILLIONS)

Type	2013	2014	2015	2020	CAGR% 2015-2020
Controlled packaging	19,040.6	19,347.7	19,858.3	22,158.2	2.2
Active packaging	11,118.4	11,357.6	11,658.4	13,192.0	2.5
Advanced packaging components	7,020.8	7,236.0	7,279.8	8,003.5	1.9
Intelligent packaging	4,461.8	4,547.7	4,576.8	4,942.2	1.5
Total	41,641.6	42,489.0	4,3373.3	48,295.9	2.2

GLOBAL REVENUE FOR ADVANCED PACKAGING BY TYPE, 2013-2020 ($ MILLIONS)



Source: BCC Research

Fig. 1 Global revenue for advanced packaging by type, through 2020 (BCC Research 2015).

[2] Depending on the definition of advanced packaging, the market size numbers are quite different among market reports. For example, Technavio's Global Advanced Packaging Market 2015-2019 stated that the global advanced packaging market was valued at $21.39 billion in 2014 and is likely to reach $31.35 billion by 2019, growing at a CAGR of 7.95%.

Detailed sector-by-sector analysis shows that market revenue for each category within advanced packaging all increased from 2013 to 2014. All sectors are expected to continuously increase through 2020.

Global sales of authentication packaging technologies to the drug and food industries amounted to $42.5 billion in 2014. Sales of packaging holograms accounted for the largest share, at 49%. End use of authentication packaging technologies in the food industry represented 67.2% of global sales in 2014. Global sales of authentication packaging technologies to the drug and food industries are projected to reach nearly $96.4 billion in 2020, with a CAGR of 17.7% from 2015 to 2020. Global sales of track and trace packaging technologies to the drug and food industries amounted to nearly $31.5 billion in 2014, with North America representing 77.3% of the market share. The ubiquitous packaging bar codes accounted for the bulk of the sales, representing 97.7%. End use of track and trace packaging technologies in the food industry accounted for 69.4% of global sales in 2014. Global sales of track and trace packaging technologies to the drug and food industries are projected to grow at a CAGR of 4.5% from 2015 to 2020, reaching nearly $39.3 billion in 2020 (Marcos et al 2012).

GLOBAL MARKET FOR ANTI-COUNTERFEITING PACKAGING TECHNOLOGY SALES TO THE DRUG AND FOOD INDUSTRIES BY TYPE, THROUGH 2020 ($ MILLIONS)

Type	2014	2015	2020	CAGR% 2015-2020
Authentication technologies	42,522.2	42,650.2	96,368.4	17.7
Track and trace technologies	30,318.7	31,549.1	39,280.6	4.5
Total	72,840.9	74,199.3	135,649.0	12.8

Source: BCC Research

Fig. 2 Global revenue for anti-counterfeiting packaging technologies by type, through 2020 (Marcos et al 2012).

The following market drivers have been identified:

- Demand for hygienic packaging in the food and beverage industry;
- Rise in disposable incomes;
- Development of innovative packaging solutions;
- Consumer engagement;
- Protection against product adulteration and contamination;
- Increased demand for sustainable packaging materials;
- Prevention of counterfeiting products;

- Rising need for traceability systems; and
- Demand from emerging nations and increase in e-commerce.

The following market challenges still remain:

- High investment for development of advanced packaging;
- Stringent regulations;
- Increased testing costs;
- Lack of information integration and inefficiency of devices used for anti-counterfeiting;
- Lack of cold chain service producers that can provide a one-stop solution, especially in emerging nations; and
- Highly fragmented control of manufacturers over the supply chain.

Chinese Market

China is a unique market for foreign exporters, having both huge potential and great challenges at the same time. In recent years, due to the rapid economic growth over the last three decades, China has seen significant changes in eating habits, shopping behaviours, and lifestyle habits. In 2015, China overtook Japan to become the second largest beef importer after the US. China imported 663,000 tons of beef and veal in total in 2015, which is nearly 8 times the amount imported only three years prior (86,000 tons in 2012). This overall increase is also reflected in increased interests and demands for Australian food products in the Chinese market, especially in the emerging second tier markets and wealthy coastal cities.

One of the major concerns of Australian meat producers is substitution and counterfeiting. In addition to the counterfeiting problem, it is also important for foreign exporters, including Australian food producers, to understand the cultural differences and consumer preferences, perceptions, and behaviours towards imported products. For the purposes of this report, some cultural insights are discussed below to raise awareness of Australian meat industry players of the impacts of food packaging on Chinese consumers.

Sustainable and Green Food Packaging Materials

A consumer study by Mintel has shown that 86% of middle class Chinese consumers note that it is their responsibility to use more products that can help to protect the environment, with consideration of factors such as biodegradability or recyclability. However, it should be noted that the general consensus is that such a broad claim is likely still too early for the market and requires further validation. Regardless, the notion of consumer awareness and responsibility is gaining momentum, especially in the premium segment. For example, 41% of Chinese bottled water drinkers believe that environmentally friendly products tend to be associated with premium bottled water. These studies indicate that environmentally friendly claims are in fact important for premium brand image and to reach out to affluent middle class Chinese consumers.

Consumer Communication

Mintel's consumer studies show that 84% of Chinese consumers agree that they want to see more information about products on the packages. For example, consumers from Chengdu, Changzhou, Foshan and Kunming are more likely to be attracted by innovative packaging when compared to consumers from other cities. Also, high spending Chinese consumers are more engaged with brand interaction and are more proactively following brand information. These data indicate that affluent middle class Chinese consumers will appreciate packaging that interactively communicates with consumers on product information and brand value.

Mobile-Engaged Packaging

Many foreign companies have begun to use mobile engagement to fight counterfeiting in China. For example, the Chinese arm of Unilever has signed a deal with Alibaba that will see Unilever brands carry a new QR code-based technology (via dotless visual codes) that the company recently adopted to help fight counterfeits. Consumers, by using a smartphone app, can easily tell whether they have purchased counterfeits and, in the meantime, experience a rather special brand interaction. This new QR code was discussed in the previous technology trend section.

Greatview Aseptic Packaging has developed an individually traceable milk carton with unique QR codes printed on the packages. The company has teamed up with WeChat and Chinese retailer RT-Mart to apply the technology for Mengniu Selected Meadow Traceable+ milk. Consumers are able to trace item-level product information by scanning the Selected Meadow products. By doing so, consumers can also get product discounts. Scanning the QR code also allows the consumer to view real time video of the pasture and factory.

Fig. 3 Mengniu's Selected Meadow Traceable+ Milk, showing QR Code.

List of Key Stakeholders and Potential Commercial Partners

The objective of this section is to identify companies, universities and organizations that are actively involved in research and development of smart packaging technologies and products for the following purposes:

1) Identify industry and academia experts who can be candidates for the Problem Definition Workshop and later "All-Star" Inventor Workshop;

2) Identify potential partners that can undertake proof of concept development projects for selected inventions sourced by Invention Development Fund; and

3) Identify potential partners that can help the MLA formulate technical development and commercialization strategies in Asian markets, particularly the Chinese market, for developed technologies based on selected inventions sourced by Invention Development Fund.

All the original data used in this section are from the IP landscape analysis by Thomson Reuters (TR) under MLA's project V.RDP.1003.

According to TR's IP landscape analysis, there are 11 entities that hold large patent portfolios (ie having 101 or more granted or pending patent applications) in relation to "smart packaging" technologies and hold 22% of the patent landscape. Among these 11 entities, Toppan Printing (Japan) and Mitsubishi (Japan) have the highest numbers of patents. Fig. 8-1 shows the timeline and the total patent filing activities of these 11 entities.

On the academic and government side, the Korea Food Research Institute (South Korea) and the University of Jiangnan (China) are the most prolific inventing entities. However, academic and government entities only comprise 7% of all patent data in this area.

The Spanish National Research Council is the leading source of published literature pertaining to smart packaging technologies, followed by the Foggia University (Italy) and Ghent University (Belgium). Fig. 8-2 shows the number of publications by top researching entities. Unfortunately, none of the entities from the list is located in Australia or New Zealand.

Tier 1 Entities	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	Total Inventions	% Filed Since 2009
Toppan Printing	15	20	24	28	31	26	58	48	75	60	43	58	38	31	29	18	35	33	43	22		735	24%
Mitsubishi	25	14	41	38	31	26	35	62	29	30	23	17	14	16	32	12	36	29	29	10		549	27%
DIC Corp	10	9	13	28	14	20	16	25	26	29	36	44	38	20	18	32	28	7	18	10	1	442	26%
Sumitomo Group	7	16	11	24	25	17	9	23	18	14	2	5	6	3	8	4	9	8	10	9		228	21%
Sealed Air	15	14	17	17	16	13	10	9	17	13	20	6	11	11	6	7	3	1	6	4		216	13%
Toyobo Group	2	9		15	16	15	16	18	21	9	27	3	11	6	3	4	2		2	3		182	8%
Toyo Seikan Group	2	2	7	3	10	18	9	25	20	15	14	9	8	8	4	6	3	4	3	4		174	14%
Kuraray	3	5	9	10	11	12	8	5	7	8	10	6	10	15	12	8	4	2	5	7		157	24%
Tetra Pak	9	6	9	6	5	6	11	9	5	7	7	7	6	3	7	6	7	2	2	6		126	24%
Mitsui Chemicals		6	10	8	9	10	8	9	8	4	6	8	5	5	5		6	4	3	2		116	17%
Toray Industries	2	3	4	3	3	1	8	14	5	7	9	3	5	6	9	7	5	2	2	3		101	28%

Fig. 1 Timeline and total patent filing activities for the 11 entities that hold large patent portfolios (having 101 or more granted or pending patent applications) relating to "smart packaging" technologies.

Top Entities	Total Publications
Spanish National Research Council	154
Foggia University	88
Ghent University	85
US Dept. of Agriculture	82
Zaragoza University	82
National University of Ireland	59
Technical University of Cartagena	51
Tianjin University of Science & Technology	44
Federal University of Vicosa	42
Lleida University	41
National Research Council (CNR)	41
Agricultural University of Athens	40
Michigan State University	40
Milan University	40
Helsinki University	38
Ioannina University	38
Kyungnam University	36
Technical University of Denmark	33
Catania University	32
Florida University	32
Kansas State University	32
Agriculture & Agri-Food Canada	31
Vigo University	30
Kasersart University	29
Univ Santiago de Compostela	29
University of Naples Federico 2	29

Fig. 2 Number of publications by top researching entities

In the previous section on RFID technology development, work done by Dr Nemai Karmakar from Australia's Monash University was discussed. Dr Karmakar's team from the Department of Electrical and Computer Systems Engineering may be a candidate for potential partnering for RFID related packaging technology development.

Smart Packaging Technology Discussion

In this section, technologies and commercial solutions related to smart packaging are identified and reviewed in the five key areas most relevant to the Australian red meat industry, namely

- Food safety,
- Shelf life,
- Anti-counterfeiting,
- Traceability, and
- Provenance.

Emerging consumer and market trends are also discussed in order to better prepare Australian meat producers to understand the overseas markets and consumers, especially the China market and Chinese consumers. This report forms the basis for later stages of this project:

- Identification of technical areas where inventions and solutions are needed for the "Food Without Fear" theme that has been identified as a key consumer trend in the Chinese market through a Problem Definition Workshop;
- Development of two Request for Inventions (RFI) topics based on the outcomes of the Problem Definition Workshop;
- Review of Xinova patent assets to identify if any has application to the selected 2 RFI topics;
- Invention sourcing through Xinova's inventor network;
- Conducting "All-star" Inventor Workshops; and
- Selection of two sourced inventions for proof of concept development.

Smart packaging technologies have been continuously evolving in response to growing challenges from a modern society. The purpose of this report is to identify existing solutions and technology trends that may address the challenges faced by Australian meat exporters in the above five key areas and to make recommendations that may help them to explore and thrive in Asian markets.

To ensure successful deployment of any innovative technologies developed, all partners in the value chain have to cooperate. This is especially true for Australian meat exporters, who often must work with local agents and distributors to ensure business interests and success in export markets. Even though a value chain analysis is out of the scope of this report, we still would like to address its importance when deciding whether to adopt any particular technology.

Another important factor to consider is consumer acceptance when making decisions on technology adoption. Better understanding of consumer adoption of innovative packaging systems can help minimise the risk of market rejection of new technologies and can help the product providers to develop better market strategies. Compared to research and development work on various active and intelligent packaging technologies, there are relatively few studies on consumer acceptance and their purchasing behaviour with regard to those innovations. Although some previous consumer behaviour studies were considered and cited in the following recommendations, please note that consumer perceptions and preferences towards certain technologies may differ widely among consumer demographics. Therefore, these recommendations may require additional consideration with further analysis of consumer and market insights.

Recommendation 1 – Evaluate existing solutions

The following existing smart packaging products may provide solutions to Australian meat exporters to address some of the challenges in the areas of food safety, provenance, shelf life, anti-counterfeiting, and traceability. All these existing solutions, which are either already available in the market or in the process of deployment, are relevant to the Chinese market, if not necessarily tested by market research and analysis. While there is no “silver bullet” for all the challenges identified, these existing technologies may be a part of the solution or can serve as a reference to help close the gap between research and industry.

Dotless Visual Codes

Israeli start-up company Visualead has developed a new QR code, dotless visual codes, as part of the “Blue Stars” platform for product engagement and anti-counterfeiting. Established in partnership with Chinese e-commerce giant Alibaba, this system can help consumers authenticate purchased products and receive product-specific information, such as targeted online promotions for the product. In addition to the authentication function of dotless visual codes, these codes can be custom made for products and companies by utilizing aesthetic shapes and colour, thereby providing a more engaging communication channel between the brand and the consumers. This innovative technology, built on deep expertise in computer vision, machine learning, and mathematics and protected by granted and pending patent applications in several countries, answers product providers’ needs for battling counterfeiting while increasing consumer engagement. Fig. 10-1 shows a consumer authenticating a product by scanning a Dotless Visual Code with a smartphone.

Fig. 10-1 A consumer is authenticating a product by scanning a Dotless Visual Code on the packaging of a product

Authenticateit

Authenticateit, an Australian company, has developed a traceability system that provides a convenient way to track and verify products at any point in the supply chain, including the point of sale. The company has successfully assisted a number of companies, especially SMEs, in entering Asian markets in different sectors, including clothing, footwear, meat, and dairy. The essence of Authenticateit's brand protection platform is the unique product identifiers, GS1 Datamatrix codes that are in line with the GS1 Global Traceability Standard. Fig. 10-2 shows an example of the GS1 Datamatrix codes that can be printed on the product packaging. In essence, these codes ask consumers to verify before purchasing by scanning the code with the free Authenticateit App from 360 Zhou or iTunes. When a code is scanned, the system compares the geolocation of the consumer (via mobile phone GPS) with the registered address of that particular product. If the product's barcode has been copied and offered to a consumer in a different location, the system will immediately alert the consumer and the brand owner of this occurrence. In addition to its consumer authentication function, the Authenticateit traceability system also records and stores information in the cloud of each change in the chain of custody when products move through the supply chain. Authenticateit's traceability system enables the brand owner to register all members of their supply chain, including online stores. In this way, this system can be integrated into e-commerce sales channels easily where consumers are able to verify whether the online-store is linked to an authorised distributor. The average per label cost for products using the Authenticateit system in China is around US$0.0147 per item per year for 1 million items, or US$0.0036 per item per year for 10 million items (O'Brien 2015).

Fig. 10-2 An example of Authenticateit's GS1 Datamatrix codes

Invisible Tracers

Chinese-based company YPB developed an anti-counterfeiting technology based on invisible tracers made from rare earth materials that can be attached to any product or packaging as an authenticating identifier. YPB's anti-counterfeiting solution produces a covert and forensic trace signature which, together with a specialised, hand-held scanner of a smartphone app, allows brand owners and others to easily detect and report counterfeits. YPB estimates that the process of embedding the tracer adds less than a cent to the cost of a 7 cent tamper-proof soy sauce cap, for example (Condon 2015). Fig. 10-3 shows YPB's hand-held scanner. In March 2016, YPB announced that it has entered into a three-year contract to provide its invisible supply chain authentication solution to a major US casual footwear brand, incorporating the tracer technology into more than 70% of its entire production (Houston and Whitten 2016).

Fig. 3 YPB's hand-held scanner

<u>*Greatview Aseptic Packaging*</u>

In answer to China's revised 'Food Safety Law' which now requires manufacturers to establish full supply chain traceability systems, Chinese company Greatview Aseptic Packaging, said to be the world's second largest supplier of roll-fed aseptic beverage cartons, has developed an individually traceable milk carton printed with unique QR-codes, meaning each Greatview milk carton carries its own separate ID. In collaboration with Tencent's WeChat and Chinese retailer RT-Mart, Mengniu's 'Selected Meadow' Traceable+ milk became the first to apply this innovative smart packaging technology in promoting its milk brand. Consumers who use their smartphones to scan 'Selected Meadow' products will be able to trace item-level information about the milk contained in the carton (Packwebasia.com 2015). Fig. 4 shows the product of Mengniu's 'Selected Meadow' Traceable+ milk packaged with the traceable Greatview milk carton.

Fig. 4 Mengniu's 'Selected Meadow' Traceable+ milk packaged with traceable Greatview milk carton

Recommendation 2 – Mobile-engaged intelligent packaging technologies

China has the world's largest penetration of smartphone and mobile network usage, which provides an excellent infrastructure base for food track and trace systems and for consumer communication and engagement. The mobile-enabled packaging technologies listed in previous sections, such as smartphone-enabled trackable authentication solutions, smartphone aided consumer communication, and smartphone-readable freshness sensors are all good examples of how packaging can be revolutionised by mobile-engagement in the current market. Therefore, our recommendation is to develop novel mobile-enabled integrated systems that can specifically address Australian meat exporters' needs in key market segments.

Recommendation 3 – Next generation RFID technologies

As discussed in previously in this report, the standalone application of food quality indicators or sensors may not be able to achieve much commercial success because food producers are reluctant to use packaging systems in the market which could display a false reading (e.g., indicating that a product is not fresh). As a result, a better solution would be to incorporate sensors into tracing systems such that no compromised food products would reach the retailers or the consumers. Sensor-enabled RFID technology is a promising solution that not only can benefit consumers by ensuring freshness and quality, but also Australian meat exporters along with their local distributor and retailer partners, in order to more efficiently manage food stocks and fight counterfeiting. As discussed previously, several research and development trends in the RFID field have been identified, for example, printable sensor-enabled RFID tags, printable chipless RFID tags with integrated sensors, and passive RFID sensors. Our recommendation is to review recent RFID technology trends and explore not only from a technical perspective, but also other factors relevant to market introduction, such as cost benefit analysis (e.g., which use of RFID sensor tags is more beneficial and at what level, retail pack level vs pallet level), consumer perception and acceptance, and legislation and regulation requirements.

Recommendation 4 – Smart components incorporated in modified atmosphere packaging

Although active and intelligent packaging technologies have attracted significant research and development interest, the market size of MAP has always been dominant within the total market of advanced packaging. The share of MAP was 51.64% in 2014 and is expected to further increase to 53.12% in 2019 (Technavio 2015). Despite the significant market share of the MAP segment, our technology and product scanning implied there is not much active research with regard to this technology, except for those activities related to O_2 scavengers/indicators and CO_2 emitters. Our recommendation is to identify research opportunities in the area of smart components (active and/or intelligent) incorporated with MAP technologies.

Recommendation 5 – Brand differentiation

Australian beef imports are already thriving in China but they are still largely distributed in commodity form. As a result, no active branded beef presence can be seen aside from the general brand of “Australia” as a premium meat products provider. Consumer studies have shown that affluent middle class Chinese consumers will appreciate packaging that communicates to consumers regarding product information and brand value. Our recommendation is to develop novel meat packaging technologies that not only can provide information on provenance, but also other features that can boost emotional brand connection and recognition for consumers.

Bibliography

Akbar, A, Anal, AK, 2013. Zinc oxide nanoparticles loaded active packaging, a challenge study against Salmonella typhimurium and Staphylococcus aureus in readyto-eat poultry meat. Food Control (2014), 38, 88-95.

Ammu, S, Dua, V, Agnihotra, SR, Surwade, SP, Phulgirkar, A, Patel, S, and Manohar, SK, 2012. Flexible, all-organic chemiresistor for detecting chemically aggressive vapors. Journal of the American Chemical Society (2012), 134, 4553-4556.

Arvanitoyannis, IS and Stratakos, AC, 2012. Application of Modified Atmosphere Packaging and Active/Smart Technologies to Red Meat and Poultry: A Review, Food Bioprocess Technol (2012) 5:1423–1446

BCC Research 2015. Active, Controlled, and Intelligent Packaging for Foods and Beverages, BCC Research, FOD038D, October 2015

BCC Research 2015. ANTI-COUNTERFEITING PACKAGING TECHNOLOGIES IN THE GLOBAL PHARMACEUTICAL AND FOOD INDUSTRIES, BCC Report, FOD042C, August 2015, ISBN: 1-62296-129-3

BeQRious, 2016. Kraft Foods trials NFC and QR Codes. http://beqrioustracker.com/kraft-foods-trials-nfc-and-qr-codes/

Borison, R, 2013. QR Codes may not be the best choice for anti-piracy. http://www.mobilemarketer.com/cms/news/software-technology/16372.html

Borison, R, 2013. Haagen-Dazs launches augmented reality app to entertain users during temper time. http://www.mobilemarketer.com/cms/news/software-technology/15883.html

Botao, S, Qiang, C, Amin, Y, Mendoza, DS, Ran, L and Li-Rong, D, 2010. An ultra-low-cost RFID tag with 1.67 Gbps data rate by ink-jet printing on paper substrate. Solid State Circuits Conference (A-SSCC), 2010 IEEE Asian, pp. 1- 4.

Brockgreitens, J and Abbas, A 2016, Responsive Food Packaging: Recent Progress and Technological Prospects. Comprehensive Reviews in Food Science and Food Safety, 15: 3–15.

Brooks, C, 2007. Beef Packaging, National Cattlemen's Beef Association. http://www.beefresearch.org/CMDocs/BeefResearch/PE_Fact_Sheets/Beef_Packaging.pdf

Busolo, MA and Lagaron, JM, 2012. Oxygen scavenging polyolefin nanocomposite films containing an iron modified kaolinite of interest in active food packaging applications, Innovative Food Science & Emerging Technologies (2012) 16:211-217

Byelashov, OA and Sofos, JN, 2009. Strategies for on-line decontamination of carcasses. In F. Toldra (Ed.), Safety of meat and processed meat (pp. 149–182). New York: Springer.

Calatayud M, López-de-Dicastillo C, López-Carballo G, Vélez D, Hernández Muñoz P and Gavara R, 2013. Active films based on cocoa extract with antioxidant, antimicrobial and biological applications. Food Chemistry (2013), 139(1–4), 51–58.

Camo J, Beltrán JA and Roncalés P, 2008. Extension of the display life of lamb with an antioxidant active packaging. Meat Science (2008), 80(4), 1086–1091.

Cantatore, E, 2015. Printed electronics for food packaging sensors - advancements in processing and design enable printed electronics for applications including ultra-low-cost sensors to monitor food quality. 11 November 2015, SPIE Newsroom. DOI: 10.1117/2.1201510.006173

Chaffey, D, 2016. Mobile marketing statistics compilation, Smart Insights. http://www.smartinsights.com/mobile-marketing/mobile-marketing-analytics/mobile-marketing-statistics/

CheckPack, 2016. https://www.checkpack.ugent.be/about

Chow, DCK, 2000. Counterfeiting in the People's Republic of China, Washington University Law Review, Volume 78, Issue 1, http://openscholarship.wustl.edu/cgi/viewcontent.cgi?article=1427&context=law_lawreview

Colleen, 2015. ZEGO packaging boldly recasts allergen-level QR code, http://zegosnacks.com/zego-packaging-boldly-recasts-allergen-level-qr-code/

Condon, J, 2015. Technology protects against “counterfeit” Australian meat in export markets, Beef Central. http://www.beefcentral.com/features/beef-2015-report/technology-protecting-against-counterfeit-australian-meat-in-export-markets/

Cryptoglyph. 2016, http://www.alpvision.com/cryptoglyph-covert-marking.html

CSP Technologies, 2016. Patented Activ-Polymer® technology. http://csptechnologies.com/products/activ-polymer.cfm

Dias MV, Soares Nde F, Borges SV, de Sousa MM, Nunes CA, de Oliveira IR, Medeiros EA, 2013. Use of allyl isothiocyanate and carbon nanotubes in an antimicrobial film to package shredded, cooked chicken meat. Food Chemistry, 14(3) (2013), 3160–3166.

Duncan, TV, 2011. Applications of nanotechnology in food packaging and food safety: Barrier materials, antimicrobials and sensors, Journal of Colloid and Interface Science Volume 363, Issue 1, 1 November 2011, Pages 1–24

Ellouze, M and Augustin, JC, 2010. Applicability of biological time temperature integrators as quality and safety indicators for meat products. International Journal of Food Microbiology, 138(1–2), 119–129.

Emco Active and Intelligent Packaging Technology. Oxygen Indicator Labels. http://www.emcopackaging.com/index.php/products/oxygen-indicator-labels , accessed 30 May 2016.

Emerging Technologies and Trends for Packaging Red Meat, Meat and Livestock Australia Limited, A.RHC.0004, January 2015

Fernández-Salmerón J, Rivadeneyra A, Martínez-Martí F, Capitán-Vallvey LF, Palma AJ, and Carvajal MA., 2015. Passive UHF RFID tag with multiple sensing capabilities, Sensors (Basel). 2015 Oct 22;15(10):26769-82.

Food and Beverage Industry News, 2015. Tapping into Value-adding for the Chinese Market, Food & Beverage Industry News, April 20, 2015, https://foodmag.com.au/tapping-into-value-adding-for-the-chinese-market/

Fortin, C and Goodwin, Jr, HL, 2008. Valuation of Temp-Time's Fresh-Check® Indicator on Perishable Food Products in Belgium, Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting Dallas, Texas February 2-5, 2008

FreshCase® active vacuum packaging, n.d. http://curwoodinnovates.com/freshcase/ (Last accessed: 20/03/2014)

Garcia-Betances, RI, and Huerta, MK, 2012. A Review of Automatic Patient Identification Options for Public Health Care Centers with Restricted Budgets, Online Journal of Public Health Informatics * ISSN 1947-2579 * http://ojphi.org *4(1):e9, 2012

Ghaani, M, Cozzonlino, CA, Castelli, G and Farris, S, 2016. An Overview of the Intelligent Packaging Technologies in the Food Sector, Trends in Food Science & Technology, 51, 1-11.

Global Industry Analysts, Inc., 2015. Printed and flexible sensors – A global strategic business Report http://www.strategyr.com/pressMCP-7074.asp

Han, JH, 2005. Innovations in Food Packaging, Edited by:Jung H. Han, 2005. ISBN: 978-0-12-311632-1

Harrop, P and Das, R, 2010. Printed and Chipless RFID Forecasts, Technologies & Players 2011-2021, IDTechEx

Hayes, M, 2015. Anti-Counterfeit Packaging – A Primer, http://www.epsvt.com/blog/anti-counterfeit-packaging-a-primer/

Hernández-Jover, T, Izquierdo-Pulido, M, Veciana-Nogués, MT , and Vidal-Carou, MC, 1996. Ion-Pair High-Performance Liquid Chromatographic Determination of Biogenic Amines in Meat and Meat Products, J. Agric. Food Chem., 1996, 44 (9), pp 2710–2715

Houston, J and Whitton, R, 2016. Major US Footwear Brand Adopts YPB Authentication Solution, YPB Group Ltd. http://www.asx.com.au/asxpdf/20160311/pdf/435rjrzc2rc6d3.pdf

Jacobovitz, GR 2014. A colorimetric Sensor of Food Spoilage Based on a Molecularly Imprinted Polymer, http://www.jhuapl.edu/ott/technologies/technology/articles/P01491.asp

Jofre, A, Aymerich, T and Garriga, M, 2008. Assessment of the effectiveness of antimicrobial packaging combined with high pressure to control Salmonella sp. in cooked ham. Food Control, 19(6)(2008), 634–638.

Kerry, JP, 2012. Advances in Meat, Poultry and Seafood Packaging, edited by Joseph P. Kerry, ISBN: 9780857095718,22 Jun 2012

Kerry, JP and Butler, P, 2008. Active packaging of food, Smart packaging technologies for fast moving consumer goods (pp. 1–18). J. P. Kerry, & P. Butler (Eds.), John Wiley & Sons, Ltd.

Liu, SF, Petty, AR, Sazama, GT and Swager, TM, 2015, Single-Walled Carbon Nanotube/Metalloporphyrin Composites for the Chemiresistive Detection of Amines and Meat Spoilage. Angew. Chem. Int. Ed., 54: 6554–6557.

Lunden, I, 2015. 6.1B Smartphone users globally by 2020, overtaking basic fixed phone subscriptions, Tech Crunch. http://techcrunch.com/2015/06/02/6-1b-smartphone-users-globally-by-2020-overtaking-basic-fixed-phone-subscriptions/

Marcos, B, Aymerich, T, Garriga, M and Arnau, J, 2012. Active packaging containing nisin and high pressure processing as post-processing listericidal treatments for convenience fermented sausages, Food Control, Volume 30, Issue 1, March 2013, Pages 325–330

Matheson, R, 2015. “Fingerprinting” chips to fight counterfeiting, MIT News, http://news.mit.edu/2015/fingerprinting-chips-fight-counterfeiting-0501

Mehmet, Seckin, Aday, Ugur and Yener, 2015. Assessing consumers’ adoption of active and intelligent packaging, British Food Journal, Vol. 117 Iss 1 pp. 157 - 177

Mintell, n.d. Future Impact: How the next-generation of packaging is engaging consumers in 2016 and beyond, Mintel

Mondi 2011. Nor®Absorbit makes your food nice and crispy. http://www.mondigroup.com/de/desktopdefault.aspx/tabid-2179/472_read-22564/

O’Brien, P, 2015. Harness China's Demand For Safe Foods and a Traceable Food Supply Chain, LinkedIn. https://www.linkedin.com/pulse/harness-chinas-demand-safe-foods-traceable-food-chain-o-brien-%E4%BF%9D%E7%BD%97

P.PSH.0765, Project Proposal of Intellectual Ventures Smart Packaging Open Innovation for RnD4profit (insights2innovation) March 2016.

Packwebasia.com, 2015. World’s first item-level traceable milk cartons using QR codes, http://www.packwebasia.com/design/structural-graphic-design/3833-world-s-first-item-level-traceable-milk-cartons-using-qr-codes

Paper Pak Industries, 2016. The natural way to extend freshness. http://paperpakindustries.com/products/ultrazap_xtendapak.php

Pennanen, K, Keskitalo-Vuokko, K, KumpusaloSanna, K, Korhonen, M. Smolander and Ollila, M, 2013. Consumer and Time-Temperature Indicator: Implications for Further Development, 26th Iapri Symposium on Packaging, Espoo, June 10-13, 2013

Product authentication and tracking, 2016. http://www.spsy.com/trubrand.html

Realini, C E, and Begonya, M, 2014. Active and Intelligent Packaging Systems for A Modern Society, Meat Science, 98, 404-419

Rohan, n.d. Biosensors Market worth $22.68 Billion by 2020, http://www.marketsandmarkets.com/PressReleases/biosensors.asp

RR Donnelley, 2016. CustomWave RFID Solutions. http://www.rrdonnelley.com/printed-electronics/customwave/

RR Donnelley, 2016. Lenticular Labels. http://www.rrdonnelley.com/print-solutions/labels/promotional-labels/lenticular-labels.aspx

ScanTrust, n.d., We Protect Against Counterfeiting. http://www.sapolaris.com/SCANTRUST_English.pdf

Ščetar, M., Kurek, M & Galić, K, 2010. Trends in Meat and Meat Products Packaging – A Review, Croat. J. Food Sci. Technol. 2(1) 32-48.

Shamah, D, 2015. Israeli start-up helps Chinese retail giant beat counterfeiters, Start-Up Israel. http://www.timesofisrael.com/israeli-start-up-helps-chinese-retail-giant-beat-counterfeiters/

Shihab, M, n.d., QR-CODE for the ITGSopedia Logo. http://itgsopedia.wikispaces.com/QR-code

Smolander, M, Hurme, E, Ahvenainen, 1997. Leak indicators for modified-atmosphere packages, Trends in Food Science & Technology, 8(4):pp 101-106.

Soler, SY.; Lis, RJV.; Bono, VJL.; Mañez, MR.; Martínez, MMD.; Romero, AS.; Herranz, N, 2014. A novel colorimetric sensor array for monitoring fresh pork sausages spoilage. Food Control, 35(1), 166–176.

Stranger and Stranger, n.d.. Lo Tengo. http://www.strangerandstranger.com/lo-tengo/

Supply Chain Digest, 2015. RFID and AIDC News: New chipless RFID tag could transform the industry. http://www.scdigest.com/ontarget/15-04-22-1.php?cid=9228

Technavio, 2014. Global Nano-enabled Food and Beverage Packaging Market 2014-2018, Technavio

Technavio, 2015. Global Advanced Packaging Market 2015-2019, Technavio

Technavio, 2016. Global Anti-counterfeit Packaging market, 2016-2020, Technavio

Thinfilm, 2013. Thinfilm builds first stand-alone sensor system in printed electronics. http://thinfilm.no/2013/10/16/stand-alone-system/

Thinfilm, 2016. Thinfilm and Constantia Flexibles partner to deliver smart packaging solution to the beverages market. http://thinfilm.no/2016/02/18/16557/

Trafton, A, 2014. Detecting gases wirelessly and cheaply. http://news.mit.edu/2014/wireless-chemical-sensor-for-smartphone-1208

Trujillo, P, 2015. Barcode: The ultimate guide to barcodes, http://www.waspbarcode.com/buzz/barcode/

USDA's Livestock and Poultry: World Markets and Trade, April 2016, http://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.PDF

Uysal, I, Emond, JP and Bennett, G, 2011. Tag Testing Methodology for RFID Enabled Temperature Tracking and Shelf-life Estimation, 2011 IEEE International Conference on RFID-Technologies and Applications

Vanderroost, M, Ragaert, P, Devlieghere, F, De MeulenaerIntelligent, B, 2014. Intelligent food packaging: The next generation, Trends in Food Science & Technology 39 (2014) 47-62

Visualead, 2015. Visualead Launches Dotless Visual Code Technology, http://press.visualead.com/en/89/34

VTT, 2015. VTT sensor detects spoilage of food, http://www.vttresearch.com/media/news/vtt-sensor-detects-spoilage-of-food

Vu, CH and Won, K, 2013. Novel water-resistant UV-activated oxygen indicator for intelligent food packaging, Food Chemistry, Volume 140, Issues 1–2, 1–15 September 2013, Pages 52–56

Warner MG, Grate JW, Tyler A, Ozanich RM, Miller KD, Lou J, Marks JD, Bruckner-Lea CJ, 2009. Quantum dot immunoassays in renewable surface column and 96-well plate formats for the fluorescence detection of botulinum neurotoxin using high-affinity antibodies, Biosens Bioelectron. 2009 Sep 15;25(1):179-84

Wasserman, T, 2016. NFC packaging updates the lowly QR Code, but will consumers care? http://www.campaignlive.com/article/nfc-packaging-updates-lowly-qr-code-will-consumers-care/1380081

Webb, T, 2015. 3D Barcodes may stop counterfeits. http://www.abc.net.au/radionational/programs/scienceshow/3d-barcodes-counterfeit-goods/6850820

Williams, GM, 2012. Nanoparticle Security Coatings And Inks Benefit Brand Owners, -----Photonics Online, http://voxtel-inc.com/files/2012/07/Nanocrystal-Brand-Authentication-Coatings-Article-3_2012.pdf

Yam, KL and Lee, DS, 2012. Emerging Food Packaging Technologies: Principles and Practice, 15 Mar 2012 ISBN :9781845698096.

Australian Trade Commission 2011, *China 2nd-tier City Market Research Report*, Australian Trade Commission, Beijing.

Canadean 2016a, *China – Identifying and Profiling Attractive Cities for Australian Agricultural Products - Phase III Deliverable – Recommended Approaches for Success in the Final Five Chinese Cities*, Canadean, Australia.

Canadean 2016b, *China - Identifying and Profiling Attractive Cities for Australian Red Meat – Project Summary Report*, Canadean, Australia.

Honey & Fox 2017b, *High Value Australian Exports - Learnings From The Australian Wild Industry*, Honey & Fox, Australia.

Honey & Fox 2017a, *High Value Australian Exports - Learnings From The Australian Finfish Industry*, Honey & Fox, Australia.

Insights2Innovation 2016, *China Consumer Insights for Smart Packaging Development Workshop*, Insights2Innovation, China.

KPMG 2016, *China Value Chain and Business Model Innovation Research*, Meat and Livestock Australia, Sydney.

Solomon, N 2016, Smart Packaging, Thompson Reuters.

Thompson Reuters 2016, *Top 5 Competitors In Smart Packaging Technology -Business Intelligence Report*, Thompson Reuters.

Appendix 2: Food Packaging Conferences

Following are lists of industry, science and technology conferences relating to packaging. While not exhaustive, the lists highlight the conferences considered to be the most important with regard to food packaging.

Industry Conferences

- SIAL (Paris 16-20 Oct 2016) https://www.sialparis.com/

SIAL, Paris, has a reputation as the largest and best food exhibition. SIAL has satellite exhibitions, also, including in Shanghai, Manila, Jakarta, Abu Dhabi and Canada.

- Propak Asia (Bangkok 15-18 July, 2016) http://www.propakasia.com/

Consists of an number of co-hosted events.

- Institute of Food Technologist, IFT Annual Meeting & Food Expo (Chicago Jul 16-19, 2016) http://am-fe.ift.org/cms/

- Tokyo Pack 2016 (Oct 4-7, 2016) Japan Packaging Institute. http://www.tokyo-pack.jp/en/

- Food and Drink Expo (16-18 April 2018) http://www.foodanddrinkexpo.co.uk/

Science and Technology Conferences

- Innovations in Food Packaging, Shelf Life and Food Safety. (15-17 September 2015 Munich, Germany) http://www.foodpackconference.com/

- 6th International Symposium on Food Packaging: Scientific Developments supporting Safety and Innovation. (16-18 Nov 2016 Barcelona, Spain) http://www.ilsi.org/Europe/Pages/Packaging-Materials-Symposium-2016-General-Information.aspx

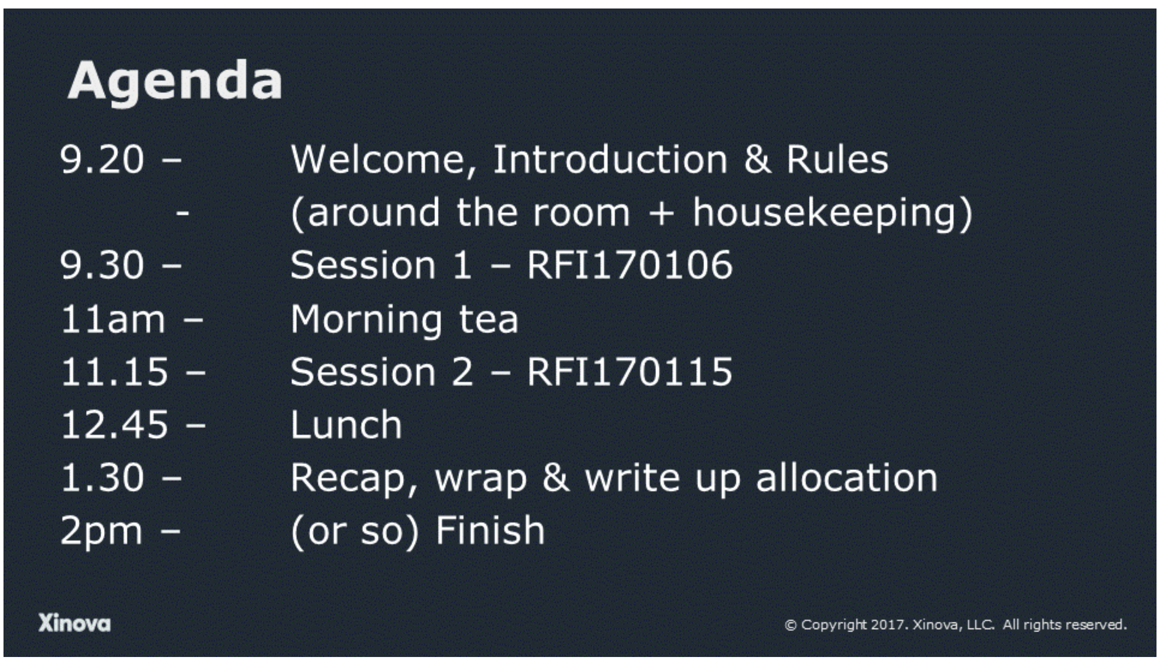
- Food Integrity and Traceability Conference (Belfast 8-10th April) http://www.qub.ac.uk/asset2014/

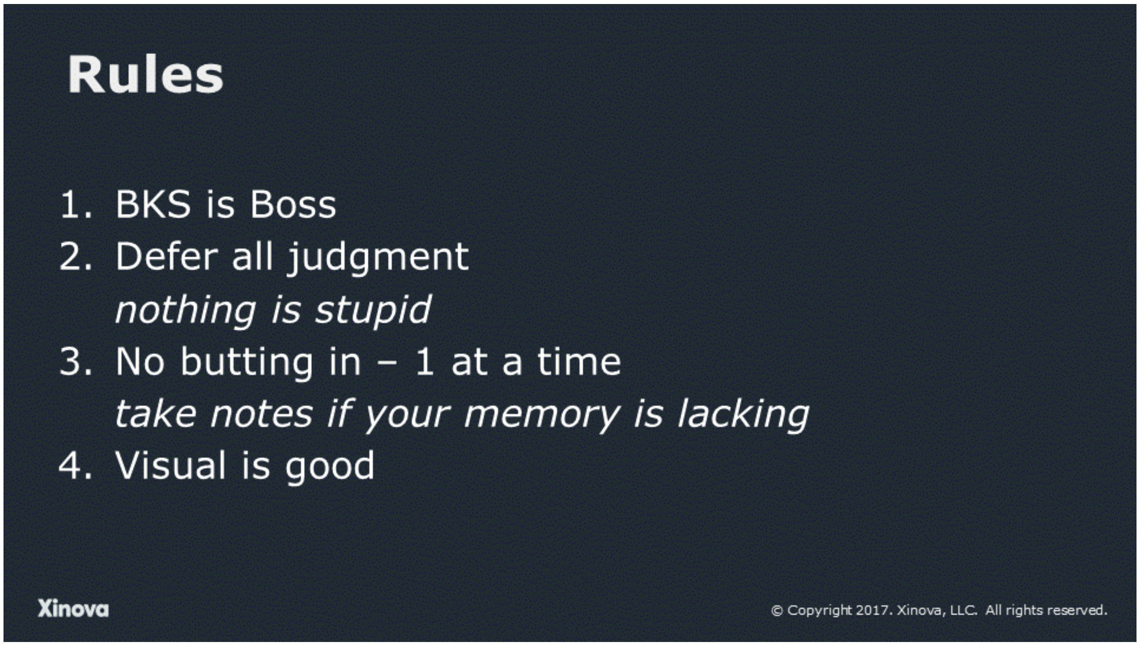
- 15th International Conference on Food Processing & Technology (November 07-09, 2016 Istanbul, Turkey)

Other related conferences

- EU Food Integrity project https://secure.fera.defra.gov.uk/foodintegrity/index.cfm?sectionid=21

Appendix 3: All-Star Inventor Workshop Presentation Slides




Rules
1. BKS is Boss
2. Defer all judgment
nothing is stupid
3. No butting in – 1 at a time
take notes if your memory is lacking
4. Visual is good
Xinova
© Copyright 2017. Xinova, LLC. All rights reserved.


Session 1
RFI-170106
Tracking Exported Meat Products from Farm to Fork
Xinova


Tracking Exported Meat ...
~ 80% of Australian red meat is exported
China is a growing market for AU beef (6% and growing)
AU beef is a premium product with a clean & green image
Currently, 95% of AU beef exported to CN is shipped via "common export mode"
(ie not direct to consumer)
Xinova


Tracking Exported Meat ...
"Common export mode"
NVD/NLIS/ MSA Data
GS1 Barcode
X
No traceability remains
Control is lost once the primal hits China
Xinova


Tracking Exported Meat ...
• Problems with loss of control:
➢ Substitution
➢ Fraudulent geographical indications
➢ Improper handling
➢ Impact on AU brand, both through fraud and through inability to differentiate the AU brand strongly from chief competitors
Xinova


Tracking Exported Meat ...
• Why is control lost?
➢ Original packaging is discarded on China entry
➢ Primals are further processed in China, and repackaged
➢ Traceability is lost at that stage
Xinova

Tracking Exported Meat ...

- *Desired invention characteristics*:

- New methods/devices to allow traceability to the point of sale or consumer
- Interaction between packaging and meat
  (playing on inherent feature(s) of the product, or something added to/put on the product)
- Tamper proof or evident
- Mobile-engaged
- Interactivity?

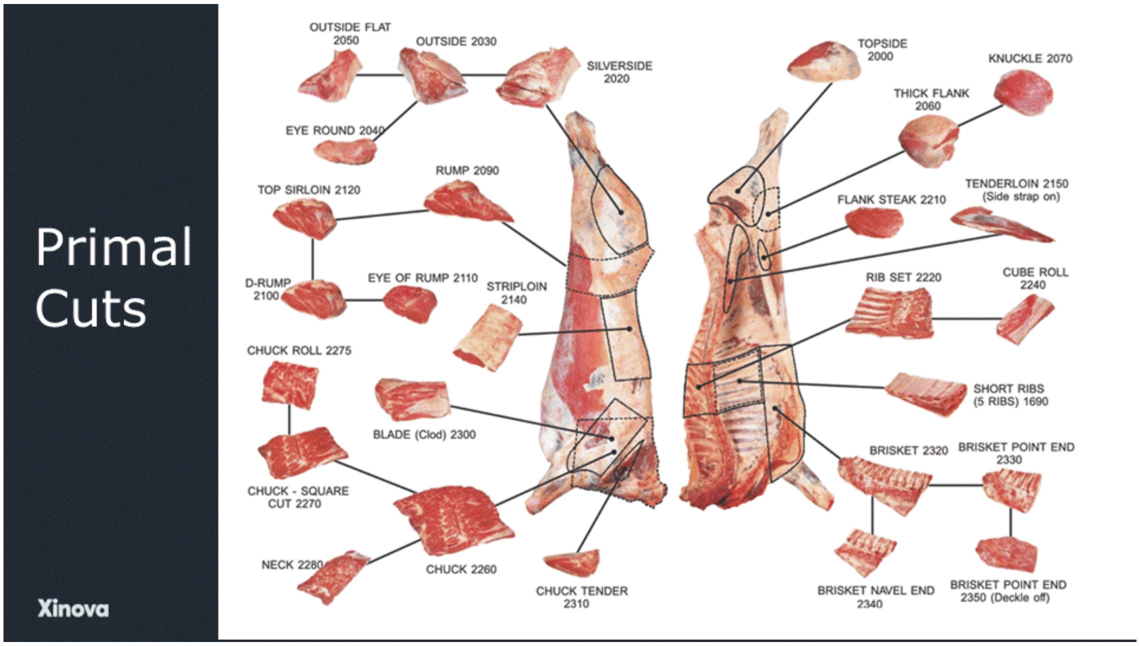
Xinova

Tracking Exported Meat ...

- *Out of scope*:

- RFID, unless it's independent of the packaging in a tamper proof/evident way
- Systems that require physical verification/analysis offsite, such as in a lab
- Devices that are lost when the packaging is discarded

Xinova


Primal Cuts
OUTSIDE FLAT 2050
OUTSIDE 2030
SILVERSIDE 2020
EYE ROUND 2040
TOP SIRLOIN 2120
RUMP 2090
D-RUMP 2100
EYE OF RUMP 2110
STRIPLOIN 2140
CHUCK ROLL 2275
BLADE (Clod) 2300
CHUCK - SQUARE CUT 2270
NECK 2280
CHUCK 2260
CHUCK TENDER 2310
TOPSIDE 2000
KNUCKLE 2070
THICK FLANK 2060
TENDERLOIN 2150 (Side strap on)
FLANK STEAK 2210
RIB SET 2220
CUBE ROLL 2240
SHORT RIBS (5 RIBS) 1690
BRISKET 2320
BRISKET POINT END 2330
BRISKET NAVEL END 2340
BRISKET POINT END 2350 (Deckle off)
Xinova


Session 2
RFI-170115
Intelligent Interactive Packaging
Xinova


Intelligent Interactive Packaging
• The AU beef industry wants technology to allow a 2-way communication between the industry and the consumer
• 2-way means communicating with the consumer about the product, while learning what the consumer is doing with the product
Xinova

Tracking Exported Meat …

- *Desired & example invention characteristics*:

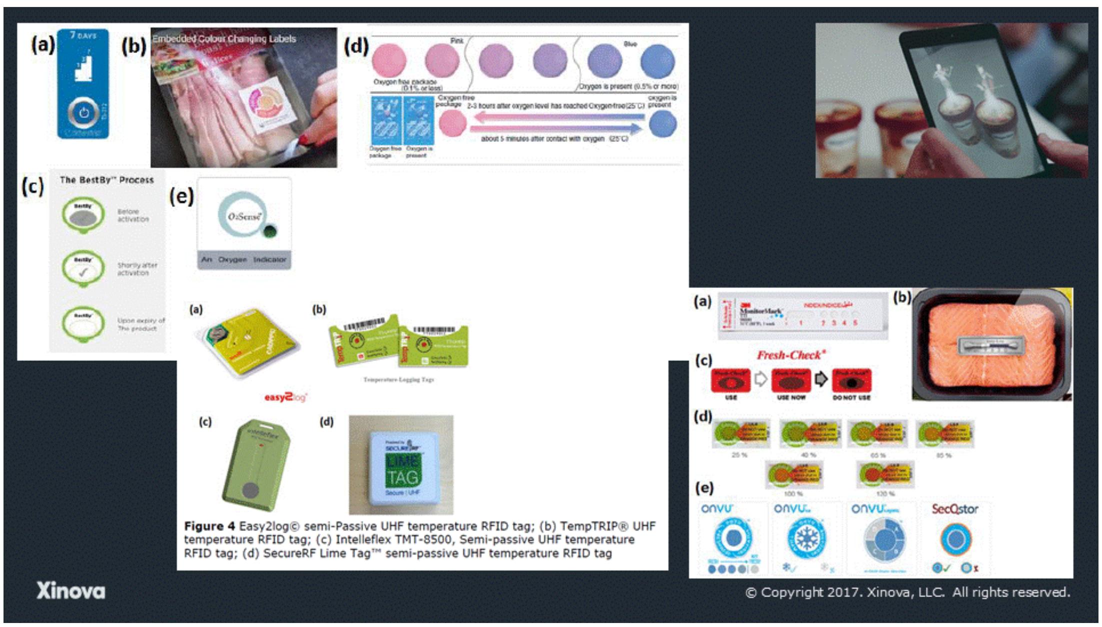
➢ Interactive packaging used to interact with consumers and collect information during transport, in-store storage, retail and at-home storage and use

➢ Sensors for recording information about temperature, location, time and storage conditions

➢ Devices/systems to allow consumer interaction, such that interaction can be used to gain info on consumer insight & behaviour

➢ Mobile-engaged, consumer motivating, gamified, loyalty awards, etc

Xinova



Appendix 4: All-Star Inventor Workshop Outcomes

Results for RFI-170106 Tracking exported meat products from farm to fork.						
Concept #	**Who****	**What**	**Type***	**Rank (1 good - 3 poor, M - pure marketing, nothing technical)**		**Questions / comments**
				BKS	**ML**	
1	SU	System to link CN further processing to AU database; scales to print UID to put on packaging, that can be scanned by client on AU app to confirm. Requires accredited butchers in CN.	S,R	1		
2	BM	Antibody tracking. Introduce foreign (eg fish) protein into animals early in life. Can later detect antibodies in cattle (sheep) as identification (non-UID). Improvement to have more than one protein, to help reduce risk of false negatives. Difficult to trace back to original protein. Testable by test strip	C, M	2		Can it be detected in meat (ie dead animal)?
3	SW	Delivery mechanism for taggant. Use of a food substance that is desirable to cattle/sheep (eg, mollases based). Contain small spikes that pierce mouth lining to provide innoculant/taggant. Could be used in conjunction with #2 above. Spikes wouldn't necessarily be noticeable by animal if in micro/nano range	C, M	3		A bit off topic
4	NH	Internal marking in AU of primals using HIFU - ALTERNATIVELY, focussed laser. Could mark	C	2		

		with machine readable code, or other branding. Only visible once primal is further processed.				
5	NH	Larding using unique threaded colour pattern. Threaded through primal, such that when further processed, cross section of larding is visible and offers a visible indicator.	C	3		
6	NH	CO2 laser holgraphic surface labelling. Perhaps not truly holographic, but branding on surface to create multi-depth branding.	C	1		
7	SU/NH	Use of automated cutting blade to form unique shape laterally in the cut meat. Mechanised further processing of primal.	R	3		
8	NH	Fluid passed into meat, post-exsanguination. Fluid unique colour which is either visually detectable or machine detectable.	C	3		
9	EK (SU/NH)	Marbling Finger Print. Primal scanned to determine internal marbling. Could be scanned in AU, & internal, invisible pattern recorded in AU db. Marbling (or other internal pattern) becomes visible on further processing of meat. Meat can be scanned by purchaser to be corellated with db image.	C, M	1		SR submitted under previous MLA RFI to imaging of internal marbling, but not with use of db and as a UID
10	EK	Take image of external surface. Match cut back to original image.	C, M	2		not sure how it would cope with loss of trimmings from primal to steak
11	SW	Unique traceable packaging. Includes self-destruct component. Part of overall system with fixed supply of packaging to supply chain. Self destruct allowing only one use of the packaging.	R	2		

12	SU	Mailable external packaging. Consumer is encouraging, potentially through loyalty/rewards/lottery to return packaging to central body for data collection. Configured for sealing post opening (for hygiene reasons), or mailed portion is external such that it doesn't come into contact with meat.	R	3		
13a	BM	Gel-like hydrophillic coating on primal, such that when the primal is further processed, some of the gel/coating is spread onto the meat, thus tagging it.	C	2		possibly combine 13a & 13b - need more detail
13b	NH	Wax coat, or dipping of meat in UV cured coating, which adheres to the meat and acts as a hermetic seal.	C	2		
14	NH	Induce diabetes in animal, then detect increase or decrease in blood sugars.	C, M	3		welfare issues
15	NH	HelOx environment	C	3		welfare issues
16	NH	Feed l-sugar to cattle, such that it can be measured, and is an indicator of origin	C, M	2		would require substantial improvements to current l-sugar manufacture
17	SW	Put meat in Ar environment when packaging, < shrinking wrapping, such that it is present in meat and detectable as identifier	C, M	2		
18	NH	Hold primal in vacuum prior to packaging. Dissolved O2 is drawn out. Could be a unique measure.	C, M	3		
19	SW	Block chain backbone variation on #1	S,R	1		

20	NH	Tamper evident non-planar RFID, where part of the RFID is inserted into cut meat. Inserted part remains in meat when RFID body is removed. RFID only works properly when in complete form - if removed and reused, it doesn't work.	R	2		
21	SW	Use of water basting needles with unique pattern as UID.	C	2		
22	EK	microlaser/heat branding etching on primal in a 2D pattern.	C	2		
23	EK	Dotted ink on exterior of primal with pattern integrity similar to patterns on bank notes.	C	2		
24	NH	QA label. Image of actual meat on part of packet, with see through window also on back, so can match part image with actual meat.	R	2		
25	SW	Similar to 7 above, could use 2 or more offset knives for further processing, such that it provides a unique cutting pattern in the meat which is determinable by image analysis, using app, etc.	R	3		

Results for RFI-170115 - Intelligent Interactive Packaging						
Concept #	**Who**	**What**	**Type***	**Rank (1 good - 3 poor, M - pure marketing, nothing technical)**		**Questions / comments**
				BKS	**ML**	
1	NH	Supermarket Kiosk. Scan meat at "kiosk" in supermarket. It suggests recipes. On recipe selection, metered dose of required spices is supplied, along with link or print of recipe. Could also dispense other things, but initial suggestion is recipe and spices. Could be configured such that only AU meat will scan on kiosk. Could also provide shopping list for recipe.	R	1		
2	EK	App to scan meat, recognise cut & suggest recipes/shopping list	C	1		
3	NH	Virtual cooking assistant. App enabled. Has step verfication from camera images before moving to next step.	C	2		
4	SW	Cooking classes - BYOM - either actual or virtual	R	M		
5	NH	Cooking competitions. Online. Feedback on cooking provided and consumer use ino collected	R	M		
6	NH	Lenticular label, where one half is cooked example, and other half is clear to show product.	R	2		
7	EK	Active QR code. Portions of B/W QR squares are changeable dependent on variable such as time or temperature. Change of QR Code means QR code provides link to different website over time.	R	1		

8	NH	Microbial surrogate TTI. Allow to grow in external packaging component as TTI. Bacteria (for example) grow at known rate wrt temp, moisture, time, and so	R	2		Cross contamination?
9	NH/SU	Proof of purchase card sent by customer to centralised service. Butcher puts under meat sold to customer. Couple with customer incentive.	R	3		
10	NH	Limited strip proof of purchase. Further processors in China are provided with a limited number of strips (or labels) to put with processed meat. Aim is that they can only lable a fixed amount of meat as Australian	R	3		really for previous RFI
11	SU	Laser projection onto primal for butcher, to provide unique cutting lines	R	3		really for previous RFI
12	SU	Freshness indicator. Colour change of specific numbers in the serial number (or other UID) depending on time. Therefore, in effect have a 2 step verification, as the serial number (or parts of it) should only be a particular colour at a particular time - can be verified via an app.	R	1		
13	EK	Machine readable freshness indicator. Coupled to scanned area and could be either visible or invisible. Would be in or on QR code/bar code, and thus linked to it.	R	?		In retrospect, I need more detail to understand this one
14	EK	AR video to provide steak feedback to consumer. Could use sizzle sound as indicator of cooking.	C	2		
15	EK	Temperature indicator in packaging goes into pan to show when pan is ready for cooking or meat ready to turn. Would likely be beside meat, not in or on or under it.	R	2		
16	EK	Room temperature indicator. Helps with knowing when to cook meat, after sufficient warming to RT. Could be QR code on packaging that changes colour at RT (when packagin is taken out of the fridge).	R	2		

17	NH	Piercing pyramid. Internal colour viewer, could be in shape of inverted pyramid, pierces top of meat and spreads it out to allow viewing of internal meat as it's cooked or cooking.	R	2		
18	NH	Dynamic pricing indicator on shelf. Laser (or other) light display onto shelf to show dynamic price, likely reducing with time as meat approaches fridge shelf life. Possibly configured to read label for age & price	R	3		on periphery of scope of either RFI
19	BM	Meat battery. Enabler for uses requiring electric power. Uses meat fluid as electrolyte. Could be used to power LED (or other light source). Could use fluid from soaker pad. Could be used as a tamper evident mechanism - eg, opening the packet completes or breaks a circuit which lights or sounds, etc. (SW) could emit noise on opening which is detectable by app.	R	2		
20	NH	Could use 19 in combination with RFID. RFID could be interrogated, where the RFID has impedance aspect to tell age of product, as time indicator.	R	2		
21	NH	Include USB stick with each pack, which is useful for the consumer. However, it would also send information pack to centralised service when used for the first time. Could be combined with sensor(s) which records info on handling which is sent back to centralised service.	R	3		
22	SW	sell cut of meat in cooking package - or beside optional cooking devices. Gives insight to how it's used, given can tell which devices are sold with the meat.	R	2		
23	SW	Talk of sponsoring a cooking show (suggestion was Midnight Dinners) with AU meat in use	R	M		
24	BM	Strain sensor on hermetic packaging. If breached/hole, etc, there is a change in stretch, therefore affecting strain sensor. Could be linked to another means for visible or other indicator, eg colorimetric indicator.	R	2		perhaps more applicable to first RFI
25	NH	Recordable device (eg coin) goes in cooking and is returnable to centralised service. Records information about the food as cooked,	R	2		

26	NH	Re-usable primal bag that is openable by further processor in CN, and reusable as packaging of further processed meat, such that label is kept when further processed meat is sent to supermarket, etc. Can be configured to	C	2		

*Type	Meaning
M	Meat Inherency
S	System
C	Carries from AU to saleable meat
R	(Most likely) Requires CN processor to use accredited device/label, etc after further processing primal

** Who	Name
BM	Ben Millar
EK	Ed Kearney
NH	Noam Hadas
SU	Shmuel Ur
SW	Steve Wilson

Appendix 5: RFI170106 Tracking Exported Meat Products from Farm to Fork.

Xinova is looking for your invention

REQUEST FOR INVENTION (RFI)

Tracking Exported Meat Products from Farm to Fork

Key words: Meat, beef, lamb, sheep, trace, track, traceability, geographic origin, provenance, DNA fingerprinting, authentication, geographic traceability, genetictraceability, farm to fork.

Circulation Date:
26 May 2017

Request for Invention
RFI-170106
MLA

Please read the instructions for Submission for more information on method, terms and conditions of your submission of Solution Reports. For the most recent closing date for all Requests for Invention please log in to your account at http://network.xinova.com.

Xinova

Tracking Exported Meat Products from Farm to Fork

SUMMARY

Xinova seeks the disclosure of inventions that track exported meat products from the farm to the consumer.

Over 80% of beef produced in Australia is exported, of which over 90% is exported as primal cuts of beef which are processed in export markets and repackaged for local markets ("Common Export Mode"). This repackaging leaves the beef open to fraudulent marking and substitution with inferior meat products.

Xinova seeks the disclosure of inventions that increase consumer confidence in the provenance of meat being purchased. Suitable inventions include traceability solutions that can be used in Common Export Mode which can provide complete and continuous traceability of meat products from the farm to consumer households, even when all original packaging materials are completely discarded when imported primal cuts are further processed and packed in importing countries. Ideally, the traceability should be tamper-proof, available to consumers, low cost, and able to provide a result to the consumer at the point of sale.

Desired invention characteristics and some suggested areas of exploration are described on page 21.

Tracking Exported Meat Products from Farm to Fork

Problem Definition

Australia is the world's third largest exporter in the category of meat products, after India and Brazil. In the past five years, the ratio of exported beef and veal to total production in Australia has been steadily increasing, from 65.4% in 2012 to 72.8% in 2015, with China having the most remarkable increase in imported meat from Australia, from 86,000 tons in 2012 to a record high of 663,000 tons in 2015.

While Australian meat producers and exporters are grateful for the new business opportunities, particularly those presented by emerging nations, many are concerned about the enormous degree of counterfeiting and substitution activities in these countries and regions, which could negatively influence consumer sentiment toward Australian meat. These counterfeiting challenges must be addressed in order to maintain the quality and integrity of the Australian meat product for the consumer. In addition, Australian meat producers hope to identify solutions which provide clear and effective communication to overseas consumers about a product's provenance, to tell the story and history of the brand, and to boost the value of "brand Australia" as a premium meat product provider, in order to increase the competitiveness of Australian meat products over other major meat exporters.

Modern consumers are concerned about the meat products they purchase and eat. Choice of one product over another generally reflects various aspects of consumer lifestyle, religion, and confidence in certain brands from certain geographic origins, with consumers also paying increasing attention to food safety and authentication issues. Traditionally, consumers rely on the food labeling to help them make informed decisions regarding which food to purchase. Recent food scandals, such as adulteration and willful misbranding of meat products in both developed and developing countries, have resulted in an increasing lack of consumer confidence towards meat products of animal origin in particular. All of these reasons have contributed to the need for new technologies to track and trace meat. Secure traceability is the ultimate answer to consumer demand for trustworthy knowledge about the meat products they purchase.

In order to identify innovative solutions addressing both Australian meat producers' goals and international consumers' concerns over authentication and counterfeiting issues, it is important to understand how Australian meat products are exported to other countries. Using China, the world's largest consumer market, as an example, a typical supply chain of an Australian meat export involves several entities and transactions, in the following order:

- Farm producers;
- Feedlots where cattle are hand or mechanically fed for the purpose of production (about 30% of Australian beef cattle are finished in feedlots);
- Abattoirs (slaughterhouses) where cattle are processed into large sub-products, such as individual vacuumed bagged primal cuts, and packaged into cartons ready for transport;
- Cold storage and transportation to an Australian port;

Tracking Exported Meat Products from Farm to Fork

- Export of meat products to China via sea or air (usually by sea);
- Additional/further processing of primal cuts into retail ready or food service products within China, with the original packaging being discarded;
- Cold storage and transportation within China; and
- Wholesale / retail (physical or online) / food service providers and consumer purchase.

The above list describes only the general flow of Australian meat products from farm to international consumers. There are several different modes in which Australian meat products are exported, the two most common of which are Common Export Mode and Retail Ready Export Mode, which are described below. Note that while both Common Export Mode and Retail Ready Export Mode are described below for completeness, this RFI is primarily focused on Common Export Mode.

Common Export Mode

As illustrated in Figure 1, Common Export Mode involves processing and partially processing carcasses to primal cuts (https://en.wikipedia.org/wiki/Primal_cut) at the local abattoirs in Australia. Primals are then packaged in vacuum bags and stored in cartons, then transported by sea freight, arriving at foreign ports. Once the freight passes customs clearance, the primals are further processed at local processing centers to complete the processing of consumer portions to wholesalers, retailers (physical or online), or food service providers. At this stage, the original packaging, including the vacuum bags and the cartons, are discarded, and the retail cuts are packaged at local processing centers. As a result, any devices or labels that are used with the original packaging materials to provide traceability back to the carcasses (usually archived with the National Vendor Declaration (NVD), the National Livestock Identification System (NLIS) and/or Meat Standards Australia (MSA) data) are lost.

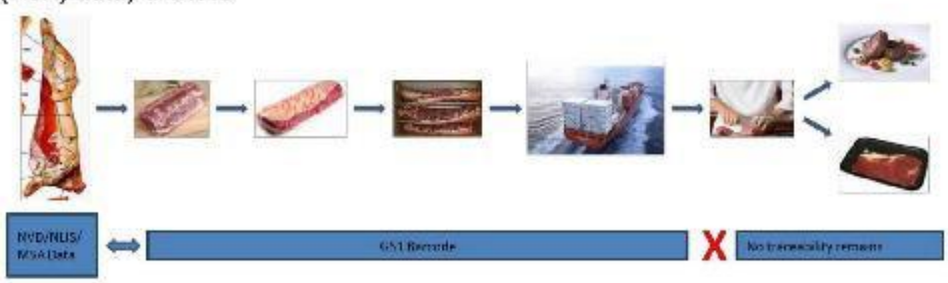


Figure 1. Illustration of Common Export Mode supply chain, with disconnected traceability at local processing centers in exporting countries.

Tracking Exported Meat Products from Farm to Fork

Retail Ready Export Mode

As illustrated in Figure 2, Retail Ready Export Mode involves processing and partially processing carcasses to primals at the local abattoirs in Australia. The primals are then further processed and packaged into retail ready packs. Individual packs are then packed into cartons for air or sea shipment. Once the freight arrives in importing countries and passes customs clearance, it is transported and stored ready for traditional wholesalers, retailers, or e-commerce shopping platforms. In this mode, since the retail-ready products are processed and packed in Australia, it's relatively easy to apply traceability solutions, such as barcodes, RFID tags, and smart packaging technologies to trace and track individual packs all the way from local consumer households to Australian abattoirs.

Figure 2. Illustration of Retail Ready Export Mode supply chain, with full treatability.

*This RFI will focus on innovative solutions that can enable international consumers to track and trace purchased imported Australian meat products by providing consumers with information about provenance assurance, including the breed or even individual cattle from which the particular meat product comes (for example, the specific production system, number of days on feed, animal welfare, etc.). While both Common Export Mode and Retail Ready Export Mode have been described above for sake of completeness, the focus of this RFI is on technologies applicable to Common Export Mode. While proposed solutions which are usable in either export mode will be acceptable, <u>the primary focus of this RFI is for technological solutions specifically crafted for **Common Export Mode**.</u>*

Tracking Exported Meat Products from Farm to Fork

Why This Problem Is Valuable to Solve

The Australian red meat industry exports approximately 75-80% of its production. However, Australia's competitiveness in the meat export market cannot be taken for granted, as new competitors are constantly entering the market, and existing competitors are also looking to increase their market share which may impact the volume of the Australian red meat supply and its pricing competitiveness. Furthermore, the international markets are not without their unique challenges to foreign imports, with reports of fraudulent geographical origin labeling, substitution with inferior products, and sales of meat that has been improperly handled across the supply chain, all of which can have a negative impact on the consumer trust of the Australian meat products. This RFI focuses on identifying technologies and solutions related to traceability which are applicable to Common Export Mode. The inventions and solutions that will be identified by this RFI will ultimately assist the Australian meat industry to explore and thrive in rapidly expanding international markets, with a particular focus on developing countries, such as China, and to protect Australia's brand as a provider of high quality and consistent meat products.

Background

As defined by the European Regulation (ER) 178/2002, food traceability is "the ability to trace and follow a food, feed, food producing animal or ingredients, through all stages of production and distribution." An example of a traceability system for meat is Australia's National Livestock Information System (NLIS). The NLIS collects data on individual animals that extend across their lifetime and along the value chain from birth to slaughter through the use of a NLIS Breeder Tag. About 99.5% of movement transactions are received and recorded electronically within 24 hours of the movement occurring. Further along the supply chain, bar coding and numbering of carcass tickets and carton labels using the "GS1" system (http://www.gs1.org/) is used from slaughter to export or local retail. The information stored in carcass tickets and carton labels can link back to the live animal origin. In such a traceability system, the source of food safety problems can be identified quickly, and the impact of recalls during events of foodborne illness outbreaks will therefore be significantly reduced. From the consumer perspective, a robust and transparent traceability system is an excellent tool to boost consumer confidence with respect to concerns over food quality, identity preservation, and counterfeiting.

In addition to conventional traceability, there are two other types of traceability systems that have been developed in relation to the meat industry, namely geographic traceability and genetic treatability. Additional types of traceability systems can be designed to encompass some, most, or all of the life-cycle, from the birth of the animal to consumer consumption of the meat products.

Tracking Exported Meat Products from Farm to Fork

Geographic Traceability

Geographic traceability, unlike conventional traceability, does not aim to identify an individual or a batch of animals but rather the geographic origin of a meat product, by utilizing a geoidentifier, such as volatile compounds, microbial flora, and stable isotopes. Geographic traceability combines the functionalities of the conventional traceability system and the functionalities of the geographical information system to provide the consumer with information regarding the geographic origin of the food and the environment in which it is produced. The geographic traceability can also be used for marketing purposes to promote products from a particular region or local area. For example, for many global consumers, "brand Australia" means a guarantee of high quality clean, green, and disease-free meat products. From a marketing point of view, an authenticated geographic traceability system linking meat products with an Australian origin may provide strong differentiation from similar products in the same category on the market and have a favorable influence on sales.

Inductively coupled plasma mass spectroscopy (ICP-MS) of trace elements and stable isotope ratios are predominantly used in authentication of geographic origin of meat products. Some cattle breeds are country specific and as a result, DNA analysis has also been used in indirect identification of geographic origin. However, identification of breed alone cannot be used to determine geographic origin for all breeds, since individual breeds can be raised in different countries. DNA analyzing tools will be discussed in detail in the following section on Genetic Traceability.

Exemplary academic research works using various analytical methods to identify geographic origin of meat products are summarized in Table 1.

Meat Products	Analytical Methods	Work Description	Reference
Poultry meat and dried beef	ICP-MS of trace elements	^{75}As, ^{23}Na, ^{85}Rb, ^{77}Se, ^{88}Sr, and ^{205}Tl for poultry meat and ^{75}As, ^{10}B, ^{137}Ba, ^{42}Ca, ^{111}Cd, ^{63}Cu, ^{163}Dy, ^{167}Er, ^{57}Fe, ^{7}Li, ^{55}Mn, ^{104}Pd, ^{85}Rb, ^{77}Se, ^{88}Sr, ^{128}Te, ^{203}Tl, ^{238}U, and ^{51}V for dried beef; isotope levels differ significantly between countries.	Franke, B., Haldimann, M., Gremaud, G., Bosset, J. O., Hadorn, R., & Kreuzer, M. (2008). Element signature analysis: its validation as a tool for geographic authentication of the origin of dried beef and poultry meat. *European Food Research and Technology*, 227(3), 701–708.
Beef and chicken	Oxygen isotope ratio	$^{18}O/^{16}O$ levels in the meat's water fraction are clearly different in different regions (Australia vs. Europe vs. North America).	Franke, B., Koslitz, S., Micaux, F., Piantini, U., Maury, V., Pfammatter, E., et al. (2008). Tracing the geographic origin of poultry meat and dried beef with oxygen and strontium isotope ratios. *European Food*

Tracking Exported Meat Products from Farm to Fork

			Research and Technology, 226(4), 761–769.
Beef	Carbon and nitrogen isotopes	Differentiating between beef originating from Japan, Australia, and the United States of America and originating from Europe and the United States of America.	Nakashita, R., Suzuki, Y., Akamatsu, F., Iizumi, Y., Korenaga, T., & Chikaraishi, Y. (2008). Stable carbon, nitrogen, and oxygen isotope analysis as a potential tool for verifying geographical origin of beef. *Analytica Chimica Acta*, 617(1-2), 148–152. Schmidt, O., Quilter, J. M., Bahar, B., Moloney, A. P., Scrimgeour, C. M., Begley, I. S., *et al.* (2005). Inferring the origin and dietary history of beef from C, N and S stable isotope ratio analysis. *Food Chemistry*, 91(3), 545–549.
Beef	DNA analysis	Analysis of 24 breeds was used to build a Bayesian statistical model based on single nucleotide polymorphisms (SNP) markers, and indirect differentiation between Italy, France, Spain, and the United Kingdom was possible.	Negrini, R., Nicoloso, L., Crepaldi, P., Milanesi, E., Marino, R., Perini, D., et al. (2008). Traceability of four European Protected Geographic Indication (PGI) beef products using single nucleotide polymorphisms (SNP) and Bayesian statistics. *Meat Science*, 80(4), 1212–1217.

Table 1. Exemplary academic work on authentication of geographic origin of meat products.

Genetic Traceability

Each animal has a unique genetic fingerprint which can be used as a powerful tracing tool to track all meat products from the specific animal. Based on the levels of DNA analysis, genetic traceability can be further classified into individual genetic traceability and breed traceability. Individual genetic traceability can trace back to the individual animal that produces a certain meat product and therefore provide a direct link to food safety; the breed traceability is also of interest for detection of food adulteration and substitution.

In order to determine the animal's unique genetic fingerprint, the DNA is first extracted from the chosen matrix (e.g., animal tissue, blood, hair, sperm, faeces or a processed meat product), and then is analyzed by molecular markers to obtain a DNA identifier for individual animals or animal breeds. Since the introduction of

Polymerase Chain Reaction (PCR) testing, many different markers have been discovered. At present, microsatellites, single nucleotide polymorphisms (SNPs), and simple sequence repeats (SSRs) are all largely used. In practice, the specific choice of the most suitable molecular approach depends on various factors, including the amount of genetic variation of the analyzed species, the time needed for the analysis, and the cost and the expertise of laboratories. Furthermore, these approaches all require access to the correct DNA sequence of the origin organisms, and they all have the common problem of lacking standardization and universality.

In 2003, a new DNA-based biological identification technology called DNA barcoding was first introduced by researchers from University of Guelph, Canada. DNA barcoding uses a short section of DNA from a standardized region of the genome for species identification. As its name suggests, DNA barcoding uses the specific DNA sequence to identify different species in the same way a supermarket scanner uses black stripes of the UPC barcode to identify commercial products. While DNA barcoding is technically not completely new technology, as molecular identification approaches have already been in use, it has the advantage of combining three important innovations: 1) molecularization of identification, based on the use of nucleotide variations in a molecular marker as a genetic descriptor and taxonomic identifier of any form of life; 2) computerization of the analyses by means of querying non-redundant databases of verified sequences using bioinformatic tools; and 3) standardization of the barcoding process as a whole, from sample collection to species identification, through the production and interpretation of molecular data.

Species identification using DNA barcodes begins with the specimen. Once the DNA from the specimen is extracted, the barcode region (a 648 base-pair region in the mitochondrial cytochrome c oxidase 1 gene ("CO1") is used for almost all animal groups) is isolated, replicated, and sequenced. The sequence is represented by a series of letters representing the nucleic acids, namely cytosine, adenine, thymine, and guanine (C, A, T, and G). For example, the barcode sequence of an Arctic warbler (*Phylloscopus borealis*) looks like:

CCTATACCTAATCTTCGGAGCATGAGCGGGCATGGTAGGC..., and the image of the DNA barcode looks like Figure 3 below. Once the DNA barcode for a specimen is obtained, it is placed in the Barcode of Life Data Systems (BOLD), a searchable repository for DNA barcode records.

Figure 3. A DNA barcode example of an Arctic warbler (Phylloscopus borealis) (Source: http://ibol.org/about-us/what-is-dna-barcoding/).

DNA barcoding is most successful when applied to seafood, primarily because in comparison to other animal sources (e.g. cattle, sheep, goats, and horses), the number of species of seafood is higher. DNA barcoding has also been applied to

Tracking Exported Meat Products from Farm to Fork

the genetic identification and traceability of mammalian food products (e.g. beef, pork, lamb, venison, and horse); however, in some cases where breeds of cattle are derived from hybridization events, they will have the same DNA profile. As a result, no correct identification result can be obtained by DNA-based technologies, including DNA barcoding.

At present, DNA barcoding seems to be the most reliable and standardizable tool of authentication of animal origin among all molecular-based technologies. The easy implementation and relatively low cost makes it a sustainable solution, either for use as verification in specific cases (e.g. when recall is required for a batch of products) or for routine traceability tests on a range of food products. The successful application of DNA barcoding will primarily depend on the availability of a worldwide repository, where a vast number of DNA samples will be gathered and deposited for the massive amount of foods. The success of DNA barcoding will also depend upon broad molecular variability between the ever-growing varieties of foods.

DNA testing still has major impediments for the effective applicability of DNA-based technology, such as the associated cost and time to return results. As a result, at present, such methods are primarily used as verification but not as routine tests. In addition to cost and time, the current DNA-based traceability systems all require lab tests and hence are not available at the consumer level.

Birth to Slaughter Traceability

Among countries that have a livestock traceability system in place, birth to slaughter traceability is often mandatory. For example, Australia has the National Livestock Identification System (NLIS), which was introduced in 1999 to meet European Union (EU) requirements and enable individual animals to be traced quickly, from property of birth to slaughter, for food safety purposes. Figure 4 illustrates how the NLIS system works.

Figure 4. Illustration of NLIS system,

(Source: https://www.nlis.mla.com.au/NLISDocuments/NLIS%20Cattle%20brochure%20(Mar%2009).pdf)

In the NLIS system, Australian breeders apply a white NLIS device (either an ear tag, or a rumen bolus/ear tag combination) to cattle bred on their properties. The

Tracking Exported Meat Products from Farm to Fork

NLISID number assigned to each device is linked to the electronic RFID number encoded in the microchip inside each device. Each device is also assigned with a unique Property Identification Code (PIC) that indicates the property information. When cattle move, the RFIDs can be scanned, or the NLISIDs can be read visually and recorded manually. The person who receives the cattle will record the transfer in the database. In this way, a life history of an animal's residency, and which animals it came into contact with, is established.

The National Livestock Breeding Center (NLBC) of Japan works in a similar way in compiling and keeping the record of each animal. When there is a change in the situation of an animal (e.g. being purchased by a trader or another farmer, death, shipment for slaughterhouse), the owner of the animal reports it to the NLBC along with the unique identification number assigned to each animal.

Post-Slaughter Traceability

Post-slaughter traceability covers the trace and the track from the animal carcasses, quarters (both hindquarters and forequarters), and primals/subprimals/trimmings, all the way to the retail-ready packed meat products. In small- and medium-volume processing plants, identification of primal/subprimal cuts from a specific carcass can be achieved by tagging, plus complete separation/segregation of the trimmings from a single-carcass process. For example, in a post-slaughter traceability system in Ireland, the identity and the history of the animal is first transferred into a central database when the animal arrives at the slaughterhouse. After the animal is slaughtered and quartered, a carcass label will be attached to each quarter, containing information such as carcass number, ear tag number, farmer name and address, country of origin, date of birth, factory of slaughter, slaughter date, sex, grade, and cold weight. All this information is also recorded in a central database. Once the animal has been quartered, it moves to the boning hall, where the animal is deboned and each quarter made into primal cuts. After the cutting takes place, the cut is weighed, vacuum packed, and labeled with an EAN 128 barcode. The EAN 128 label contains the product code, batch code, country of origin, country of slaughter, factory of slaughter, factory of cutting, kill date, pack date, cut by date, and use by date. With this barcode label, primal cuts can be traced back to a single group of animals which were slaughtered on a particular date. The primals will then be checked into the central database-linked chilling storage. At distribution level, the primal cuts are scanned out of storage and transported directly to the store where they will be processed for in-store pre-pack. At the store level, the traceability information contained in the EAN 128 label on the primal will be transferred via the retailer's scales onto the pre-packed products.

In large-volume plants, such as plants in the US, the carcass processing is not linear but rather a "disassembly" process (i.e. cuts and trimmings from a given carcass are prepared and exit the fabrication room at different times). As such, direct tracking of primal/subprimal cuts and trimmings is practically impossible. In this case, DNA-based technologies may be the only feasible solution to the traceability requirement.

Tracking Exported Meat Products from Farm to Fork

In a typical DNA technology-based post-slaughter traceability system, a sample of muscle needs to be first archived (recording information such as carcass ID, calendar date, and time of day) from each individual carcass when it enters the fabrication room. As each box of fabricated meat products moves past the box scale, it is time-stamped and recorded in the packer's computer system. At the retailer's site, the box serial number can be used to identify each retail package generated from the primals/subprimals in that box. If there is a need for traceback, a sample of muscle from the retail cut in question, plus the serial number of the box from which it came, are sent back to the packer, and the packer locates the box serial number in the computer database. Knowing the average length of time required for the cut of beef to be produced, boxed, and scaled on the fabrication floor from the time the carcass entered the fabrication room, the packer can identify a range of potential carcasses from which the primal cut originated. The packer then sends the sample of the retail cut, along with the samples from that range of potential carcasses to a DNA testing laboratory, to be analyzed until a DNA fingerprint match is achieved.

Farm to Fork Traceability

Farm to fork traceability covers the entire supply chain of a meat product, from the farm to the retailer. From the above background information, when the production scale of the packing plant is relatively small with the linear carcass fabrication processing, farm-to-fork traceability can be accomplished by a combination of birth to slaughter traceability and post-slaughter traceability using RFIDs, barcodes, or paper-based systems. However, if the supply chain is long, for example, when exporting is included, the integrity of the traceability is subjected to higher risks, since the RFIDs, barcodes, and paper documents are all easy to counterfeit. Furthermore, in the Common Export Mode in Australia (as described above), the original packaging, inducing the vacuum bags and the cartons are all discarded at local processing and packing centers in the export countries. As a result, any traceability information stored in barcodes or RFIDs that are attached to the original packaging materials will be lost at this stage. While this traceability information can theoretically be recorded and transferred to any new barcode/label/paper documents attached to the retail-ready packs, food adulteration, substitution, misbranding, and mislabeling can all easily occur without effective supervision. Furthermore, local importers must be incentivized to transfer the labelling.

Tracking Exported Meat Products from Farm to Fork

Current Technology and Prior Solution Attempts

SafeTraces (formally, DNATrek, http://www.safetraces.com/company.html)

SafeTraces offers DNATrax, a technology developed at Lawrence Livermore National Laboratory, relating to a spray-on biological barcode that "prints" all traceability information directly on (or in) food products, rather than the packaging. The key component of DNATrax is a DNA spray, which contains DNA extracted from natural sources and is invisible, edible, tasteless, odorless, and FDA-approved. The researchers use different types of, for example, seaweed or plants to create a combination of DNA barcodes by adjusting the presence or the absence of these elements in the mixture. In this way, they essentially create a DNA barcode that encodes traceability information and can be "printed" on the food product.

Each barcode has two parts. The first part is a fixed code unique to the company that produces the food products, while the second part is a configurable code based on whatever parameters the company would like to track. Using beef products as an example, it can be the geographic location where the cattle were grown, the breed of the animal, or the slaughter date. According to the SafeTraces website, the DNA spray can be easily applied with standard coating steps or as a food product ingredient. The spray is highly stable and passes normal product shelf-life. The encoded traceability information can be recovered and tested anywhere in minutes, via a handheld device. One of the important features of DNATrax is that it is applied onto the food itself, rather than the packaging. Therefore, this method is tamper-proof and has far-reaching effects in the battle against food adulteration and substitution.

Exemplary Patents Related to DNATrax

Patent or application #	Title	Abstract	Primary Independent Claim
WO/2016/ 114808A1	DNA Based Barcode for Improved Food Traceability	Food distributed to consumers through a distribution chain may be traced by tagging the food with DNA tags that identify the origin of the food, such as the grower, packer and other points of distribution, and their attributes. This makes it much quicker and easier to trace the food in case of food contamination or adulteration. Preferably these attributes indicate the field, location, crew and	1. A food product, said food product made and distributed to consumers along multiple nodes of a distribution chain, comprising: a food material; and at least one DNA bar code attached to or mixed with said food material, said at least one DNA bar code identifying at least two attributes of at least one node of said distribution chain.

Tracking Exported Meat Products from Farm to Fork

		machine used to grow and process the food, and the dates of the various steps of food harvesting, processing and distribution. Natural or synthetic DNA pieces may be used to tag items, including food items. Multidigit binary or other types of bar codes may be represented by multiple types of DNA. Each digit of the bar code may be represented by one, two or more unique DNA pieces.	
US 9023650	DNA Tagged Microparticles	A simulant that includes a carrier and DNA encapsulated in the carrier. Also a method of making a simulant including the steps of providing a carrier and encapsulating DNA in the carrier to produce the simulant.	1. A product comprising: a first carrier; at least one fluorophore encapsulated in the first carrier; and at least one DNA barcode encapsulated in the first carrier, wherein the first carrier comprises a non-toxic material, wherein the product is in an aerosol form and is biosafe, wherein the non-toxic material is selected from a group consisting of: a vitamin, talc, an antacid, and combinations thereof.
US 20150361490	DNA Tagged Microparticles	In one embodiment, a product includes a plurality of particles, each particle including: a carrier that includes a non-toxic material; and at least one DNA barcode coupled to the carrier, where the particles each have a diameter in a range from about 1 nanometer to about 100 microns.	3. A product, comprising a plurality of particles, each particle comprising: a carrier comprising a non-toxic material; and at least one DNA barcode coupled to the carrier, wherein the particles each have a diameter in a range from about 1 nanometer to about 100 microns, wherein the at least one

Tracking Exported Meat Products from Farm to Fork

			DNA barcode has greater than or equal to about 80 bases to less than or equal to about 150 bases.

Eurofins TAG™ (http://www.meat-testing.com/authenticity-testing/eurofins-tag.aspx)

Eurofins TAG™ is a DNA-based meat traceability system developed by Eurofins Scientific, a leading international group of laboratories providing a variety of analytical testing services. The Eurofins TAG™ system includes:

- Establishing a specific sampling plan for each client;
- Elaborating a tissue database (reference samples);
- Genotyping the samples (DNA extraction, amplification of selected molecular markers, generation of genetic fingerprints); and
- Validating the announced traceability by comparison of the genetic fingerprints of the reference and control samples.

Exemplary Patents Held by Eurofins

Patent or application #	Title	Abstract	Primary Independent Claim
EP1865070	Method for marking a product using nucleic acids to determine its identity and origin	The method for marking of liquid products such as oils or oil-based products to its identity proof- and origin proof, comprises marking the product with DNA or RNA having a coding range, whose sequence is assigned to a character sequence. The character sequence is a letter- and/or a numerical sequence. The numerical sequence is a decimal number. The coding of the decimal number takes place in the sequence of the coding range. The conversion of the decimal number takes place in binary-, tertiary or quaternary number system. The method for marking of liquid products such as oils or oil-based products to its identity proof- and origin proof, comprises marking the product with DNA or RNA having a coding range, whose sequence is assigned to a character sequence. The character sequence is a	Not available in English

Tracking Exported Meat Products from Farm to Fork

		letter- and/or a numerical sequence. The numerical sequence is a decimal number. The coding of the decimal number takes place in the sequence of the coding range. The conversion of the decimal number takes place in binary-, tertiary or quaternary number system. The decimal number is transformed into another number system and identical numbers of the resulting number of the other number system are assigned to a nucleotide of the nucleic acid. The coding the letters takes place that each letter is assigned to an unique triplet, quadruplet or a quintuplet by nucleotides of nucleic acid to be synthesized. A triplet is assigned to each indication of the character sequence by nucleotides within the coding range of nucleic acid. The nucleic acid has primary hybridizing places and/or spacer. The character sequence denominates the product number, the batch number, the production time and/or the production place of the product. An independent claim is included for a method for identity determination- and origin determination of marked products.	

Tracking Exported Meat Products from Farm to Fork

DNA Traceback® (http://dnatraceback.ca)

DNA TraceBack is a Canadian company offering a traceability system that traces DNA in meat products to verify the exact origin of grocery products. The way the system works is illustrated in the following figure.

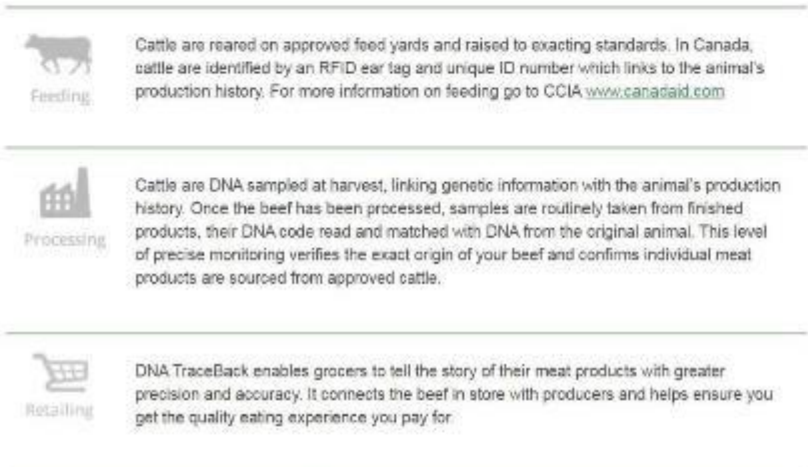


Figure 5. Illustration of DNA TraceBack's traceability system.

Exemplary Patents Related to DNA TraceBack®

Patent or application #	Title	Abstract	Primary Independent Claim
WO/2016/008884	A METHOD FOR DETECTING PCR AMPLIFICATION IN A SAMPLE	The method for marking of liquid products such as oils or oil-based products to its identity proof- and origin proof, comprises marking the product with DNA or RNA having a coding range, whose sequence is assigned to a character sequence. The character sequence is a letter- and/or a numerical sequence. The numerical sequence is a decimal number. The coding of the decimal number takes place	1. A method for detecting PCR amplification of a target DNA molecule in a sample, which method employs: - a forward PCR primer having a sequence that is complementary to the target double stranded nucleic acid and a tail sequence; - a reverse PCR primer having a sequence that

Tracking Exported Meat Products from Farm to Fork

		in the sequence of the coding range. The conversion of the decimal number takes place in binary-, tertiary or quaternary number system. The method for marking of liquid products such as oils or oil-based products to its identity proof- and origin proof, comprises marking the product with DNA or RNA having a coding range, whose sequence is assigned to a character sequence. The character sequence is a letter- and/or a numerical sequence. The numerical sequence is a decimal number. The coding of the decimal number takes place in the sequence of the coding range. The conversion of the decimal number takes place in binary-, tertiary or quaternary number system. The decimal number is transformed into another number system and identical numbers of the resulting number of the other number system are assigned to a nucleotide of the nucleic acid. The coding the letters takes place that each letter is assigned to an unique triplet, quadruplet or a quintuplet by nucleotides of nucleic acid to be synthesized. A triplet is assigned to each indication of the character sequence by nucleotides within the coding range of nucleic acid. The nucleic acid has primary hybridizing places and/or	is complementary to the target double stranded nucleic acid; and - a dual labelled probe containing an oligonucleotide sequence identical to the tail sequence of the forward PCR primer oligonucleotide, and a reporter label and a quencher-label separated by a nuclease susceptible cleavage site, the method comprising the steps of: - incubating the forward and reverse PCR primers, dual labelled probe, and sample together; - performing at least two rounds of PCR to generate a double stranded nucleic acid comprising the tail region and a sequence complementary to the tail region; and - initiating a further round of PCR in which the oligonucleotide probe binds to the sequence complementary to the tail region, whereby the oligonucleotide probe is displaced and cleaved resulting in a detectable signal from the reporter label.

		spacer. The character sequence denominates the product number, the batch number, the production time and/or the production place of the product. An independent claim is included for a method for identity determination- and origin determination of marked products.	

YPB Forensic Covert Tracer
(http://www.ypbsystems.com/technology/forensic_covert_tracer.php)

Chinese-based company YPB has developed an anti-counterfeiting technology based on invisible tracers made from inorganic, non-radioactive rare earth materials that can be attached to any product or packaging as an authenticating identifier. YPB's anti-counterfeiting solution produces a covert and forensic trace signature which, together with a specialized, hand-held scanner or a smartphone app, allows brand owners and others to easily detect and report counterfeits. According to one media report, the active ingredient of this tracer is safe and has been certified by US, EU, and Chinese food and drug administrations for contact with food items, thus allowing the tracer to be embedded directly onto food itself rather than the packaging materials. YPB has estimated that the process of embedding the tracer adds less than a cent to the cost of a 7-cent tamper-proof soy sauce cap, for example. The following figure shows YPB's fine powder of rare earth mineral tracers and its hand-held scanner.

In March, 2016, YPB announced that it has entered into a three-year contract to provide its invisible supply chain authentication solution to a major US casual footwear brand, incorporating the tracer technology into more than 70% of its entire production. At present, there has been no report that YPB's anti-counterfeiting tracer technology has been used commercially in food products. (Note that it would likely be challenging to use this concept on meat.)

Figure 6. YPB's Forensic Covert Tracer and the handheld scanner.

Tracking Exported Meat Products from Farm to Fork

Exemplary Patents Held by YPB

Patent or application #	Title	Abstract	Primary Independent Claim
US 8137811	Multicomponent taggant fibers and method	Taggant fibers and methods of use provide for enhanced protection and security when the fibers are used in documents such as land titles, currency, passports and other documents of value. The taggant fibers consist of a minimum of two separate zones with each zone containing a different taggant to emit different wave lengths when excited. The taggants may consist of organic or inorganic compounds as are conventionally known and can be manufactured using for example polymeric materials which can be extruded during the fiber manufacturing process. Authentication of the fibers or documents containing such fibers can be readily viewed using conventional techniques.	1. A multicomponent taggant fiber comprising: a. a first zone, said first zone comprising a first polymer, a first taggant, said first taggant within said first polymer; b. a second zone, said second zone separate from said first zone and comprising a second polymer, a second taggant, said second taggant within said second polymer, said first taggant being chemically incompatible upon contact with said second taggant.

Tracking Exported Meat Products from Farm to Fork

Invention Suggestions

The goal of this RFI is to seek traceability solutions that can be used in Common Export Mode and can provide complete and continuous traceability of meat products from the farm to consumer households, even when the original packaging materials are entirely discarded when the primals are further processed and packed in exporting countries. Ideally, the traceability will be tamper-proof and available to consumers.

Solutions may include, but are not limited to, the following areas of innovation:

- Geographic tracing and genetic tracing technologies that are independent from the meat product packaging and enable consumers to learn about the food origin at the point of sale;
- Mobile-engaged analytical technologies that can facilitate the tracking and tracing of meat products from farm to fork;
- Anti-tampering or tamper evident smart packaging technologies (for example, invisible tracers, security inks, etc.) that can facilitate the tracking and tracing of meat products from farm to fork; and
- Solutions may require a consumer or salesperson to interact with the product at point of sale.

Please note that the following directions are out of scope of this RFI:

- RFID technologies, unless such technologies can operate independently from the meat product packaging and in a tamper-proof or tamper-evident way;
- Traceability systems that require verification and analysis at laboratories; and
- Track and tracing technologies that are associated solely with the food packaging (i.e. wherein the traceability is lost when the packaging materials are discarded).

Solutions should be generally regarded as safe (GRAS) according to US Food and Drug Administration (FDA) standards

Tracking Exported Meat Products from Farm to Fork

Current Market Review

Market for Meat Products

Australia processed 2,547,000 tons of beef and veal in 2015, of which 1,854,000 tons were exported. Australia is the world's third largest exporter in this category of meat products, after India and Brazil. In the past five years, the ratio of exported beef and veal to total production in Australia has been steadily increasing, from 65.4% in 2012 to 72.8% in 2015. On the import side, the amount of global imported beef and veal has increased from 6,680,000 tons to 7,583,000 tons, with China having the most remarkable increase, from 86,000 tons in 2012 to a record high of 663,000 tons in 2015.

Market for Traceability Technology

Consumer demand for tracking the origin of food products is fueling growth of traceability technology. Allied Market Research has predicted that the global market for food traceability technologies (including but not exclusive to red meat products) will grow by 8.7% annually, to reach revenue of USD 14.1 billion by 2020. According to a 2013 BBC Research report, the meat traceability market is expected to achieve the highest revenues of the global food traceability market, growing from nearly $3.1 billion in 2011 to about $4.5 billion in 2016, at a CAGR of 8.0% from 2011 to 2016.

Market	2009	2010	2011	2016	CAGR% 2011-2016
Meat	2,664.5	2,867.1	3,087.8	4,527.1	8.0
Fresh produce and seeds	1,119.7	1,175.3	1,230.3	2,089.5	11.2
Beverages	698.7	718.7	801.9	1,037.6	5.3
Dairy	697.0	750.2	809.2	1,092.9	6.2
Fisheries	476.4	505.0	535.4	1,205.4	17.6
Others	470.3	507.0	548.6	776.3	7.2
Total	6,126.6	6,553.3	7,013.2	10,728.8	8.9

Table 2. Global food traceability market, by application, through 2016 (in millions) (Source: BCC Research).

Tracking Exported Meat Products from Farm to Fork

Competitive Landscape

CARLISLE TECHNOLOGY, Canada -- Carlisle Technology provides integrated information solutions, with specialization in product traceability and recall management primarily to the food industry in North America. Its integrated solutions enable processors to achieve higher standards of plant productivity, product quality, and food safety.

EUROFINS SCIENTIFIC, Luxembourg -- Eurofins Scientific is an international life sciences company which provides a unique range of analytical testing services to clients across multiple industries. Eurofins believes it is the world leader in the testing of food, environment, and pharmaceutical products and that it is also one of the global independent market leaders in certain testing and laboratory services for agroscience, genomics, and discovery pharmacology and for supporting clinical studies. In addition, Eurofins is one of the significant emerging players in specialty clinical diagnostic testing in Europe and the USA.

FOOD LOGIQ CANADA INC., Canada – Food Logiq provides solutions relating to the day-to-day production system of record for traceability, food safety, and sustainability for food companies and value chains. The solutions are utilized by produce and grain growers, livestock packers, processors, distributors, and wholesalers, retailers, and restaurant chains. The software is social networking-based and supports modules for the following areas: consumer mobile access; product ID and traceability; internal and external audit and lab testing; and quality management procedures automation.

IDENTIGEN LIMITED., USA -- IdentiGEN is a leading global provider of DNA-based identification and verification solutions for enhancing food safety and building consumer confidence in the food and agriculture industries. Its signature product, the proprietary DNA TraceBack® traceability system, provides food retailers, processors, and producers with the capability to identify and trace the source of protein products throughout the entire supply chain. This advanced level of supply chain transparency enables food businesses to source with integrity and provides value-added assurance for consumers.

INTERNATIONAL TRACEABILITY SYSTEMS LIMITED, India -- International Traceability Systems Limited (ITS) has business interests in trading, mining, security and power systems, housing, and e-agriculture. The company provides services, develops, manufactures, and markets products to its clients, including consultancy for agriculture, livestock, and food processing and training on record maintenance for e-agriculture management.

SAFETRACES, USA – SafeTrace provides natural, edible, odorless, tasteless, and on-food traceability solutions for tracing of origin information in minutes for food and other industries, including environmental monitoring and healthcare. The company was founded in 2015 and is based in Livermore, California.

YOTTAMARK, INC., USA -- YottaMark's provides fresh food traceability solutions, such as HarvestMark, the company's most prominent brand. The company's products are used in various sectors, such as the pharmaceutical, electronics, fresh

Tracking Exported Meat Products from Farm to Fork

produce, and consumer packaged goods industries. YottaMark has five issued U.S. patents, and more are pending in the U.S. and other countries.

YPB GROUP LIMITED, Australia -- YPB is a brand protection and customer engagement solutions company. YPB's patented anti-counterfeit technology, combined with its security packaging and anti-theft solutions, consulting services, and YPB's proprietary CONNECT platform, enables clients to protect their high value brands and vital documents from the risks of counterfeit, product diversion, and theft, while providing the tools to connect directly with their customers. YPB is expanding its global footprint with an established presence in Australia, China, Thailand, USA, Mexico, and India.

Tracking Exported Meat Products from Farm to Fork

References

- About the (Australian) National Livestock Identification System, https://www.mla.com.au/meat-safety-and-traceability/red-meat-integrity-system/about-the-national-livestock-identification-system/
- Advances in Food Traceability Techniques and Technologies: Improving Quality Throughout the Food Chain, *Woodhead Publishing*, Jun 18, 2016
- Allied Market Research Report: Advanced Packaging and Tracking Technologies, Jan. 2014
- Australian Meat Processor Corporation, http://www.ampc.com.au/
- Authentication of meat and meat products, *Meat Science* 86 (2010) 577–587
- BCC Research Report: FOOD TRACEABILITY: TECHNOLOGIES AND GLOBAL MARKETS, FOD045A
- Beef traceability with GS1 standards, https://www.gs1ie.org/Download_Files/Traceability_Files/Beef-Traceability-Case-Study.pdf
- DNA Barcoding as a Molecular Tool to Track Down Mislabeling and Food Piracy, *Diversity* 2016, *8*(1), 2
- DNA barcoding as a new tool for food traceability, *Food Research International* 50 (2013) 55–63
- Food traceability: New trends and recent advances. A review, *Food Control* 57 (2015) 393-401
- Genetic traceability of livestock products: A review, *Meat Science* 77 (2007) 437–449
- Geotraceability: an innovative concept to enhance conventional traceability in the agri-food chain, *Biotechnol. Agron. Soc. Environ.* 2010 14(4), 633-642
- Meat Standards Australia, https://www.mla.com.au/marketing-beef-and-lamb/meat-standards-australia/Post-slaughter traceability, *Meat Science* 80 (2008) 66–74
- Primal Cut, Wikipedia. https://en.wikipedia.org/wiki/Primal_cut
- Technology protects against 'counterfeit' Australian meat in export markets, http://www.beefcentral.com/features/beef-2015-report/technology-protecting-against-counterfeit-australian-meat-in-export-markets/
- USDA's Livestock and Poultry: World Markets and Trade, http://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.PDF

Tracking Exported Meat Products from Farm to Fork

Awards for Selected Solutions

We will conduct a global review of your invention using a team of experts who will examine the technology, potential products, markets, future customers and existing landscape.

We will select the best proposed solutions gathered during the circulation period of this RFI.

We will pay any awards in installments, as per your written and executed contract with us.

Tracking Exported Meat Products from Farm to Fork

Notices

Please contact:

Xinova, LLC
701 Fifth Avenue, Suite 4100
Seattle, WA 98104 USA

Xinova Asia Pte. Ltd.
150 Beach Road, # 08-06/08, Gateway West
Singapore 189720

Inquiries:
Brett Kensett-Smith
bksmith@xinova.com

RFI template version: 5.00

Tracking Exported Meat Products from Farm to Fork

Instructions for Submission

Please read carefully before submitting Solution Reports

1. Terms and conditions of this RFI apply to anyone submitting proposed solutions.
2. We accept only original, new and novel proposed solutions. Proposed solutions not satisfying these requirements will not be considered.
3. Please direct any questions you may have to your local Xinova office. Suggestions to refine, broaden or to include new information are welcome. Any suggestions you provide are given entirely voluntarily and shall not create any confidentiality obligation for us. We may use the suggestions without obligation or restriction of any kind.
4. You may submit one or more Solution Reports during the circulation period of this RFI. Please see the first page for the circulation period. We will not accept any proposed solutions after the RFI Closing Date.
5. Please contact your local Xinova office for the Solution Report form. Please fill out the form accurately and completely. Incomplete forms may be returned to you for further action and may not be considered for acceptance.
6. Each proposed solution should be embodied in one Solution Report form. Do not include multiple proposed solutions in one form.
7. We reserve the right to cancel or terminate this RFI at any time.
8. We may share information on select proposed solutions and/or provide feedback to some or all of the inventors who submitted Solution Reports in response to this RFI. All information shared and/or feedback provided is our confidential information.
9. We will not retain any rights or obligations with respect to declined proposed solutions.

Appendix 6: RFI170115 Intelligent Interactive Packaging

Xinova is looking for your invention

REQUEST FOR INVENTION (RFI)

Intelligent Interactive Packaging

Key words: Interactive packaging; Intelligent packaging; Smart packaging; Advanced packaging; Functional packaging; Two-way communication; Red meat products; System integrity; Supply Chain; Asian markets; Brand message; Feedback provider; Packaging/user interface; Information provider; Database; Network; Consumer engagement; Understanding of market trends; Food packaging indicator; Integrity indicator; Time-temperature; Freshness indicators; Enhanced communication; Electronic animation; Augmented reality; Sensors in packaging; Consumer experiences; Information collection; Information communication; Cloud storage; Consumer insight; Mobile-engaged; Mobile devices; Real-time communication.

Circulation Date:	Request for Invention
June 1, 2017	RFI 170115

Please read the instructions for Submission for more information on method, terms and conditions of your submission of Solution Reports. For the most recent closing date for all Requests for Invention please log in to your account at http://network.xinova.com.

Xinova

Intelligent Interactive Packaging

Problem Definition

For years, packaging has fulfilled the important needs of the supply chain in protecting products by retaining their integrity, bringing them safely to market without damage and providing communication to the consumer regarding the product and its attributes. The further important role for packaging is as a key communicator for the product. With the right application and insights it can be turned into a powerful media channel that communicates and appeals to a diverse audience, enhances brand message and leverages whatever is relevant in that moment.

One market in which this is the case is with red meat exports from Australia into Asia. Australia exports over 80% of its red meat production, over 6% of which is exported to China, increasing annually. Asian consumer demand for premium imported beef is expected to continue to grow, driven by increasing urbanisation, higher disposable incomes and health awareness. However, Australia's growth in Asian meat import markets cannot be taken for granted, as other countries (eg Brazil and Uruguay), continue to threaten Australian market share with the same claims for clean and green meat products.

In the red meat industry, there is a growing demand by consumers for foods perceived as natural, fresh-tasting, nutritious, healthy and safe (Grunert & Valli, 2001; Morrissey, Sheehy, Galvin, Kerryh, & Buckleyh, 1998). A survey commissioned by MLA in 2016 of Chinese consumers indicated that "colour", "flavour" and "freshness" are among the most important intrinsic quality cues for meat. All these quality and safety properties are highly dependent on meat packaging materials and technologies. Improvements to packaging could influence consumers' appreciation for Australian beef and recognise that it offers advantages that are worth paying more for, such as safety and consistent quality standards as well as its superiority when it comes to taste and nutritional value.

New packaging technologies and materials are available which address some of the communicative issues mentioned above. However, only a limited number of these technologies address the issues in the Chinese red meat market. For example, current freshness indicators tend to be a date fixed to the original packing date, which may not be a true reflection of the freshness. Moreover, the knowledge of how to handle and cook Western-style cuts is typically limited in Asian markets. Beef and beef offal have traditionally been used in a variety of stir fry, stew, soup and hot pot recipes in China. Due to lower familiarity with how to cook beef, particularly western-style cuts, beef meals are typically eaten out. The quality of premium cuts may be compromised by inappropriate cooking techniques. Furthermore, the meat industry has little idea of the consumer's at home experience with meat products.

Two-way communication between the consumer and the meat industry could be beneficial to both parties. Consumer insight gained through package and product

Intelligent Interactive Packaging

interaction could benefit the meat industry's understanding of how consumers are handling their products, eg in terms of storage and cooking, and what information they are looking for prior to cooking. Furthermore, interesting, informative and interactive packaging can differentiate meat products in the marketplace, especially where the consumer finds value in the packaging to help them with their purchase. It may also address counterfeiting problems with high-value products.

This RFI is focused on finding interactive intelligent packaging solutions that can both educate & inform the consumer on how to deal with the meat they have bought, and to provide feedback to the meat industry as to what the consumer is doing with the product and how they are handling it. It focuses on improvements and innovation at the packaging/user interface, principally to enhance communication. The packaging needs to communicate more effectively both on shelf and at home, to support the meat industry in a more innovative manner and be designed with the consumer in mind.

Why This Problem Is Valuable to Solve

The Chinese meat export market has grown rapidly over the past couple of years and is now Australia's fourth largest beef and largest sheep meat export market by volume, exporting 148,000 tonnes of beef and 60,000 tonnes of sheep meat to the market in 2015. However, the Australian red meat industry has limited insights of Chinese markets. Chinese (and other Asian) consumers handle, cook and serve red meat differently to Western society. They also have limited experience with cooking Western-style cuts. The differences in cooking present a great impact on selecting and handling Australian red meat products. Currently, there is limited or impractical access to this information. This missing information to consumer and producer/retailor/ exporter states unique challenges to foreign exporters including Australia.

Also, Australian meat is typically differentiated from equivalent products in Asia as a high-quality meat product that has been grown in clean and green spaces. It is becoming more difficult to use this claim as a differentiator, as other countries, such as Brazil and Uruguay, are making similar claims.

Therefore, there is an opportunity to further improve the relationship of Asian and Chinese consumers with Australian red meat products through better, more functional packaging improved packaging could be used to build a strong network of local consumers through in-store and at-home interaction and engagement. It may assist to maintain these relationships, while providing a detailed understanding of market trends and the supply chain.

Intelligent Interactive Packaging

Background

The Australian meat industry recognised many years ago that packing and delivery are two critical links in the beef supply chain, particularly for international customers. The Australian processing sector employs the latest packaging technologies to ensure that Australian beef is delivered to export markets in the same high quality condition in which it left the packing house. Australian chilled beef primal cuts are vacuum packed to maintain freshness and quality and to ensure extended shelf life. Strict temperature control is maintained throughout the delivery process, inhibiting bacterial growth and giving Australian beef a shelf life of up to 120 days under optimal storage conditions.

There are a number of different beef packaging methods that may be used to ensure the best possible presentation of beef to consumers. Some of these provide added benefits such as extended shelf life and the convenience of having a "shelf ready" product out of the transportation container. The choice of packaging will depend on the purpose of packaging as well as the cut and grade of the beef. It is likely that more advanced packaging will be economical where beef is packaged earlier in the supply chain, and where it is being considered as a product rather than a commodity. Advanced packaging methods such as modified atmosphere packing, vacuum packing and aluminium foiled pouching allow beef to be converted to a "shelf ready" state earlier in the supply chain minimising possible areas of contamination, achieving better product quality control and integrity, and preventing physical damage in transit. Table 1 outlines some widely used beef packaging.

Table 1 Types of Beef Packaging Source: MLA (2012)

Method	Description
Individually wrapped (IW)	• Cuts of meat wrapped individually in sheet, netting or bags of approved material. • Common for larger primal cuts. • Suitable to be used by processors and/or wholesalers in the supply chain.
Layer packed (LP)	• Two or more layers of product packed into a carton with a separating material between each level. • Common in flank steaks and backstraps for both primal and portion cuts.

Intelligent Interactive Packaging

	• Suitable to be used by processors in the supply chain.
Multi wrapped (MW)	• A single bag that contains two or more cuts. • Common in small and medium size primal cuts such as chuck tenders. • Suitable to be used by processors and/or wholesalers in the supply chain.
Tray packed (TP)	• Meat is packaged on a supporting tray (e.g. Styrofoam tray) and then covered in a plastic film. • Common in smaller primal cuts or portion controlled cuts. • Suitable to be used by processor, wholesaler and/or retailer in the supply chain.
Modified atmosphere packed (MAP)	• Meat is contained in a modified atmosphere "bubble" by packaging that is impermeable to gases. This maintains beef quality and extends shelf life by restricting bacterial growth. • Common in primal cuts, retail ready and portion controlled cuts. • Suitable to be used by processors, wholesalers and/or retailers in the supply chain
Vacuum packed (VAC)	• Meat is contained in a gas impermeable wrapper which is then vacuum sealed. Bacterial growth is slowed by absence of oxygen. • Suitable across all of the above packaging processes but is limited to certain MAP packaging. Can be used for primal through to portion controlled packaging. • Suitable to be used by processors, wholesalers and/or retailers in the supply chain.
Aluminium foiled pouch (AFP)	• Similar to VAC but uses aluminium foil on one side to produce a pouch. The pouch is then vacuum sealed. The aluminium side serves as part of the label and prevents light from reaching the beef product. • Designed as a portion controlled, "shelf ready" packaging system. • Suitable to be

Intelligent Interactive Packaging

	used by processors, wholesalers and/or retailers in the supply chain.

95% of Australian beef is exported as vacuum packed primals in cartons. The packaging is discarded before sale, as the meat tends to be processed further and repackaged soon after entry into the country of import.

Current Technology and Prior Solution Attempts

Smart packaging has been defined as packaging that does more than the important though traditional functions of storing, protecting and providing information about the product (Kerry and Butler, 2008). This kind of packaging has been classified in many other different ways – the terms 'active', 'controlled', 'intelligent', 'diagnostic', 'functional', 'communicative' and 'enhanced' have all been used.

Following are some example of "Smart Packaging" technologies that have been developed for a range of industries. The classification of smart packaging technologies may have minor discrepancies from different sources, but it can be generally described as in Table 2:

Table 2 Classification of Smart Packaging

Type of Smart Packaging	Descriptions
Active Packaging	The incorporation of certain components into packaging systems that release or absorb substances from or into the packed food or the surrounding environment so as to prolong shelf life and sustain the quality, safety and sensory characteristics of the food (Realini C. E. & Marcos B. 2014). Includes: Moisture Absorber; Oxygen Scavenger; Antimicrobial Packaging; Carbon Dioxide Emitter; Antioxidant Packaging; Colour Formation Packaging; Odor Absorber; Edible Coating; UV Blocking Packaging
Modified Atmosphere Packaging (MAP)	Packaging involving the alteration of surrounding air/internal atmosphere of a package with gases (e.g., oxygen, carbon dioxide and nitrogen) (BCC Research). Includes: Low Oxygen (or anoxic) MAP and Vacuum Packaging, and High Oxygen MAP.
Intelligent Packaging	Packaging capable of detecting, sensing, recording, tracing, or communicating information about the quality and/or the

Intelligent Interactive Packaging

	state of the product during the whole supply chain (Realini C. E. & Marcos B. 2014). Includes: Time Temperature Indicators (TTIs), Integrity Indicator, Freshness Indicator, Barcodes and Radio-frequency Identification System (RFID).

Interactive packaging differs from smart packaging in that the 'smart' elements are largely external to the packaging. With this approach, the packaging remains essentially unchanged but the external smart device can only operate in conjunction with the packaging.

Intelligent Packaging Indicators

Based on types of information they convey; indicators can be generally classified into three categories:

1. Freshness indicators;
2. Integrity indicators; and
3. Time-temperature indicators (TTIs)

The conveyed information, which can be presence or absence of a substance, the extent of a reaction between two or more substances, or the concentration of a specific substance or class of substances most often is displayed by immediate visual changes, for example, different colour intensities or the diffusion of a dye along the indicator geometry (Trends in Food Science & Technology). Although there are differences among types of information conveyed and the mechanisms to obtain such information, these three types of indicators can all communicate food safety related information to retailers and consumers.

Table 3 outlines commercial applications of indicators that may help retailers, consumers or other stakeholders throughout the supply chain to determine whether food safety has been compromised. Some commercial applications in other food sectors other than red meats are also included since the mechanism or the format of the indicator itself may be adopted for red meat industry.

Table 3 List of commercial applications of food indicator technologies

Trade or Product Name	Supplier	Format/Function
Freshness Indicator		
Fresh Tag®	COX Technologies	Colourimetric indicator
SensorQ™	FQSI Inc.	pH-sensing indicator
Freshness Guard1	UPM Raflatac	Colourimetric indicator (silver nanolayers)

Intelligent Interactive Packaging

RipeSense™	Ripesense Limited	Colourimetric indicator for ripeness
Integrity Indicator		
Timestrip®	Timestrip Ltd.	Time indicator label
Novas®	Insignia Technologies Ltd.	Time indicator label
Best-by®	FreshPoint Lab.	Time indicator label
Ageless Eye®	Mitsubishi Gas Chemical Inc.	Gas indicator tablet
O2Sense	Freshpoint Lab	Gas indicator tablet
Vitalon®*	Toagosei Chemical Inc.	CO_2 gas indicator
Freshilizer*	Toppan Printing Co	CO_2 gas indicator
Tell-Tab	IMPAK, USA	O_2 gas indicator
Time Temperature Indicators (TTIs)		
3M Monitor Mark®	3M Company	Fatty acid ester TTI
Keep-it®	Keep-it Technologies	Chemical TTI
Fresh-Check®	Temptime Corp.	Polymerization reaction TTI
VITSAB®	VITSAB International AB	Enzymatic TTI
OnVu®	Freshpoint and Ciba	Photochemical reaction TTI
TopCryo®	TRACEO	Microbiological TTI
FreshCode®	Varcode Ltd.	Barcode based label TTI
Tempix®	Tempix AB	Barcode based label TTI

Freshness indicators monitor the quality of the packed food by reacting to changes taking place in the package leading to changes in the concentration of metabolites such as glucose, organic acids (e.g. L-lactic acid), ethanol, carbon dioxide, biogenic amines, volatile nitrogen compounds or sulphuric compounds (Realini C. E. & Marcos B. 2014). By indirect detection of target metabolites, freshness indicators give direct visual information, e.g., colour changes indicating the freshness of the product.

Commercial applications of freshness indicators have not achieved much success. Figure 1 shows a few product examples (shown below).

Intelligent Interactive Packaging

Figure 1 Examples of freshness indicators: (a) SensorQ™, a stick-on sensor label applied by the meat packer to the inside of meat and poultry packages. The label detects the gaseous byproducts of food-borne bacteria growing inside the package; (b) Freshness Guard, a freshness indicator for poultry meat based on a nanolayer of silver that reacts with hydrogen sulphide, a breakdown product of cysteine; (c) RipeSense® changes colour by reacting to the aroma released by fruit as it ripens.

One type of **integrity indictor** provides information on how long a product has been opened. Such indicator is activated at the moment of breakage of the package and then shows a colour change with time. It can either notify consumers of an unintended leak within the packaging or encourage them to use the food product before the expiration date. Figure 2 shows three commercial examples (a-c) of such integrity indicators.

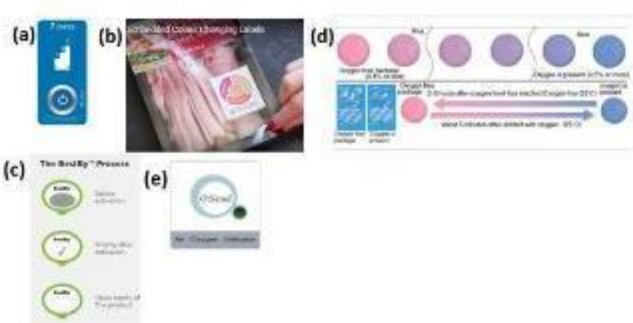


Figure 2 Examples of integrity indicators: (a) Timestrip® : offering a helpful visual reminder of service and maintenance schedules for consumable components; (b) Embedded label into a film lid and activated when consumer opens the package and triggers a timer to show a strong colour change as the food loses freshness; (c) BestBy® a visual indicator that clearly signals the end of the product's secondary shelf life, encouraging consumers to use the product at its best, and designed to stimulate re-purchase when the product is determined to have expired; (d) AGELESS EYE: reversible O2 indicator; when exposed to oxygen, the AGELESS EYE turns blue or purple, then returns to its original pink colour as the oxygen in the

Intelligent Interactive Packaging

container is reduced; (e) O2Sense: patent pending oxygen sensing products aimed at the Modified Atmosphere Packaging (MAP) market; can either be eye-readable or machine readable.

TTIs are indicators that can provide visible response to mechanical, chemical, electrochemical, enzymatic of microbiological changes to the food products throughout the supply chain. Figure 3 shows several commercial applications of TTIs which use time-temperature dependence of various reactions for continuous monitoring of the time and temperature history of the packed food.

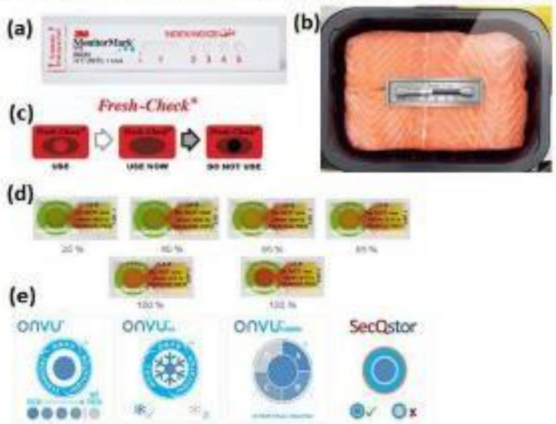


Figure 3 Examples of TTIs: (a) MonitorMark™: self-adhesive label for monitoring thermal exposure of temperature-sensitive products during transportation and storage; (b) Keep-it: TTI that predicts remaining shelf-life; (c) Fresh-Check®: self-adhesive TTI specifically formulated to match the shelf life of the food products to which it is affixed; (d) VITSAB: customized TTI label, the L5-8 Seafood label providing consumers with a full history of customized cold chain information; (e) OnVu™: tailored TTIs calibrated to cater for the different spoilage behaviour of various foods and beverages and to be highly accurate and consistent in recording and displaying the freshness of the products, based on their time and temperature histories.

Barcodes

There are two main track and trace packaging technologies: barcodes and radio-frequency identification systems (RFID). A barcode consists of a series of parallel, adjacent bars and spaces. Predefined bar and space patterns or "symbologies" are used to encode small strings of character data into a printed symbol. The encoded information is read by an optical barcode scanner that sends the information to a system where it is stored and processed.

Intelligent Interactive Packaging

RFID
Radio-frequency identification (RFID) tags use RF electromagnetic fields to store and communicate real-time information of the product for automatic product identification and traceability. A typical RFID tag consists of an integrated circuit attached to an antenna for the transmission of information stored in the chip to a reader. RFID tags differ in size but are generally small so that they can be attached or incorporated in product packaging. RFID technologies include two types of tags: active and passive tags. The main difference between the two is the active tags use a battery whereas the passive tags do not. Active tags have much larger data storage capacity and typically are used in larger objects that require tracking over long distance such as container and rail cars. Passive RFID tags do not have a power source so that they depend on a transceiver for activation. Passive tags can be applied in many forms such as implantation, embedded under skin, mounted on substrates, between layers, and embedded in packages. RFID technologies can also be classified into three groups based on the RF frequency: Low-Frequency RFID Tags, High-Frequency RFID Tags and Ultra-High-Frequency RFID Tags.

Figure 4 illustrates several commercially available products of non-integrated and non-flexible sensor-enabled RFID tags.

Figure 4 Easy2log© semi-Passive UHF temperature RFID tag; (b) TempTRIP® UHF temperature RFID tag; (c) Intelleflex TMT-8500, Semi-passive UHF temperature RFID tag; (d) SecureRF Lime Tag™ semi-passive UHF temperature RFID tag

Interactive packaging – enhanced communication directly via packaging

Animated graphics using lenticular labels
A lenticular label is a simple low- cost optical way of providing striking three-dimensional (3D) optical effects, image flipping, zooming and morphing, to enhance visual communication between a consumer and the packaging. The technology is not new and has been applied over the years to CD, movie and magazine covers,

Intelligent Interactive Packaging

toys, greetings cards, book covers, postage stamps, bottle labels and other novelty items. Much of these applications have been little more than visual tricks in the marketer's tool kit, designed to differentiate products in a crowded shelf space. But with recent improvements in lenticular technology to provide better resolution, brand marketers and package designers are re- evaluating the potential of lenticular effects (and also holographic images) on packaging as a more sophisticated way to communicate product attributes and provenance to a consumer (Swientek, 2002).

LO TENGO® is a Malbec wine from Argentina that uses a photograph of legs of two dancers dancing on a paved street in Argentina on a lenticular label on its wine bottle, as shown in Figure 5. When consumers view the label from different angles or walk past the bottle, they see the knees and toes of the two dancers flipping back and force, which suggests something of the passion of old-time Argentina.

Figure 5 LO TENGO's lenticular label that reinforces the product's provenance.

Electronic animated lighting effects on packaging

Moving up in terms of cost and level of complexity, are packaging communication possibilities using today's miniature electronics, circuitry and power sources. The first of these to be considered are powered visual labels using the phenomenon of electroluminescence (EL), whereby a material emits light in response to the passage of an electric current. EL devices can be produced in thin flexible format that produce a light of different colours when stimulated by AC current, whilst at the same time producing no heat. For label purposes, a colour image can be sandwiched on top of the EL device so it becomes back- lit when the device is activated, creating 2D illuminated display.

One disadvantage of this type of packaging is the quantity of waste generated at disposal. The base contains two AAA batteries and associated electronics housed in a relatively heavy plastic casing, which cannot be considered a good example of sustainable packaging, which more and more consumers are looking for. This factor is a basic problem with the use of conventional electronics in disposable packaging, leading to significant consumer resistance to purchase, which could partially explain why this type of packaging is so transient.

Intelligent Interactive Packaging

Electronic animated graphics and sound on packaging

Combining light and sound effects is also possible using conventional electronics but the complexity is likely to add at least several dollars to the cost of a package, putting it out of bounds for all but high value products.

Using conventional silicon device circuitry with LED or EL illumination and sound chip technology, all driven by coin cell battery power on packaging, enables speech and sound on packaging. It is just a question of time before electronic smart packaging becomes more widely used and useful to society, moving away from novelty towards more serious applications. There are many potentially life-saving applications in the healthcare sector, where smart packaging could significantly assist patients to adhere to medication regimes by visual communication and spoken electronic reminders.

The question of lack of sustainability and cost remain, which could lessen with the advent of printed electronics. In all forms of electronic smart packaging however, a significant technological problem to overcome is the power drain from miniature or even printed batteries that can severely limit the lifetime and scope of the sound and vision effects. One solution to this problem for disposable packaged items is to separate the power source from the packaging and couple these together via the use of smart shelves or other surfaces that incorporate wireless power.

Electronic animation with integrated wireless power

In a transformer, coil- to-coil inductive coupling permits the transfer via magnetic fields of electric current from one coil to another. This principle can be applied to provide power to packaging to drive displays and sound when the package sits on an activated surface below which there is a powered primary coil. This interacts with a printed copper receiver coil inside the packaging. Backlit EL display labels would be the technology of choice for this arrangement, since they produce no heat when illuminated and are voltage compatible with 110 V AC.

At the Consumer Electronics Show in Las Vegas in 2011, Fulton Innovation (2011) showed what might be possible in the future in terms of real- time communication from the package to the consumer to differentiate a brand in a unique eye-catching way.

However, the greatest commercial application of this technology probably lies with the retailer, as the pack could also be configured to communicate via the store shelf back to the store's inventory management system. Product quantities could be identified and tracked, expiration dates monitored, and new stock automatically ordered when supplies are low, all to help reduce lost sales. Consumer benefits might accrue in the smart home of the future.

Intelligent Interactive Packaging

Interactive packaging – enhanced communication via internet connectivity

Augmented reality (AR)

Augmented reality (AR) refers to the technology of superimposing computer generated content, such as sound, video, graphics or GPS data, over a real-world view of the environment (How Stuff Works, 2011), familiar to sports TV fans worldwide as arrows indicating the movement of players or yardage lines marked out that do not actually exist on the playing surface. From a packaging perspective, the augmented content can be superimposed on real- world images, such as the packaging itself. The fused real and virtual content can be viewed on display screens, which can be a video, TV, PC, smart phone or tablet screen, either in the home or in-store. When brand- developed applications are available and can be downloaded for free to a smart phone or smart tablet, together with logo-recognition software, the stage is set for some exciting developments in interactive packaging.

Häagen-Dazs® has developed an augmented reality smartphone app that allows consumers to watch a two-minute video while waiting for their ice cream to reach the ideal temperature for consumption, as shown in Figure 6. The Häagen-Dazs® Concerto Timer app uses 3D Kinect technology to provide consumers with an augmented reality experience, while also playing music.

Figure 6 Häagen-Dazs's® augment reality smartphone app showing a virtual violin performance

Webcam-based augmented reality

The most successful use of webcam-based AR on packaging to date has been initiated in France on Nestlé children's cereal packets, where software from Dassault Systèmes has allowed true customer interaction in the form of a range of on- line interactive games and interactions. In these promotions, the cereal package is purchased and taken home where AR can be experienced via a personal PC and webcam. The packaging itself is the platform on which the AR content is projected. Consumers hold the package in front of the webcam and the computer generated game is superimposed on it. Playing the game involves watching the

Intelligent Interactive Packaging

webcam image and moving and tilting the packaging, so the packaging becomes an AR game console.

There is no doubt that these AR developments are attracting a lot of attention and, being interactive, they have the advantage of engaging the consumer for a longer period than some of the other light and sound packaging effects discussed earlier. AR strongly differentiates brands from the competition and has the potential to bridge the communication and emotional gap between a brand and a consumer. The digital marketing of brands is developing rapidly and for a game the PC/webcam/TV environment can provide the best experience, particularly if large screen and 3D effects become more widespread. However, the smart phone and tablet platform has the advantage of mobility and has been quick to respond to AR.

Smart phone/tablet- based augmented reality

All that is needed to enter the mobile marketing world of AR is an internet-capable smart phone or tablet with a camera and a previously downloaded software app. When the object is scanned with the camera, the device immediately displays the additional AR content.

Ben & Jerry's® was an early adopter of this type of AR with a free iPhone app containing a programme called Moo Vision, entertaining consumers by giving them product information, facts and AR content, by pointing the iPhone camera at the carton lid of one of the flavours. For example, imaging the lid of the New York Super Fudge Chunk flavour presents a virtual tour of New York, with the Statue of Liberty holding an ice cream cone. This software development marked an important future trend – that of eliminating the need for markers such as QR codes, or coded squares like those used on the Nestlé® cereal packages, to trigger an AR response. Since this technology does not rely on computer generated symbols for identification, relying instead on software to search for existing visual patterns on the product packaging, the existing packaging does not need to be specially designed and printed for the user to access the AR content.

Intelligent Interactive Packaging

Invention Suggestions

This RFI seeks packaging solutions that can be used to interact with consumers and collect information during transport, in-store storage, retail and at-home storage and use. The information can be stored in the cloud and analysed for further application.

Solutions may include, but are not limited to:

- Sensor(s) for recording information about temperature, location, time and storage conditions
- Devices or systems to allow consumers to interact with the product, where the interaction can be analysed to gain consumer insights and behaviours
- Mobile-engaged intelligent packaging technologies

Information collected by the packaging should be useful to inform the meat industry about how the product is being stored and used such that, when analysed, it can help improve the consumer experience. For example, this may include information about how the meat has been stored either or both in the supply chain and the consumer, recipes the consumer has been searching or using, where the consumer is, etc.

Information communicated with consumers should be useful to the consumer and engage the consumer, such that the consumer is motivated to interact with the proposed solution(s). The type of information communicated with the consumer may include recipes directly related to the product, loyalty awards, dynamic best by information (which takes into account the storage life of the meat with which the packaging is associated), provenance information, and so on. As an example, the dynamic best by information may determine the best recipe to use given the condition of the product. Or, it may be determined that a majority of consumers use a cut of meat for a completely different cooking purpose than that which is intended. The type of recipe suggested may also take into account other conditions, such as available time to cook it.

Intelligent Interactive Packaging

Current Market Review

Market of Meat Products

Australia processed 2,547,000 tons of beef and veal in 2015 of which 1,854,000 tons were exported. Australia is the world's third largest exporter in this category of meat products, after India and Brazil. In the past five years, the ratio of exported beef and veal to total production in Australia has been steadily increasing, from 65.4% in 2012 to 72.8% in 2015. On the import side, the amount of global imported beef and veal has increased from 6,680,000 tons to 7,583,000 tons, with China having the most remarkable increase from 86,000 tons in 2012 to a record high of 663,000 tons in 2015.

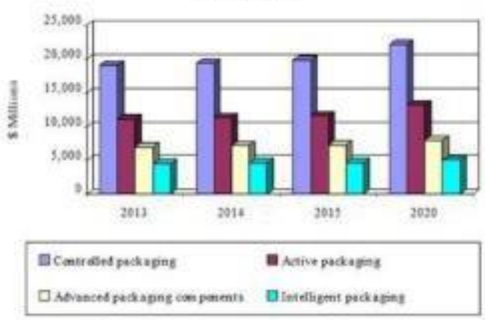
Market of Smart Packaging

According to a BCC report, global advanced packaging market revenues were about $42.5 billion in 2014, and they are estimated to grow at a five-year compound annual growth rate (CAGR) of 2.2% through 2020 to about 48.3 billion 2. Globally, controlled packaging accounted for the highest revenue within the advanced packaging market followed by active packaging. Figure 7 shows the global revenue for advanced packaging by type, through 2020 (BCC report).

GLOBAL REVENUE FOR ADVANCED PACKAGING BY TYPE, THROUGH 2020 ($ MILLIONS)

Type	2013	2014	2015	2020	CAGR% 2015-2020
Controlled packaging	19,040.6	19,347.7	19,858.3	22,158.2	2.2
Active packaging	11,118.4	11,357.6	11,658.4	13,192.0	2.5
Advanced packaging components	7,020.8	7,236.0	7,279.8	8,003.5	1.9
Intelligent packaging	4,461.8	4,547.7	4,576.8	4,942.2	1.5
Total	41,641.6	42,489.0	4,3373.3	48,295.9	2.2

GLOBAL REVENUE FOR ADVANCED PACKAGING BY TYPE, 2013-2020 ($ MILLIONS)



Source: BCC Research

Figure 7 Global revenue for advanced packaging by type, through 2020 (BCC Report)

Intelligent Interactive Packaging

Detailed sector-by-sector analysis shows that market revenue for each category within advanced packaging all had increased from 2013 and 2014, and are expected to continuously increase through 2020.

Global sales of authentication packaging technologies to the drug and food industries amounted to $42.5 billion in 2014. Packaging holograms sales accounted for the largest share, representing 49%. End use of authentication packaging technologies in the food industry represented 67.2% of global sales in 2014. Global sales of authentication packaging technologies to the drug and food industries are projected to reach nearly $96.4 billion in 2020, with a compound annual growth rate (CAGR) of 17.7% from 2015 to 2020. Global sales of track and trace packaging technologies to the drug and food industries amounted to nearly $31.5 billion in 2014, with North America representing 77.3% of the market share. The ubiquitous packaging bar codes accounted for the bulk of the sales representing 97.7%. End use of track and trace packaging technologies in the food industry accounted for 69.4% of global sales in 2014. Global sales of track and trace packaging technologies to the drug and food industries are projected to grow at a CAGR of 4.5% from 2015 to 2020, reaching nearly $39.3 billion in 2020.

Intelligent Interactive Packaging

Competitive Landscape

WIPAK-All Wipak packages with Scan Me-Logo are interactive. They use invisible watermark codes and augmented reality technology to deliver a truly unique consumer experience. The watermark printing provides invisible and unique code, impossible to replicate. It assists in anti-counterfeiting and brand protection. Augmented reality offers 'rich marketing opportunities' for product promotion. It adds value to the pack design and provides product/manufacturer information.

Thinfilm- specialises in printed electronics, partnered with G world to produce the industry's first smart wine bottle. Using Thinfilm's OpenSense NFC technology – where the tag senses the 'sealed' or 'opened' state of the bottle – a smartphone can communicate whether the wine bottle has been tampered with since it was sealed. Once opened it offers interactive mobile content. ThinFilm also joined forces with Evrythng – which provides a cloud-based IoT software platform – and Diageo to produce a smart Johnnie Walker whisky bottle. It enables cross-industry solutions, including brand authentication, track-and-trace monitoring and, once opened, engaging content to consumers.

Zapper-has reimagined it to create a 'zapcode'. A modern thunderbolt design facilitating fast scanning, it delivers augmented reality experiences to consumers via its content authoring platform ZapWorks.

Bemis North America-One cloud-based technology makes use of a mobile device in order to share coupons, recipes and more information through augmented reality. Since customers are encouraged to interact with packaging in order to get special deals or recipes, this transforms the point of purchase.

UK supermarket chain Tesco-Rum maker Malubu is equipping 40,000 of its bottles with NFC tags to create smart product packaging. With these connected tags, consumers will be able to use their mobile devices to scan the iconic sunset logo on the product packaging in order to easily access daily prize draws and other #BecauseSummer branded content experiences.

Buonamici, La Ranocchiaia, SPO and Il Cavallino- Italian olive oil brands that are now integrating NFC tags into bottles of olive oil. These NFC bottles enable authentication and increase engagement, all the while offering relevant product information and content to a consumer. The smart packaging system is connected to iOlive's mobile app, which stores data on more than 150 extra virgin olive oil products from Tuscany. These smart labels help to give consumers a sense of trust, as they are easily able to be educated about new bottles of olive oil.

Intelligent Interactive Packaging

References

- USDA's Livestock and Poultry: World Markets and Trade, http://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.PDF
- Carolina E. Realini and Begonya Marcos, Active and Intelligent Packaging Systems for A Modern Society, Meat Science, 2014, 98, 404-419
- Active, Controlled, and Intelligent Packaging for Foods and Beverages, BCC Research, FOD038D, October 2015
- Emerging Technologies and Trends for Packaging Red Meat, Meat and Livestock Australia Limited, A.RHC.0004, January 2015
- Trends in Meat and Meat Products Packaging – A Review, Croat. J. Food Sci. Technol. (2010) 2(1) 32-48.
- An Overview of the Intelligent Packaging Technologies in the Food Sector, Trends in Food Science & Technology, 51 (2016) 1-11.
- Leak indicators for modified-atmosphere packages, Trends in Food Science & Technology, 8(4):101-106, April 1997
- A novel colorimetric sensor array for monitoring fresh pork sausages spoilage. Food Control, 35(1), 166–176, 2014.
- Corey Fortin and H.L. Goodwin, Jr., Valuation of Temp-Time's Fresh-Check® Indicator on Perishable Food Products in Belgium, Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting Dallas, Texas February 2-5, 2008
- http://www.emcopackaging.com/index.php/products/oxygen-indicator-labels
- Novel water-resistant UV-activated oxygen indicator for intelligent food packaging, Food Chemistry, Volume 140, Issues 1–2, 1–15 September 2013, Pages 52–56
- Ellouze, M., & Augustin, J. C. (2010). Applicability of biological time temperature integrators as quality and safety indicators for meat products. International Journal of Food Microbiology, 138(1–2), 119–129.
- K. Pennanen, K. Keskitalo-Vuokko, V. KumpusaloSanna, V. Korhonen, M. Smolander & M. Ollila, Consumer and Time-Temperature Indicator: Implications for Further Development, 26th Iapri Symposium on Packaging, Espoo, June 10-13, 2013
- A Review of Automatic Patient Identification Options for Public Health Care Centers with Restricted Budgets, Online Journal of Public Health Informatics * ISSN 1947-2579 * http://ojphi.org *4(1):e9, 2012

Intelligent Interactive Packaging

- http://www.waspbarcode.com/buzz/barcode/
- BLOOM J. (2010) American Wasteland , Philadelphia, Da Capo Press, 166.
- BUTLER P. (2006) 'Developing a new dating game', Materials World , May 2006, 24–5.
- BUTLER P. (2009) 'Smart packaging – providing improved convenience and new functional benefits for consumers', in The Wiley Encyclopedia of Packaging Technology, 3rd Edition, New York, Wiley, 1124–34.
- BUTLER P. (2011) 'Smart packaging solutions to food waste reduction', Food Science & Technology, 25(3), 36–8.
- COGNIFEX (2011) Available from: www.cognifex.com [Accessed October 2012]. FULTON INNOVATION (2011) Available from: http://ecoupled.com/ces/packing- serioustechnology
- HOW STUFF WORKS (2011) 'How Augmented Reality Works'. Available from: http://www.howstuffworks.com/augmented- reality.htm [Accessed October 2012].
- KERRY J. and BUTLER P. (2008) Smart Packaging Technologies for Fast Moving Consumer Goods, Chichester, Wiley.
- METAIO (2011) 'By 2014: Augmented Reality will be on every Smart Phone', Press Release 28 September 2011. Available from: http://www.metaio.com/press/press- release/2011/by-2014-augmented-reality-will- be-on- every-smart phone
- NIELSEN (2011) 'Smart Phones to Overtake Feature Phones in US by 2011'. Available from: http://blog.nielsen.com/nielsenwire/consumer/smartphones-to-overtake- featurephones-in-u- s-by-2011.
- OFCOM (2011) 'A Nation Addicted to Smart Phones'. Available from: http://consumers.ofcom.org.uk/2011/08/a- nation-addicted- to-smart phones/
- SMOLANDER M. (2008) 'Freshness indicators for food packaging', in Kerry J. and Butler P., Smart Packaging Technologies for Fast Moving Consumer Goods, Chichester, Wiley,111–27.
- SUSTAINPACK (2005) 'Innovation and Sustainable Development in the Fibre-based Packaging Value Chain Instrument', IP D 6.23 Report on Retail Survey Results. Funded by the Nanotechnology RTD programme of the European Union. Available from: http://www.sustainpack.com/project%20reports/A&F_D6.23.pdf
- SWIENTEK B. (2002) 'Lenticular Labels Add Motion to Static Products on Shelves', Brand Packaging 22–24 March 2002. Available from:

Intelligent Interactive Packaging

http://www.apap-inc.com/A_R_PU/brand_article.pdf [Accessed October 2012].

- TAOUKIS P. S. (2008) 'Application of time- temperature integrators for monitoring and management of perishable product quality in the cold chain', in Kerry J. and Butler P.,Smart Packaging Technologies for Fast Moving Consumer Goods , Chichester, Wiley,61–74.
- WRAP (2009) 'Household Food and Drink Waste in the UK', final report, Banbury, Waste & Resources Action Programme. Available from: http://www.wrap.org.uk/retail_supply_chain/research_tools/research/report_household.html [Accessed October 2012].
- Grunert, K. G., & Valli, C. (2001). Designer-made meat and dairy products: consumer-led product development. Livestock Production Science, 72, 83–98
- Morrissey, P. A., Sheehy, P. J. A., Galvin, K., Kerryh, J. P., & Buckleyh, D. J. (1998). Lipid stability in meat and meat products. Meat Science, 49, S73–S86

Intelligent Interactive Packaging

Awards for Selected Solutions

We will conduct a global review of your invention using a team of experts who will examine the technology, potential products, markets, future customers and existing landscape.

We will select the best proposed solutions gathered during the circulation period of this RFI.

We will pay any awards in instalments, as per your written and executed contract with us.

Intelligent Interactive Packaging

Notices

Please contact:

Xinova, LLC
701 Fifth Avenue, Suite 4100
Seattle, WA 98104 USA

Xinova Asia Pte. Ltd.
150 Beach Road, # 08-06/08, Gateway West
Singapore 189720

Inquiries:

bksmith@xinova.com

RFI template version: 5.00

Intelligent Interactive Packaging

Instructions for Submission

Please read carefully before submitting Solution Reports

1. Terms and conditions of this RFI apply to anyone submitting proposed solutions.
2. We accept only original, new and novel proposed solutions. Proposed solutions not satisfying these requirements will not be considered.
3. Please direct any questions you may have to your local Xinova office. Suggestions to refine, broaden or to include new information are welcome. Any suggestions you provide are given entirely voluntarily and shall not create any confidentiality obligation for us. We may use the suggestions without obligation or restriction of any kind.
4. You may submit one or more Solution Reports during the circulation period of this RFI. Please see the first page for the circulation period. We will not accept any proposed solutions after the RFI Closing Date.
5. Please contact your local Xinova office for the Solution Report form. Please fill out the form accurately and completely. Incomplete forms may be returned to you for further action and may not be considered for acceptance.
6. Each proposed solution should be embodied in one Solution Report form. Do not include multiple proposed solutions in one form.
7. We reserve the right to cancel or terminate this RFI at any time.
8. We may share information on select proposed solutions and/or provide feedback to some or all of the inventors who submitted Solution Reports in response to this RFI. All information shared and/or feedback provided is our confidential information.
9. We will not retain any rights or obligations with respect to declined proposed solutions.