final report

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Final report - Review of market acceptance and value proposition for 3D printed meat

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Executive Summary

Key messages

Raw material:

1. ***Using dried powdered*** *meat requires a capital intensive, expensive process that delivers final products at a low rate and with low texture qualities and thus limits the potential markets to aged care facilities or similar where consumers have difficulty swallowing or chewing.*
2. *Using a liquid form of raw material is not as expensive but the ability to control the liquid coming out of the extruder does not exist yet. However, the production rate and product texture quality that could be achieved is significantly higher – a complete fully cooked roast complete with fibres and fat seams could be printed within 5 minutes. The higher production rate also makes this solution more acceptable to major processors.*

Broad risk categories for 3DP printing include:

1. *The development time and cost to develop the technology from current state to a fully commercial solution.*
2. *The technology risk to enable textured products and thus for access to bigger markets.*
3. *A development path that reduces investment risk all the way. One solution could be to reduce market acceptance risk and volume uncertainty by developing in collaboration with the end-consumer market. For example, development in collaboration with an aged care facility.*

Red meat is currently positioned in the minds of consumers as a good source of protein, iron and zinc, with both a taste and texture benefit over plant-based proteins. In line with this product positioning, this project investigated how red meat could be positioned using three-dimensional printing (3DP) technology to open new market opportunities and further grow the demand for red meat to the benefit of the Australian red meat industry.

3DP food is the technology where food is created (printed) layer by layer in a process called additive manufacturing. Various ingredients can be mixed, deposited and cooked, allowing quick experimentation with food combinations.

The key question at this stage of development of the technology is whether 3DP meat products are feasible (V.RMH.0034). Can it work? The answer is yes, it is possible to successfully develop, market and launch 3DP meat products because others are already doing it. 3DP food is currently served in more than 1,000 German nursing homes to residents who have difficulty chewing. Traditionally pureed food is easier and less expensive to make but 3DP provides a benefit that that the traditional pureed food cannot: meals are more appetising and residents are looking forward to meals.

That is the central message of this report: it is all about consumer benefit or rather perceived consumer benefit. A recent study on genetically modified food has shown that novel food adoption is strongly linked to perceived benefits (Vikan, 2015).

Product implementation aspects were considered around identified consumer benefits that 3DP food can provide. These are:

1. **Retail – product healthiness** - 3DP links in well with the disease prevention aspect of the current consumer health trend because nutrition can be personalised, for example products high in iron targeted to female consumers or high in protein targeted to kids or athletes. However the 3DP feed material is highly processed and in the case of powdered meat it is unpleasant (sensory) and viewed as not fresh and therefore not healthy. It thus fails to address the 'real benefits without compromised quality' consumer trend.
   One way to overcome these barriers could be to add healthy ingredients such as fibre or similar plant-based components. It could partially address the trend towards more plant-based products as well. Depending on the degree of personalisation, such a complete meal product or meat product alone could be charged at a premium for the personalisation aspect. Claims can be made that it contains natural amounts of say, iron or zinc, tapping into the naturalness trend.
   Other technologies can achieve similar products. That doesn't mean 3DP shouldn't try.

2. **Retail – product convenience, direct to consumer and snacks for the institutional and commercial sectors** - In the retail sector, 3DP products do not stand out more than any other convenience prepared meal except if the supermarket sells raw material, i.e. pureed form or dried powders in various convenient sizes.
   This type of implementation could fit in with younger consumers with limited cooking expertise and limited available time using their home food printer. It also leverages the minimal mental effort need of some consumers as well as the single life needs.
   In the commercial sector, the quick service restaurants channel presents an opportunity for convenience, but 3DP cannot overcome the cost and preparation time needed to compete against existing products. 3DP has to compete on other aspects, such as appearance below or healthiness as per the retail case above.

3. **Commercial – product appearance** - 3DP performs well on product appearance. 3DP products can be sold as upmarket, high-premium items associated with luxury, quality and indulgence. This product positioning can be achieved through the intricacies of shapes and sizes that can be achieved with 3DP technology. The healthiness trend can be employed here to further the impression of quality, healthiness and personalisation.
   No other technology can offer the complexity, the easiness to create and the personalisation that can be achieved with 3DP.

4. **Institutional – aged care** - 3DP food specifically addresses dietary malnutrition of the elderly in aged care facilities where food is overcooked due to food safety requirements and therefore tough to eat. Because the competing products (pureed food) has a low score in appearance and texture, 3DP food presents a unique opportunity to overcome the barriers of this segment and offer a real consumer benefit.
   It can be further promoted on the back of the health trend, providing personal nutrition to aged care residents.

Other technologies can also offer the softer texture, but only 3DP can offer the personal nutrition, which is a real benefit over the consumer perception of processed foods being unhealthy.

Processing benefits are different from consumer benefits considered above, in that it is from the viewpoint of the Australian meat industry. *These producer benefits do not stand in isolation. The driver behind them is the estimated market volumes and is influenced by a range of factors, including consumer benefits*. Thus processing benefits were matched to consumer benefits to quantify the final market opportunities and market volumes in the modelling section.

As the project did not assume a certain fixed process in general, four 3DP processing benefit groups were identified from a red meat industry perspective by considering strategic opportunities introduced by the nature of 3DP products and processes. Where a fixed process was assumed it is clearly stated in this report.

The processing benefits are:

1. **Less waste per carcase** – this benefit group is about using more of the lower value offcuts, remains or waste of a carcase. This is possible due to the requirement that the feed material into a 3D printer should be small or fine.
2. **Additional volume of meat sold** – this benefit group is about not cannibalising other products in a specific channel or market of the supply chain.
3. **Additional value per carcase** – this benefit group is about increasing the value of a carcase by increasing the value of certain products by changing or marketing certain features.
4. **Reduced cost of processing, capital and running cost** – this benefit group is about inferring specific processing impacts based on what is known about 3DP technology at this stage and estimating the cost impacts as a result. The four processing benefit areas formed the basis of the modelling process and the value of each benefit group was quantified.

Considering the strategic benefits of 3DP technology (at present capability) for meat products, several market opportunities stand out based on consumer benefits:

- Healthy, premium prepared meals or 3DP raw material offered in the retail sector promoted for aspects related to disease prevention and personalised health.
- Direct to consumer promoted for aspects related to convenience.
- Personalised meals in the commercial sector promoted for aspects related to appearance and personalisation.
- Personalised food for the aged care market promoted for aspects related to texture and personal nutrition.

Opportunities that stand out based on market benefit, volume, risk are:

- Institutional aged care segment – this segment performs well on an industry benefit against risk index.
- Retail in total (convenience and healthiness and snacks) – this segment performs well on a volume against risk index but specifically snacks do not compete well with existing ready-meal snack products available in the retail segment.

On an international level, the aged care segment show promise in terms of volume in countries like USA and China. However, the volume figures used in the model is highly dependent on the final execution and implementation of the product and consumer adoption depends on the perceived benefit.

Applying the lessons learnt to the identified market opportunities new product combinations can be discovered. For example, within the age care segment, consumers can be further segmented and oatmeal used to further enhance the "health" positioning of the product. Depending on the raw material used, special care should be taken to develop products most suited to the technology but not at the risk of quality. To be specific, adding salt or flavouring to try to overcome the sensory barrier of powdered meat may not work as it is at the expense of the healthiness of the product in the mind of the consumer.

The following steps are recommended to further the development of the technology, not in order of importance:

1. Experimentation with final products is needed in each of the market opportunities highlighted above: retail (healthy), direct to consumer (convenience), commercial (appearance), aged care (sensory).
2. Consumer testing and adoption research is needed to assess potential market volumes.
3. Focus should be kept on **risk and consumer benefit** as opposed to the quantification of potential opportunity, because potential opportunity is highly dependent on the specific product implementation and that is the part that needs experimentation to get it right.
4. Ways to experiment while minimising risk is what is needed as a next step. Fortunately, 3DP is modular and cheap and thus easy experimentation is exactly what makes it such an appealing technology.

3DP presents a real opportunity for the Australian meat industry provided the time and effort and resources are invested to experiment and learn the technology and develop innovative products. The opportunity for beef is estimated in total at $3,900,000 per annum for beef, and for lamb the estimate is in the same range, based on the current level of skill and product opportunities and assuming the consumer adoption volumes as per the model.

As mentioned above, the consumer adoption volume is the strongest, most sensitive driver and is all dependent on the particular implementation of the product. The consumer volumes can potentially be 10 or 20 or 100 fold, depending on the user benefit offered, the product execution and the market positioning of the product, to name a few of the key aspects. Therefore the opportunity to the Australian red meat industry can potentially be 10 or 20 or 100 fold the estimated value, depending on the specific product offering.

Deloitte predicted that 3DP is the technology of the future, and that it is here to stay. Consumers will own more units than enterprises, but the bulk value will be generated by enterprises (Deloitte, 2015). The technology is still in its infancy, and the meat industry will be left behind if it doesn't put in the effort to experiment and develop products suited to the technology.

Bill Gates, together with other investors, pumped $108 million into Impossible Foods, a company making meat substitutes from plants with the health statement that it contains no cholesterol, no

antibiotics, no hormones and no meat. It is very tasty and meat lovers cannot even tell the difference, as plant ingredients are specially selected and combined to create the meat taste (King, 2015). However, the concept is directly in contrast with the food trend of “naturally functional”. Further, meat still has a lot to compete with, particularly, animal proteins are naturally satiating. Consumers will try and test and make their own conclusions. 3DP meat products can offer the Australian meat industry the opportunity to compete and if current consumer trends are applied, it can help the Australian meat industry to develop a distinctive competitive advantage.

Glossary

3DP	Three Dimensional Printing
ATAR	Awareness, Trial, Availability, Repeat
MDM	Mechanically Deboned Meat

Contents

Introduction

Red meat is currently positioned in the minds of consumers as a good source of protein, iron and zinc, with both a taste and texture benefit over plant-based proteins. In line with this consumer positioning, this project investigated how red meat could be positioned using three-dimensional printing (3DP) technology to open new market opportunities and further grow the demand for red meat to the benefit of the Australian red meat industry. The value proposition of future applications of 3D printed meat was assessed for various value chain participants following the initial review on the technical functionality and potential for 3D printed meat by the University of Queensland (V.RMH.0034).

A key aspect of this project was learnings from previous technology platform projects such as Meat Strip Alignment (MSAT - A.MPT.0018), High Moisture Extrusion Cooked (HMEC and Enzymic Hyrdrolysis - A.MPT.0049) and Micronisation/Powdered Meat (A.MPT.036). In spite of the potential benefits that these projects promise, the technologies are still to be adopted by their markets.

This project also considered specific initial markets suitable for 3DP foods such as food for the elderly, meat snacks, convenience foods and other new growth options.

1.1 Objectives

The objective of this project was to evaluate the commercial viability of 3DP technology for meat and to quantify the value proposition for the red meat industry. Raw material supply and processing costs were considered and both new and cannibalistic market opportunities evaluated.

Specific sectors were investigated, namely food for seniors, snacking and convenience foods and lessons learnt from various innovation projects considered including research on consumer adoption of genetically modified foods.

An important part of this work was also to investigate consumer adoption barriers and to suggest recommendations for the next steps and marketing mix development.

1.2 Methodology and sources of information

New and cannibalistic market opportunities were identified by considering the strategic differences between 3DP meat products and existing products as well as the differences between production processes. These strategic differences were translated into benefit groups for the meat industry, named processing and raw meat utilisation benefits, and compared against current food trends and known consumer issues and benefits derived from the market analysis and 3DP technology possibilities.

For each of the processing benefit groups' sales channels, market volumes, end consumers and finished product formulations were considered. Where applicable these product formulations were also compared with competing products in terms of pricing and product attributes. The impact of using certain raw materials was assessed, including powdered meat and lower cost ingredients that offer benefits to consumers such as the heart muscle that is high in iron content.

The model was also tested for sensitivity, specifically around adoption and sales volume impact thereof.

2 What is 3DP food?

3DP food is the technology where food is created (printed) layer by layer in a process called additive manufacturing. Various ingredients can be mixed, deposited and cooked, allowing quick experimentation with food combinations. The difference between 3DP food and automated food preparation is that 3DP food offers users the opportunity to be creative, where automated food aims to remove human effort from the process (Sun, 2015).

2.1 Product possibilities

3DP food technology can produce food with customised shape, colour, flavour, texture and even nutrition (Sun, 2015). Refer to the following images for examples of the complexities that can be achieved.

Figure 1: Examples of 3DP food already available

2.2 3DP meat products and raw material

A wide range of foods can be used as raw material for 3D printing, basically any food type that can be extruded and that will hold its shape afterwards, with or without glue-like components. Materials such as chocolate, cream cheese and even mashed potatoes have been successfully printed. And through the use of multiple extrusion nozzles, meal items with multiple ingredients can be created, from pizza to multi-layered cakes (Deloitte University Press, 2015).

Following the technical review by the University of Queensland (V.RMH.0034), meat can be used as a raw material in different forms and different processes (de Godoi, 2015). Powder-dried meat is one example with a particularly long shelf life (Dahm, 2014).

2.3 Product Limitations

Ingredient mix - A complication with having different types of ingredients is that these will all react differently during the repetitive heating and cooling that is associated with extrusion (Branden, 1998).

Protein quality – Heating during the printing process will also denature the proteins which is a breakdown in their structure. The majority of proteins are quite specific about the function they perform which is dependent on their 3 dimensional structure. At temperatures above 41^0C many proteins will denature. Combinations of proteins and desired functional food attributes would need to be considered (Creighton, 1993).

Shelf life - these ingredients are likely to have different shelf lives to start with. As a result, food safety may be an issue, especially if the particular printer or product takes a long time to get printed with cooling at less than ideal conditions from a food microbiology perspective (Fagain, 1997).

3 Market analysis

3.1 General consumer food trends

Greenleaf identified prominent food trends based on recent food trend reports that are relevant to this project. These trends are:

- Healthy food.
- Online shopping.
- Quick but satiating food to fit an “on-the-go “lifestyle.

3.1.1 Healthy food

Consumers want food that is functional, natural and healthy. They don’t want artificial and they don’t want processed. Protein-fortified products are less likely to succeed than products that contain protein naturally (Mellentin, 2015). Research findings indicate that women’s general interest in health is greater than that of men.

Further to this trend, consumers have lost faith in product health claims and so-called food experts and they want food that gives results instead of promising results.

3.1.2 Online society

Not only are consumers buying more and more online (Solomon, 2012), they are also researching products more thoroughly. To some degree this trend to research online is even further supporting the trend of natural, healthy food and researching of product results.

3.1.3 Snacks and convenience

Consumers want satiating food that is easy and quick to fit their time-poor lifestyles (Mellentin, 2015) or in the case of younger consumers can compensate for a lack of cooking expertise. Consumers know protein to be satiating and protein snacks fit well into this category (Global Food Forums, 2013). Consumers are also willing to try new ingredients, tastes and textures (Mellentin, 2015) and that make them open to 3DP products.

Although younger people eat more convenience food, an affinity for naturalness and a high level of nutritional knowledge is related to a lower intake of convenience foods. Men in general also prefer convenience food, more so than women.

3.2 Market channels and segments

The Australian domestic food market can be grouped into two segments: retail and foodservice. As indicated in the table below the master channels can be further expanded into sub-channels (Spencer, 2012).

Table 1: Australian domestic food channels and sub-channels

Segment	Master-channel	Sub-channel
Retail	Grocery	Full-service supermarkets
		Independent supermarkets
	Convenience	Independent stores
		Convenience stores
	Specialised	Bakery, cake and pastry
		Delicatessen
		Butcher, poultry, seafood
		Fruit and vegetables
		Liquor merchants
Foodservice	Takeaway	Sandwich bars
		Independent takeaway
		Quick-serve restaurants
	Dining out	Restaurants and cafes
		Pubs, clubs and function centres
	Event / leisure	Event leisure and travel
		Accommodation
	Institutional	Hospitals
		Aged care
		Defence
		Correctional
		Corporate (workplace)
		Education

Source: (Spencer, 2012).

Three consumer groups are relevant to this project, namely Generation X, the 50+ demographic and aged care facilities, because of the following trends within those groups:

- **Generation X** – this group is known to consume food with a high animal protein content, especially consumers with a lower level of education.
- **50+ demographic** – older consumers make more frequent purchases of group beef than younger consumers.
- **Aged care facilities** – Malnutrition is prevalent and dietary intakes in many aged care facilities do not meet energy or protein level requirements even though meals are served compliant with dietary advice. Food waste is higher for grains and meat than dairy and fruit although diatary advice recommends a higher protein and meat intake for elderly people.

3.3 Adoption barriers and challenges

Marketing meat-based products and convincing consumers is a challenging task – multi-disciplinary teams need to be coordinated, such as nutritionists and food technologists, to develop a sample product. The sample product needs to comply with legislative aspects, pass the consumer sensory test and then it needs to prove better than similar existing products in some regard.

The following table summarises the market drivers and barriers for each of the market segments in a general way (i.e. not barriers related to 3DP products but food in general).

Table 2: Market segments –market drivers and barriers

Trend group	Healthiness	Convenience and snacks	Older consumers (50+ demographic, Generation X, Aged care facilities)
Market drivers	• Convenient way to achieve wellness • Beauty and appearance • Disease prevention • Real benefits without compromised quality	• Lifestyle choices • Limited available time but also mental effort • Limited cooking expertise • Single life	• Dietary advice • Malnutrition • Texture • Food safety
Personal barriers	• Sensory – taste, texture, appearance, odour • Economy	• Sensory – taste, texture, appearance, odour • Health • Knowledge	• Appetite • Mood • Emotions • Sensory – appearance and texture • Economy
Societal barriers	• Naturalness • Plant-based protein and too much protein	• Traditions • Environment	• Serving sizes/decisions by aged care facility

Looking at another food technology to draw parallels from it, genetically modified foods have consumers divided. It is strange and new but offers some benefits. A recent study has shown that novel food adoption is strongly linked to perceived benefits (Vikan, 2015). It is all about perceived product benefits.

Given that health and convenience is such a big trend in food currently (Mellentin, 2015), the question is how 3DP food will be perceived. How is 3DP food currently positioned in the minds of the consumer?

In general, particular challenges around 3DP meat include:

- It is directly in contrast with the health trend as 3DP meat is perceived as highly processed, not natural and thus believed to be very unhealthy.
- Consumers do not understand what benefits the technology can offer in terms of convenience.

So the relevant question is: What does 3DP offer consumers?

3.4 Consumer benefits of 3DP meat products

3DP meat products offer consumers convenience, environmentally sustainable practises, personalised health and nutrition, texture and taste, product differentiation, direct to consumer channels.

3.4.1 Convenience

A broad definition of convenience food products is “those that help consumers minimise time as well as physical and mental effort required for food preparation, consumption and clean-up” (Brunner, 2010). This includes highly processed (ready meals in a can, ready meals chilled or frozen, instant pasta), moderately processed (sandwiches, chilled fresh pasta, warm pizza delivered or chilled or frozen ready-made pizza), single components (vegetables, fish or (crumbed or seasoned), meat (crumbed or marinated) and salads. Convenience foods have recently expanded to include healthier food options such as well-balanced cooked meals delivered frozen and ready to heat up when needed.

3DP food products offer convenience. A consumer on an average work day will select the menu item of choice while say, commuting home, and send the signal to the printer to start creating dinner. Complete meals will be printed without the mess associated with traditional food preparation and when the printer is done, just as the consumer walks in, the meal only needs heating up. The variety of complete meals that can be created with the 3D printer is as vast as the imagination, from burgers to ravioli (Rawstorne, 2013).

3.4.2 Environmentally sustainable practices

With a projected global population of 9.6 billion people there is a growing demand for food and sources of protein, including meat (OECD/Food and Agriculture Organization of the United Nations, 2015). Some consumers prefer plant-based proteins because of the perception that plant-based proteins are environmentally more sustainable (Global Food Forums, 2013). Bill Gates together with other investors invested $108 million into a food start-up company that is creating meat substitutes so good that meat-lovers cannot even tell the difference. However, the belief that plant-based proteins are environmentally sustainable and animal-based proteins are not, recently got a new perspective. Where grazing animal produce methane, cropland uses fertiliser that contains nitrous oxide, also a powerful greenhouse gas (Hobley, 2016). As mentioned above, perception is king and the message needs to get out to repair the image and positioning of red meat.

3DP meat meals would not automatically replace traditional meat meals and could be considered a way to provide people with environmentally sustainable food (Thimmesch, 2015). For example, protein could be extracted from unexplored territories such as agricultural waste products, similar to whey protein extraction.

3.4.3 Personalised health and nutrition, texture and taste

3DP food offer the possibility of nutrition tailored to an individual’s dietary needs, allergies or taste preferences. Food printing could also help to control portion sizes, reduce chemical additives and calibrate nutritional ingredients such as increasing protein for seniors.

Depending on the stages of life or medical issues, personalised nutrition could be solutions for seniors, athletes, expectant mothers or physically challenged adults.

3.4.4 Product differentiation and customisation

Through 3DP technology food can be created in the most intricate of shapes with coloured patterns and scalable sizes. Every meal can look different for the purpose of appearance but also functionality such as easy storage.

Companies are already using this technology to customise their products and differentiate themselves, from intricate paste shells, chocolate to other confectionery. Refer to the following figure as an example.

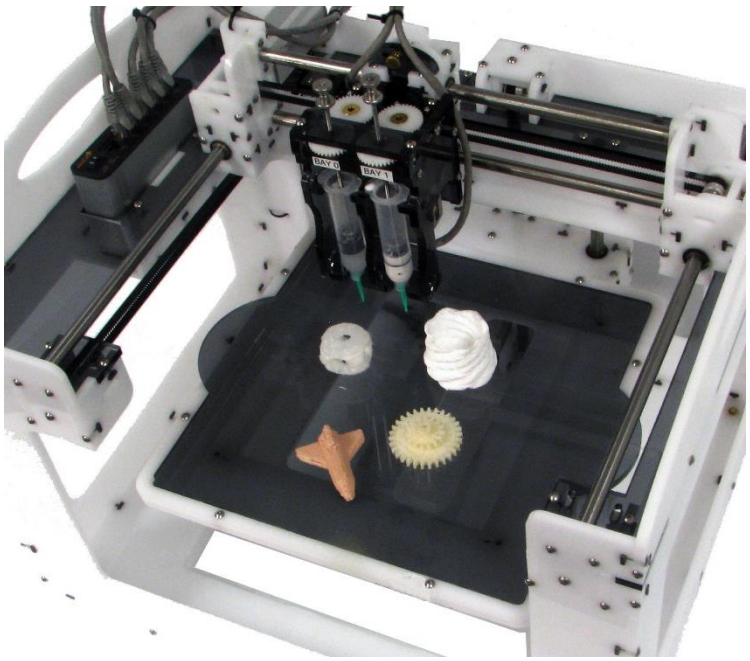

Figure 2: Example of intricacy of shapes that can be created

3.4.5 Direct to consumer

The direct to consumer channel is expected to be of greater benefit to people in rural and remote locations. These people will more likely have printers at home because of choice options, convenience (healthy and not normally accessible by people in these areas) and long shelf life of products.

3.5 Can 3DP meat work? Yes, others are already doing it

Given the consumer barriers and benefits mentioned in sections 3.3 and 3.4 above, the question is – can 3DP meat work? The answer is yes, it is possible to successfully develop, market and launch 3DP meat products because others are doing it already.

3DP food is currently served in more than 1,000 German nursing homes to residents who have difficulty chewing. Residents eat better when served 3DP meat as the conventional puree alternative is not as tasty (Fractals LAB , 2015) and dull in appearance. The company is called Biozoon and their most popular product is called Smoothfood. The Smoothfood range includes six foods: cauliflower, peas, chicken, pork, potatoes and pasta. The cooked, pureed food is inserted into the printer and meals created that look like normal food and apparently taste like normal food. However, they acknowledge that traditionally pureed food is still easier and less expensive to make but 3DP food is offering a new benefit over the traditional pureed food: 3DP meals are more appetising and elderly residents are now looking forward to meals more than before (CBS News, 2014).

3.6 Product implementation considerations

Given the general consumer trends and product benefits stated above and the capabilities offered by 3DP, the following product implementation considerations clearly define the opportunities for 3DP in terms of product implementation.

3.6.1 Retail – product healthiness

3DP links in well with the disease prevention aspect of the health trend because nutrition can be personalised, for example products high in iron can be targeted to female consumers or high in protein targeted to kids or athletes. However the feed material is highly processed and in the case of powdered meat as raw material can be both unpleasant (sensory) and viewed as not fresh and therefore not healthy. It thus fails to some degree the 'real benefits without compromised quality' consumer need.

One way to overcome these barriers could be to add healthy ingredients such as fibre or similar plant-based components. This could address the trend towards more plant-based products as well. Depending on the degree of personalisation, such a complete meal product or meat product alone could be charged at a premium for the personalisation aspect. Claims can be made that it contains natural amounts of say, iron or zinc, tapping into the naturalness trend.

Other technologies can achieve similar products. That doesn't mean 3DP shouldn't try.

3.6.2 Retail – product convenience, direct to consumer and snacks for the institutional and commercial sectors

In a retail sector, 3DP does not stand out more than any other prepared convenience meal except if supermarkets sells raw material, i.e. in pureed form or dried powders in various convenient sizes.

This type of implementation could fit in with younger consumers with limited cooking expertise and limited time using their home food printer. It also leverages the limited mental effort need of some consumers as well those of a single life.

In the commercial sector, quick service restaurants present an opportunity for convenience, but 3DP products cannot overcome the cost and preparation time needed to compete against existing products. 3DP products will have to compete on other aspects, for example appearance or healthiness as per the retail case above.

3.6.3 Commercial – product appearance

3DP performs well under the performance aspect of product appearance. 3DP products can be sold as upmarket, high-premium items associated with luxury, quality and indulgence. This implementation can be achieved through the intricacies of shapes and sizes of 3DP technology.

The healthiness trend can be employed here to further the impression of quality, healthiness and personalisation.

No other technology can offer the complexity and the easiness to create that can be achieved with 3DP.

3.6.4 Institutional – aged care

3DP food specifically addresses dietary malnutrition of the elderly in aged care facilities where food is overcooked due to food safety requirements and therefore tough to eat. Because the competing products (pureed food) has a low score in appearance and texture, 3DP food presents a unique opportunity to overcome the barriers of this segment and offer a real consumer benefit.

It can be further promoted on the back of the health trend, providing personal nutrition to aged care residents.

Other technologies can also offer the softer texture, but only 3DP can offer the personal nutrition, which is a real benefit over the consumer perception of processed foods being unhealthy.

4 3DP Processing benefit groups

Processing benefits are different from consumer benefits in that it takes the viewpoint of the Australian red meat industry, named processing benefits. *These processing benefits do not stand in isolation. The driver behind them, the estimated market volumes is determined by a range of factors, including consumer benefits*. Thus processing benefits were matched to consumer benefits to formulate the final markets and quantify the opportunities below.

4.1 Description of benefit groups

As the project did not assume a certain fixed process in general, four 3DP processing benefit groups were identified by considering strategic opportunities introduced by the nature of 3DP products and processes.

For each of the major benefit areas, several detailed benefits were also identified:

1. **Less waste per carcase** – this benefit group is about using more of the lower value offcuts, remains or waste of a carcase. This is possible due to the requirement that the feed material into a 3D printer should be small or fine. Some of the benefits that are part of this benefit group are:
    a. Using more offal, for example liver and heart are high in minerals, vitamins and proteins, ideal for the aged care market;
    b. Using more other waste products, for example tripe is also high in vitamins and proteins, also ideal for the aged care market;
    c. Exact amounts of product will be used due to very controlled or small scale processes;
    d. On-demand production processes.

2. **Additional volume of meat sold** – this benefit group is about cannibalising other products in a specific channel or market of the supply chain. Some of the benefits that are part of this benefit group are:
    a. Substitution of other animal protein products;
    b. Substitution of plant based protein products;
    c. New supply chain channels or markets;
    d. Cannibalisation of red meat products.

3. **Additional value per carcase** – this benefit group is about increasing the value of a carcase by increasing the value of certain products by marketing certain features. Some of the benefits that are part of this benefit group include:
    a. Product appearance, specifically looking at the commercial market;
    b. Product convenience, specifically looking at the retail market;
    c. Product healthiness, specifically looking at the retail market;
    d. Longer shelf life, looking at various markets;
    e. Less product going to pet food.

4. **Reduced cost of processing, capital and running cost** – this benefit group is about inferring specific processing impacts based on what is known at this stage about 3DP technology and estimating the cost impacts as a result. Some of the benefits that are part of this benefit group include:
    a. Less maintenance in terms of labour cost rate or hours;
    b. Less operational labour in terms of labour cost rate or hours;
    c. Service part costs;
    d. Modular units may allow production reliability;
    e. Modular units may allow for better production planning;
    f. Different, less or cheaper processing steps;
    g. Reduced material handling and storage as a result of simplified processing.

The four benefit areas formed the basis of the modelling process and the value of each benefit group was quantified.

4.2 Quantification of benefits

4.2.1 Summary of all benefits identified

Table 3 below shows the overall summary of the values of each of the benefit groups. The benefits in grey were not quantified due to lack of information; however these benefits should not be disregarded as they can potentially be substantial.

Further, it should be noted that the benefit per head was calculated with respect to the total production in Australia; in other words, the benefit per head is industry benefit per head. This allowed for the summation of benefits in spite of different processing rates and different channel volumes.

Table 3: Summary of quantification of benefits per benefit category

Benefit / opportunity description	Benefits	Benefit per head of total industry production	Total industry benefit per annum
1. Less waste per carcase	1.1 More offal can be used / at a higher price (for example liver, heart high in minerals, vitamins and proteins) for the old age segment	$0.00	$185,259
	1.2 More other waste products can be used/ at a higher price (tripe contains vitamin B12 and significant amounts of protein) or MDM for the old age segment	$0.00	$78,596
	1.3 Less process waste - Exact amounts of product to be used due to very controlled / small scale process		
	1.4 On-demand production		
2. Additional volume of meat sold	2.1 Substitution / cannibalisation of other animal protein products such as poultry, fish, dairy for various channels in the supply chain including food service	$0.09	$739,872
	2.2 Substitution / cannibalisation of other plant based protein products for various channels in the supply chain including food service	$0.00	$40,389
	2.3 New supply chain channels?	$0.01	$50,262
	2.4 Substitution of red meat products	$0.03	$240,910
3. Additional value per carcase	3.1 Certain product benefits may allow higher pricing for the same raw materials than before. Some benefits include: Product appearance Product convenience Product "healthiness"	$0.09	$778,415
	3.2 Longer shelf life	$0.12	$1,012,028
	3.3 Less product going to pet food (e. coli test)		
4. Reduced cost of processing, capital and running cost	Less maintenance in terms of hours?		
	Less supervision required for maintenance?		
	More / less expensive processing labour required?	$0.10	$796,340
	More / less expensive parts required when serviced?		
	Modular units may allow production volume flexibility?		
	Modular units may allow production throughput reliability?		
	Modular units may allow for better production planning		
	Not packaging the product at various stages?		
	Less processing steps / different process?		
	Reduced material handling and storage steps as a result of simplified processing?		
Total		$0.44	$3,922,070

3DP offers an industry potential benefit of at least **$3.9 million per annum** looking at beef. This is a conservative estimate and is highly sensitive to the assumed consumer adoption rates.

4.2.2 Less waste per carcase

This benefit group focused on the Institutional / aged care market only.

It was assumed that only a portion of the meat component of a meal can be replaced by liver, heart, tripe or MDM (Mechanically Deboned Meat). The benefit of MDM in $/kg was used from another GLE project on rendering and hydrolysis. Taste and texture is likely to be impacted by the replacement percentage, as well as the vitamin and mineral composition of the final product.

The replacement percentages may be changed to higher or lower numbers, but it should be noted that it is a sensitive parameter. For example, changing the percentage of tripe substituted from 10% to 20% results in the benefit to industry being almost double in for this particular benefit aspect. Therefore the replacement percentages used are quite conservative as can be seen in Table 4 below.

Table 4: Less waste per carcase / Institutional (aged care) market – replacement percentages and value generated

Replacement and value generated			
Item	Amount	Comment	Assumptions
Meat volume (weight per meal in kg)	0.15	Traditional meal item	
Meat cost ($/kg)	$3.60	Traditional meal item cost	Traditional meal used mince in meals
Replacement item	Liver, heart		
Percentage replacement (heart, liver)	20.00%		
Heart, liver volume (weight per meal in kg)	0.03	3D meal replacement item	Assume trim meat is replaced with heart, liver
Heart liver cost ($/kg)	$1.94		
Value added per meal	$0.05		
Value added per kg of ready meal	$0.15		
Replacement item	Tripe		
Percentage replacement (tripe)	10.00%		
Tripe (weight per meal in kg)	0.02	3D meal replacement item	Assume trim meat is replaced with tripe
Tripe cost ($/kg)	$2.25		
Value added per meal	$0.02		
Value added per kg of ready meal	$0.06		
Replacement item	MDM		
Percentage replacement (MDM)	30.00%		
MDM (weight per meal in kg)	0.05	3D meal replacement item	Assume trim meat is replaced with MDM
MDM benefit per kg ($/kg)	$0.02	Source: TRI413HVA / Benefit is across the entire supply chain	
Value added per meal	$0.00		
Value added per kg of ready meal	$0.00		

Another two sensitive parameters in assessing the full benefit of a particular channel or market are the potential maximum market size and the market adoption rate.

Taking the Institutional market (aged care) as an example, the total population of elderly residing in institutional facilities in Australia is **352,501**. If we assume that only a portion of this population will

be converted to adopt 3D printed meat in whatever product form, we infer the **maximum or saturated market** size.

This maximum market size can only be achieved over time; adoption differs from product to product and market to market and depends on a range of factors.

For the purposes of the modelling work, it was assumed that after 5 years only 20% of this maximum market will be achieved.

Built into the assumption of a specific adoption rate attained after a certain period are the following four elements as part of the marketing ATAR model:

- **Awareness** – a certain portion of the maximum market will be made aware of the particular product;
- **Trial** – a certain portion of the awareness group will want to try the product;
- **Availability** - a certain portion of the trial group will be able to buy the product, i.e. this factor is about the extent of availability;
- **Repeat** – a certain portion of the availability group will buy the product again and fully "adopt" it.

The following figure shows how all the factors fit together to obtain the final adoption percentage.

Figure 3: Factors considered to estimate the adoption rate of a new 3DP product

Given the above, a significant amount of effort and costs have been assumed, for example to make the target market aware of the product, to convince the target market to try the product, etc.

Table 5 below shows how the assumed adoption rates are used to assess the number of meals that will be sold for this particular market.

Table 5: Less waste per carcase / Institutional (aged care) market – Market adoption rates incorporated into modelling

Adoption: Volume of 3D meals that will be sold (Old Age Group)			
Item	Amount	Comment	Assumptions
Total population Australia	23,490,700.00	2014	http://www.abs.gov.au/ausstats/abs@.nsf/0/1CD2B1952AFC5E7ACA257298000F2E76?OpenDocument
Populaition > 65	18.30%	2014	
Population percentage age group > 65 in institutional facility	8.20%	2014	Source: http://www.un.org/esa/population/publications/livingarrangement/chapter2.pdf
Population age group > 65	352,501.44	2014	
Market saturation: Percentage of >65 age group that will adopt (max)	20.00%		
Potential total target market	70,500.29		
Adoption curve (% adoption after year 5 of total market)	20.00%		
# 3D meals per person per week	10.00		10 meals p person p week for fully "adopted" person
# 3d meals per person per year	520.00		
Total number of meals per year (after year 1)	1,833,007.51		
Total number of meals per year (after year 5)	7,332,030.04		
Total number of meals per year (after year 10)	7,332,030.04		

Sources: (Australian Bureau of Statistics, 2014), (United Nations Department of Economic and Social Affairs/Population Division, 2005)

Table 6 below shows the summary of the benefit group: less waste per carcase. As mentioned above, the market size and adoption rates have a significant impact on the summary values. Because this benefit group focused on the Institutional / aged care market only, the market potential can be improved by considering other or new channels as well. However, within the aged care market there may be several levers available to improve the adoption rates or even the maximum market, such as a targeted marketing campaign or improving the product availability as discussed in the section on product implementation considerations.

Table 6: Less waste per carcase / Institutional (aged care) market - Summary of benefit generated by using more liver, heart, tripe and MDM

Summary - Benefit 1.1	1.1 More offal can be used / at a higher price (for example liver, heart high in minerals, vitamins and proteins) for the old age segment		
Item	Amount	Comment	Assumptions
Benefit 1.1 value added ($ per ready meal)	$0.05		
Benefit 1.1 value added ($ per kg of ready meal)	$0.15		
Benefit 1.1 value added ($ per carcase)	0.00		
Benefit 1.1 value added ($ total to industry per annum)	$92,629.36	At an adoption rate stated as at the end of year 1	
Benefit 1.1 value added ($ total to industry per annum)	$185,258.73	At an adoption rate stated as at the end of year 5	
Benefit 1.1 value added ($ total to industry per annum)	$370,517.46	At an adoption rate stated as at the end of year 10	

Benefit 1.2	1.2 More other waste products can be used/ at a higher price (tripe contains vitamin B12 and significant amounts of protein) or MDM for the old age segment		
Item	Amount	Comment	Assumptions
Benefit 1.1 value added ($ per ready meal)	$0.02		
Benefit 1.1 value added ($ per kg of ready meal)	$0.06		
Benefit 1.1 value added ($ per carcase)	0.00		
Benefit 1.1 value added ($ per ready meal)	$0.00		
Benefit 1.1 value added ($ per kg of ready meal)	$0.00		
Benefit 1.1 value added ($ per carcase)	0.00		
Benefit 1.1 value added ($ total to industry per annum)	$37,665.55	At an adoption rate stated as at the end of year 1	
Benefit 1.1 value added ($ total to industry per annum)	$78,595.80	At an adoption rate stated as at the end of year 5	
Benefit 1.1 value added ($ total to industry per annum)	$150,662.22	At an adoption rate stated as at the end of year 10	

4.2.3 Additional volume of meat

This benefit group investigated various products that can substitute protein products for the Institutional / aged care market. It also considered the convenience market. Most of the substitution products for the Institutional / aged care market were selected based on its soft texture, therefore the soups, yoghurt, eggs etc.

It was assumed that only a portion of the meat component of a meal can be replaced by the substitute 3DP meat product. For example, the weight of meat per meal will be less than the total weight of soup for the same person for a meal, i.e. more yoghurt is needed than meat to be fully satiated.

Table 7 below shows how the volume and value was calculated for one of the cannibalisation products for the Institutional / aged care market.

Table 7: Additional volume / Institutional (Aged care) market - Summary of benefit generated by cannibalising yoghurt market

Replacement of other proteins and vegetable products (Benefit 2.1 & 2.2)			
Item	Amount	Comment	Assumptions
Supply chain sector	Institutional Market		
Supply chain subsector	Aged Care		
Competitor product	Soups	Competitor product means competitor to 3DP, not competitor to red meat	
Current consumption volume (Tons pa)	613.29		
Replacement product	3DP meat		
Maximum replacement percentage	15.00%		
3DP (meat component) replacement % after year 1	0.750%	Using adoption rate percentages	
3DP (meat component) replacement % after year 5	1.500%	Using adoption rate percentages	
3DP (meat component) replacement % after year 10	3.000%	Using adoption rate percentages	
Loss (kg) - cannibalisation of competitor product after y5	9,199.28	Taken at 5 year adoption rate	
Product replacement ratio (%) by weight	80.00%		
Gains (kg) - 3DP replacement meat product after y5	7,359.42	Assume 20% reduction in volume between soup and 3DP	
Value per kg of 3DP meat component ($/kg)	5.49		
Gains ($) - 3DP replacement meat product after y5	40,388.51	Taken at added value rate of 3DP meat component	
Total value added ($)	**40,388.51**	Partial output of benefit 2.2	

The following four tables show the summary benefit for each of the substitution products, including the cannibalisation of red meat products. This is across various markets. Substitution products were grouped according to existing, current or new markets and protein source (plant or animal based within existing markets).

- Table 8 below shows the achievable benefit generated by cannibalising animal protein products apart from red meat for the aged care and convenience markets.

Table 8: Additional volume - Summary of benefit generated by cannibalising animal protein products apart from red meat

Summary - Benefit 2.1	2.1 Substitution / cannibalisation of other animal protein products such as poultry,		
Item	Amount	Comment	Assumptions
Benefit 2.1 - product	Yoghurt	Aged Care	
Benefit 2.1 value added to industry	$51,108.40	At 5 year adoption rate	
Benefit 2.1 - product	Eggs	Aged Care	
Benefit 2.1 value added to industry	$99,708.92	At 5 year adoption rate	
Benefit 2.1 - product	Pork (Fresh and Frozen)	Aged Care	
Benefit 2.1 value added to industry	$150,288.41	At 5 year adoption rate	
Benefit 2.1 - product	Poultry (Fresh and Frozen)	Aged Care	
Benefit 2.1 value added to industry	$252,877.63	At 5 year adoption rate	
Benefit 2.1 - product	Prepared Meals	Convenience group	
Benefit 2.1 value added to industry	$47,400.59	At 5 year adoption rate	
Benefit 2.1 - product	Snacks	Convenience group	
Benefit 2.1 value added to industry	$138,487.76	At 5 year adoption rate	
Benefit 2.1 value added to industry	$739,871.71	At 5 year adoption rate	
Benefit 2.1 value added ($ per carcase)	$0.09	At 5 year adoption rate	

- Table 9 shows the achievable benefit generated by cannibalising plant protein products for the aged care market only.

Table 9: Additional volume / Institutional (aged care) market- Summary of benefit generated by cannibalising plant-based protein products

Summary - Benefit 2.2	2.2 Substitution / cannibalisation of other plant based protein products for various channels in the supply chain including food service		
Item	Amount	Comment	Assumptions
Benefit 2.2 - product	Soups		
Benefit 2.2 value added to industry	$40,388.51	At 5 year adoption rate	
Benefit 2.2 value added to industry	$40,388.51	At 5 year adoption rate	
Benefit 2.2 value added ($ per carcase)	$0.00	At 5 year adoption rate	

- Table 10 shows the achievable benefit generated through the development of new markets. The market considered in concept here entails end users procuring feed material directly from processors and creating home-made 3DP meals. This is possible based on the assumption that meat can be stored for longer periods than it can currently and can thus be purchased in bulk without packaging of small amounts.

  A key concern of this concept is the adoption rate of this new market. It is assumed to be possible, especially since the idea of dried protein is not foreign. For example, baby formula milk is purchased in dried powder form and water added when a meal is needed. However, this element should be carefully explored and tested with consumers, as it is viewed as a processed product and therefore unhealthy.

Table 10: Additional volume - Summary of benefit generated through new markets

Summary - Benefit 2.3	2.3 New supply chain channels?		
Item	Amount	Comment	Assumptions
Benefit 2.3 - product	3DP raw material	End consumer	
Benefit 2.3 value added to industry	$50,261.58		
Benefit 2.3 value added to industry	$50,261.58		
Benefit 2.3 value added ($ per carcase)	$0.01		

- Table 11 below shows the amount of red meat products that will be cannibalised for the Institutional / aged care market.

Table 11: Additional volume / Institutional (aged care) market - Summary of benefit generated by cannibalising red-meat products

Summary - Benefit 2.4	2.4 Substitution of red meat products		
Item	Amount	Comment	Assumptions
Benefit 2.4 - product	Beef/Veal (Fresh and Frozen)		
Benefit 2.4 value added to industry	$171,807.51	At 5 year adoption rate	
Benefit 2.4 - product	Lamb/Mutton (Fresh and Frozen)		
Benefit 2.4 value added to industry	$69,102.55		
Benefit 2.4 value added to industry	$240,910.06	At 5 year adoption rate	
Benefit 2.4 value added ($ per carcase)	$0.03	At 5 year adoption rate	

4.2.4 Additional value per carcase

Three features characteristic of 3DP products were investigated: product appearance, convenience and healthiness. The appearance feature was considered for the commercial segment, restaurants channel. The convenience and health features were considered for the retail market.

Table 12 shows how the achievable profit mark-up was calculated for a product with a certain "appearance" feature for a specific market. It was compared with an existing item marketed on the same feature and assumed that at least a portion of that mark-up against a normal product can be achieved by promoting a 3DP product with that specific feature *within the same market or channel*.

Table 12: Additional value per carcase / Product appearance benefit for the retail market

Product features added value - achievable markup (Benefit 3.1)			
Item	Amount	Comment	Assumptions
Product feature	Product appearance		
Comparison group	Gourmet meals		
S/C channel	Fine dining restaurants		
Comparison product	Lunch meal		
Comparison product cost ($) - lowest	35.00	https://www.dimmi.com.au/restaurant/palettes?date=2016-02-	
Comparison product cost ($) - highest	105.00	https://www.dimmi.com.au/restaurant/ecco-bistro?date=2016-	
Comparison product cost range	70.00		
"Standard" product	Regular restaurant lunch meal		
Comparison product cost ($) - lowest	20.00	https://www.dimmi.com.au/restaurant/o-bar-and-	
Comparison product cost ($) - highest	65.00	https://www.dimmi.com.au/restaurant/the-alliance-	
"Standard" product cost	42.50		
Markup between"standard" to featured product	64.71%		
Portion of markup that may be achieved for similar channel and product features	40.00%		Only a portion of the markup will be achieved for the particular S/C channel
Achievable markup for similar channel and product features	25.88%		
Volume of BEEF meat consumed for this S/C channel pa (T)	34,437.36		
Maximum replacement percentage / market penetration	10.00%		
3DP (meat component) replacement % after year 1	0.500%	Using adoption rate percentages	
3DP (meat component) replacement % after year 5	1.000%	Using adoption rate percentages	
3DP (meat component) replacement % after year 10	2.000%	Using adoption rate percentages	
Loss (kg) - cannibalisation of competitor product after y5	344,373.56	Taken at 5 year adoption rate	
Product replacement ratio (%) by weight	100.00%		
Gains (kg) - 3DP replacement meat product after y5	344,373.56		Assume 0% reduction in volume between soup and 3DP
Achievable benefit per kg of 3DP meat for this channel ($/kg)	1.42		
Achievable benefit for this channel ($)	489,156.30	Output of benefit 3.1	
Benefit per carcase ($/kg)	0.06	Output of benefit 3.1	

Sources: (Dimmi: QLD >> Brisbane, 2016)

Another aspect of the benefit group: additional value per carcase is the extended shelf life of 3DP products assuming a powdered meat form will be reconstituted and used as feed material. The table below shows the benefit of the extended shelf life of powdered meat on each of the markets investigated.

Regarding the extended shelf life of dried powdered meat, it is likely that cold storage will not be required. It is also likely that less product will expire. Thirdly, there may be an opportunity to reduce yield losses. These items will all have a strong impact on the benefit of 3DP in concept; however due to lack of information it was not quantified.

Table 13: Additional value per carcase / Benefit for each identified market or channel due to extended product shelf life

Target market	Product healthiness	Product convenience	End consumer	Product appearance	Prepared Meals	Snacks	Aged Care	Sources / Assumptions
Channel	Retail	Retail	Direct	Commercial	Commercial and Institutional	Commercial and Institutional	Institution	
Storage + waste - Opportunity to decrease the cost of storage - lack of data on this item								
Preparation at channel								
Number of meals				1,147,911.85			3,666,015.02	Total old age 3DP market
Prep hours per meal				0.05			0.05	Assume in bulk it takes 1 hour for 20 meals
3DP hours per meal				0.04			0.04	Assume for 3DP it takes 1 hour for 25 meals
Labour preparation cost ($/hr)				20.00			20.00	Conservative estimate
Hours saved				11,479.12			36,660.15	Conservative estimate
Total benefit from preparation cost saving				$229,582.37			$733,203.00	
Ordering								
Normal ordering cost ($/kg)	60.00	60.00		60.00	0.00	60.00	60.00	Only considered logistics Assumed: 30 km average, $1/km, labour at $1/km
Frequency ratio of order reduction	0.25	0.25		0.25	0.25	0.25	0.25	Bulk orders can be done, say monthly instead of weekly
Volume per order	1,000.00	1,000.00		1,000.00	1,000.00	1,000.00	1,000.00	Volume per order of x units
Volume reduction (powder form)	0.00%	0.00%		50.00%	0.00%	0.00%	0.00%	**No impact on **ready** products being transported Conservative estimate
Total benefit from ordering cost saving	$11,700.00	$540.00		$30,993.62	$0.00	$1,135.56	$4,873.68	
Yield loss reduction (render) - Opportunity to decrease yield loss - lack of data on this item								
Total benefit for industry								
Summation per channel	11,700.00	540.00	0.00	260,575.99	0.00	1,135.56	738,076.68	

Table 14 shows the summary of the benefit group: additional value per carcase. As can be seen, it offers a considerable benefit to industry.

Table 14: Additional value per carcase - Summary of benefit generated by promoting certain product features

Summary - Benefit 3.1	3.1 Certain product benefits may allow higher pricing for the same raw materials than before. Some benefits include: Product appearance Product convenience Product "healthiness"		
Item	Amount	Comment	Assumptions
Benefit 3.1 - product benefit	Product appearance		
Benefit 3.1 value added to industry	$489,156.30		
Benefit 3.1 - product benefit	Product convenience		
Benefit 3.1 value added to industry	$35,591.51		
Benefit 3.1 - product benefit	Product healthiness		
Benefit 3.1 value added to industry	$253,667.56		
Benefit 3.1 value added to industry	$778,415.37	At 5 year adoption rate	
Benefit 3.1 value added ($ per carcase)	$0.09	At 5 year adoption rate	

Summary - Benefit 3.2	3.2 Longer shelf life		
Item	Amount	Comment	Assumptions
Benefit 3.2 value added to industry	$1,012,028.23		
Benefit 3.2 value added ($ per carcase)	$0.12		

4.2.5 Reduced processing cost

Three scenarios were considered in assessing the benefits of reduced processing costs:

- **Current process** - normal process is followed and no 3DP meals produced;
- **Semi-3D production** - normal process is followed, except that liver, heart and tripe is used to substitute the normal meat component of a 3DP meal and 50% of production volume is due to 3DP;
- **Optimised 3D production** - an optimised process is followed where the top 50% value cuts is done as per normal i.e. middle section, and the front and back goes straight into mincer; this also includes using and implementing an MDM plant; also, 50% of the production volume is for 3DP.

Table 15 shows the processing speeds considered for the three scenarios. In total the speeds are the same for the three scenarios.

Table 15: Reduced cost of processing – operation speeds for each scenario

Operation speeds			
	Current process	Semi-3D production	Optimised 3D production
Carcases / min	0.79	0.79	0.79
Carcases / Statn./hr	47	47	47
Carcases / day	720	720	720
Annual days	240	240	240
Annual # of hd	**172,915**	**172,915**	**172,915**

Table 16 shows the reduced cost of processing due to the impact of known differences between the three scenarios. These costs are all relative to the current process and to the operating speeds selected.

- The accuracy benefit is achieved through the MDM component.
- The labour benefit is achieved by assuming:
    - Firstly, that the 3DP process can be partly automated as the raw material needs to be fine and thus rough cuts can be minced, and;
    - Secondly, cuts may not need to be as precise as before, resulting in less labour required to cut precisely.

Table 16: Reduced cost of processing – impact of known processing costs and benefits on each scenario

COST - BENEFIT ANALYSIS OF SYSTEM		
	Semi-3D production	Optimised 3D production
	$/hd	$/hd
Benefit summary	**Avg.**	**Avg.**
$ Accuracy Benefit per head	$0.00	$6.99
$ Technique Benefit per head	$0.00	$0.00
$ Labour Benefit per head	$4.61	$9.87
$ Automation costs		($0.26)
$ Overall Benefit per head	**$4.61**	**$16.60**

Table 17 shows the summary for each of the 3D production scenarios. The estimated amount of capital is based on the assumed throughput rate of approximately 170,000 head per annum for a 3DP process similar to the process for powdered meat (V.RMH.0034). This is a very rough estimate, as this project does not assume a certain process for 3DP. The optimised 3D scenario also includes the capital costs of an MDM system which will provide the in feed material. Further, it should be noted that the cost of 3D printers were estimated to be low relative to the capital cost of the grinding process. A further benefit to these machines are that they are modular and a number of units can be purchased to match whatever processing speed exactly, allowing for processing room efficiencies.

Another benefit incorporated into the summary below is the benefit derived from the MDM process separately, taking the $16.60 per head to $22.94 per head. The model for calculation of the MDM benefit used identical processing speeds.

The benefit to the processor is clearly significant. For the semi-3D production scenario, a payback period of **1.27 years** can be obtained with an NPV of **$4.6 million**. For the optimised-3D production scenario a payback period of **0.99 years** can be obtained with an NPV of **$17.3 million**. However, it is crucial for the production rates to be married to the specific volume that can be attained through different supply chain channels or markets.

Table 17: Reduced cost of processing – CBA summary

SUMMARY PERFORMANCE MEASURES		
	Semi-3D production	Optimised 3D production
Hd / annum	**172,915.20**	**172,915.20**
Production increase with equipment	**0**	**1.60**
	Avg.	**Avg.**
Capital cost (pmt option, upfront)	$1,000,000	$2,893,636
Gross return Per head	$4.61	$22.94
Total costs Per head	$0.63	$3.39
Net Benefit Per head	$3.97	$25.05
Annual Net Benefit for the plant	$ 687,259	$ 4,331,666
Annual Net Benefit for the ex cap	$ 787,259	$ 2,908,470
Pay back (years)	1.27	0.99
Net Present Value of investment	$4,593,160	$17,270,470

Given the inherent uncertainty around new products, the channels or markets identified so far will be assessed in terms of performance and risks to the processing sector in section 5.2 below.

5 Potential market opportunities

5.1 Summary of markets identified

Table 18 summarises and describes the potential markets investigated in the modelling so far.

Table 18: Description of channels identified

Supply chain channel	Product / product benefit	Description
Processor	Raw material	Processing and provision of raw material for 3DP to all of the other markets identified below. All numbers in section 5.2 *excludes the benefit from processing*; in other words it is the total potential of the 3DP based on the identified benefit groups.
Retail	Product healthiness	3DP products with a dominant health feature offered to the retail sector.
Retail	Product convenience	3DP products with a dominant convenience feature offered to the retail sector.
Direct	End-consumer	3DP products offered directly to the end consumer.
Commercial	Product appearance	3DP products with a dominant appearance feature offered to the commercial/ restaurant sector.
Commercial and institutional	Prepared meals	3DP products in prepared meal form offered to various channels of both the commercial and institutional sectors.
Commercial and institutional	Snacks	3DP products in "snack" form offered to various channels of both the commercial and institutional sectors. Items here include pies and pasties.
Institutional	Aged care	3DP products offered to the aged care segment of the institutional sector. Items here include complete pre-printed meals or meals prepared on site.

5.2 Market potential comparison

Markets were compared in three ways: the total industry benefit possible for each market, volume that can be sold through each channel and finally the ratio of benefit to volume.

The volume estimate for each scenario is the foundation of this model. It assumes a significant amount of effort in marketing and consumer communication. In other words, the specific implementation of a product and associated service, whether home delivery or supermarket attendant friendliness to name two of a million aspects, is what in the end will drive the success. It is all about the implementation of the complete package, the total product offering: the product, quality, processing, marketing, positioning, availability, etc. All those aspects combined influence the volumes that can be achieved and as a result, the feasibility of launching new products.

Figure 4 shows the benefit to volume ratio for each of the modelled markets. The ratio is by far the most significant for the **Direct / End Consumer** market, followed by the **Institutional / Aged care** market. However, it does not make sense looking at the benefit ratio without considering the risks and volumes of each market.

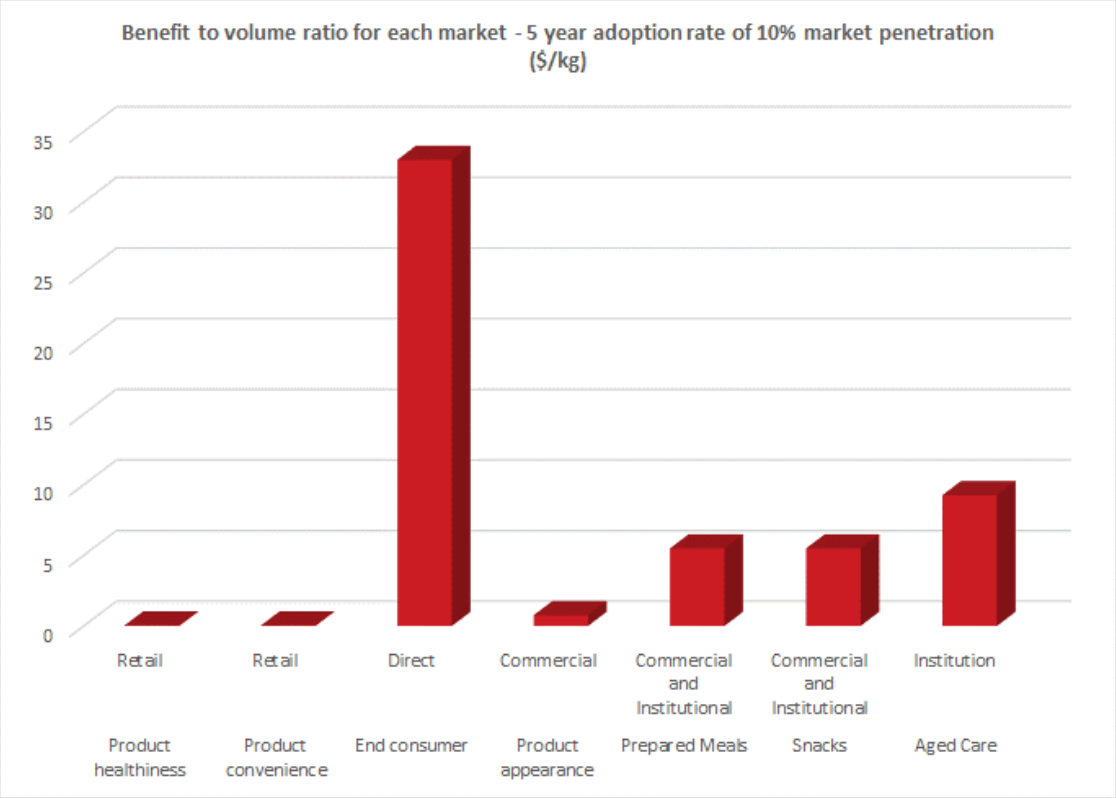

Figure 4: The benefit to volume ratio for each market at a 10% market penetration assumed after 5 years

Figure 5 shows the volumes that can be achieved under current technology performance assumptions. The figure shows the volume impact for different adoption rates, specifically 5%, 10% and 20% of maximum markets.

The figure shows that the three strongest markets in terms of volume are: **commercial - appearance**, **retail - health** and **institutional - aged care**.

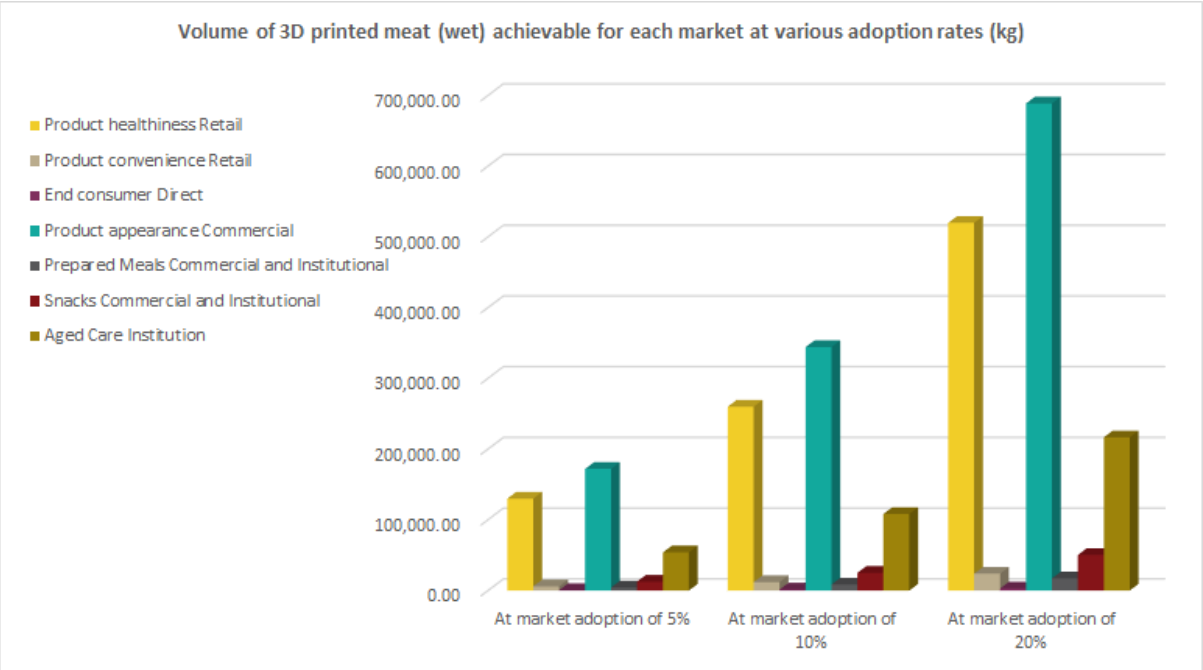

Figure 5: Volume of 3D printed meat achievable for each channel at various adoption rates

Considering the two markets with the highest benefit to volume ratios, the volume that can be achieved by the direct / end consumer market is anticipated to be low under current technology assumptions. On the other side, the institutional / aged care market appears to be a bit more promising and when considering both factors. The institutional / aged care market may be the most promising market.

The next step is to consider the risk involved for each of the markets and to incorporate that into the decision of the most feasible market.

5.3 Risk assessment and model sensitivity

It should be noted that the model parameters are very sensitive including price per unit and volumes per channel. For example, the replacement percentage of tripe into the meat component of meals to the institutional / aged care segment has a high impact on the benefit.

Therefore, it is suggested that both the process and market information get investigated in more detail. In support of that, a risk assessment is done. The intention is to show the areas where information, and as a result model numbers, are the most vulnerable.

Table 19 below shows the risk assessment by channel or market. It considers various areas of uncertainty, including the familiarity of the process, customers, competitors and others factors.

The confidence level of each market or channel should not be taken as an absolute number; rather it should be used as the basis for comparison of markets, where a higher confidence rating indicates an increased probability of success due to transferability of skills and resources and familiarity of service and product delivery.

Table 19: Uncertainty assessment by channel or market

3DP Risk Assessment by channel																
Margin = sales price - cost	Weight	Processor	Rank	Nr	Retail	Rank	Nr	Institution	Rank	Nr	Direct	Rank	Nr	Commercial	Rank	Nr
Sales price drivers	**40.00%**															
Customers	20.00%	New customers	M	6	Familiar	H	9	Unfamiliar customers	L	3	Unfamiliar customers	L	3	Unfamiliar customers	L	3
Competitors: substitutes	10.00%	Familiar	H	9	Familiar	H	9	Familiar	H	9	Unfamiliar competitors	L	3	Familiar	H	9
Product quality outcome	10.00%	New but related process	M	6	New but related process	M	6	Unfamiliar process	L	3	Unfamiliar process	L	3	Unfamiliar process	L	3
Cost drivers	**30.00%**															
Suppliers & service providers	10.00%	New but related suppliers	M	6	Familiar	H	9	New but related suppliers	M	6	New but related suppliers	M	6	New but related suppliers	M	6
Quality specification	10.00%	Unfamiliar quality specification	L	3	Familiar	H	9	New but related specification	M	6	New but related specification	M	6	Unfamiliar quality specification	L	3
Process efficiency	10.00%	Unfamiliar process	L	3	Familiar	H	9	Unfamiliar process	L	3	Unfamiliar process	L	3	Unfamiliar process	L	3
Margin drivers	**30.00%**															
ATAR	30.00%	Medium	M	6	Low	L	3	Medium	M	6	Medium	M	6	Medium	M	6
Confidence level		57.00%			69.00%			51.00%			45.00%			48.00%		

From the risk assessment table it is clear that the difference between channels are relatively small, and the only channels that stands out from the rest are the **retail channel** on the high confidence end and the **direct channel** on the low confidence end.

Using the confidence level from the risk assessment as an index against industry total benefit per market, the graph as shown in Figure 6 is obtained.

The graph clearly shows that the institutional/ aged care market stands out.

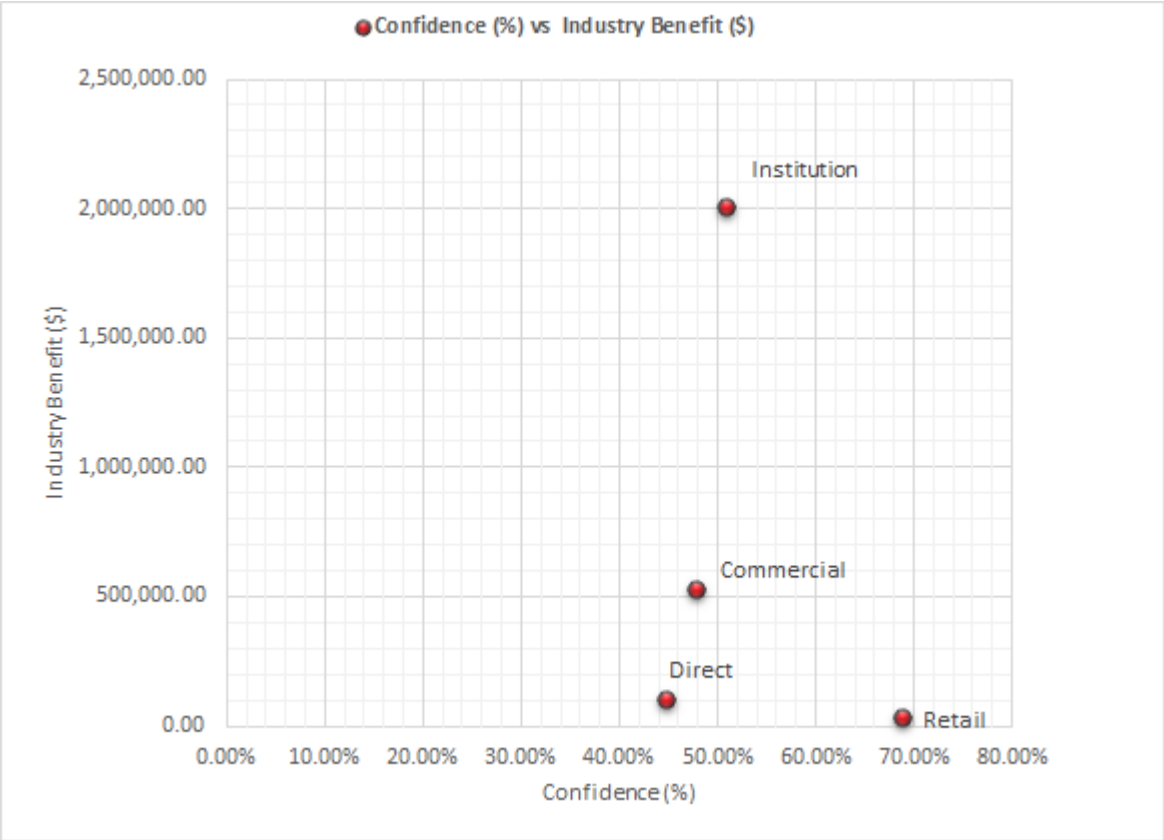

Figure 6: Channel confidence level against industry benefit

The next figure, Figure 7, shows the confidence level from the risk assessment against the volumes that can be obtained for each channel or market. As before, it needs to be considered with the benefit to volume ratio in mind.

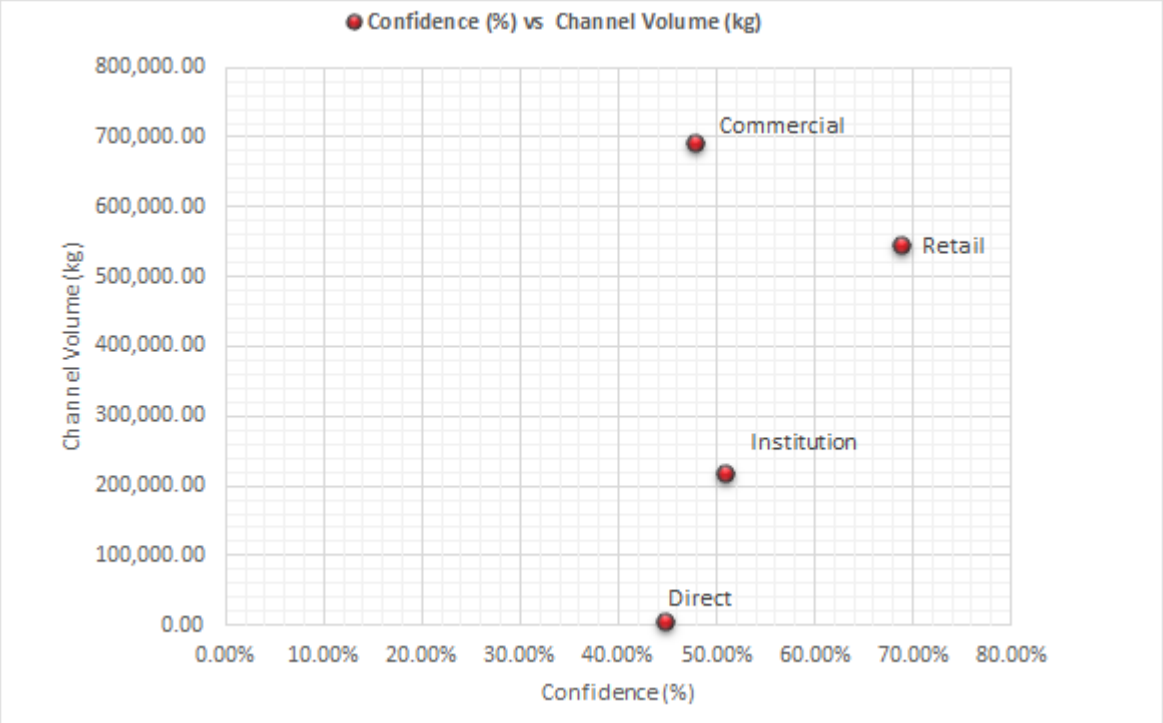

Figure 7: Channel confidence level against volume

5.4 International market projections

Given all the considerations above, the institutional / aged care market was further assessed for international opportunities.

Countries were rated based on the largest population of aged people currently as well as those countries with a large growth rate projection. The list of countries considered is: China, India, US, Japan, Germany and Brazil.

Table 20 below shows how the calculation was done to obtain the size of the total market for each of the countries for the institutional / aged care market.

It should be noted that both the percentage of aged care residents and the meat consumption per capita are very sensitive parameters in the calculation.

Table 20: International market assessment for the institutional / aged care channel or market

International Market Assessment - Institutional Aged Care Channel								
Population Assessment - Current								
	China	India	US	Japan	Russia	Germany	Brazil	Source / Assumption
Population > 65 ('000)	131,429	73,630	47,578	33,342	19,174	17,139	16,305	Source: http://esa.un.org/unpd/wpp/Download/Standard/Population/
Percentage in nursing homes / non-medical facilities	0.80%	3.00%	4.10%	4.00%	1.00%	3.80%	1.30%	Source: India: http://www.prb.org/Publications/Reports/2012/india-older-population.aspx Source: Russia, Germany, China, Brazil, Japan, USA: http://www.un.org/esa/population/publications/livingarrangement/chapter2.pdf
Population in these facilities ('000)	1,051	2,209	1,951	1,334	192	651	212	
Population Assessment - 2050								
	China	India	US	Japan	Russia	Germany	Brazil	Source / Assumption
Population > 65 ('000)	371,391	234,335	86,470	39,006	26,906	24,096	54,267	Source: http://esa.un.org/unpd/wpp/Download/Standard/Population/
Percentage in nursing homes / non-medical facilities	1%	3%	4%	4%	1%	4%	1%	
Population in these facilities ('000)	2,971	7,030	3,545	1,560	269	916	705	
Market volume projections by country for the Aged Care (Institutional) channel								
	China	India	US	Japan	Russia	Germany	Brazil	Source / Assumption
World beef consumption per capita (pounds/population)	3.60	0.60	24.50	7.00	12.90	8.90	27.00	Source: Germany: http://www.globalmeatnews.com/Industry-Markets/German-meat-trade-robust
World sheep meat consumption per capita (pounds/population)	2.80	0.60	0.40	0.10	1.20	0.60	0.40	Source: https://data.oecd.org/agroutput/meat-consumption.htm

Sources: (United Nations- Department of Economic and Social Affairs, Population Division, 2015), (Scommegna, 2012), (United Nations Department of Economic and Social Affairs/Population Division, 2005), (Robinson, 2012), (OECD Data - Agricultural output: Meat consumption, 2014)

As mentioned above, the projected population rates to 2050 were also considered. As a result, the graph shown in Figure 8 was obtained. It appears that the most feasible international markets appear to be the **US, Chinese** and **Brazilian** markets. Surprisingly, the US market exceeds the Chinese market size by far. This conclusion will have a big impact on the marketing approach, as culture is a key adoption driver.

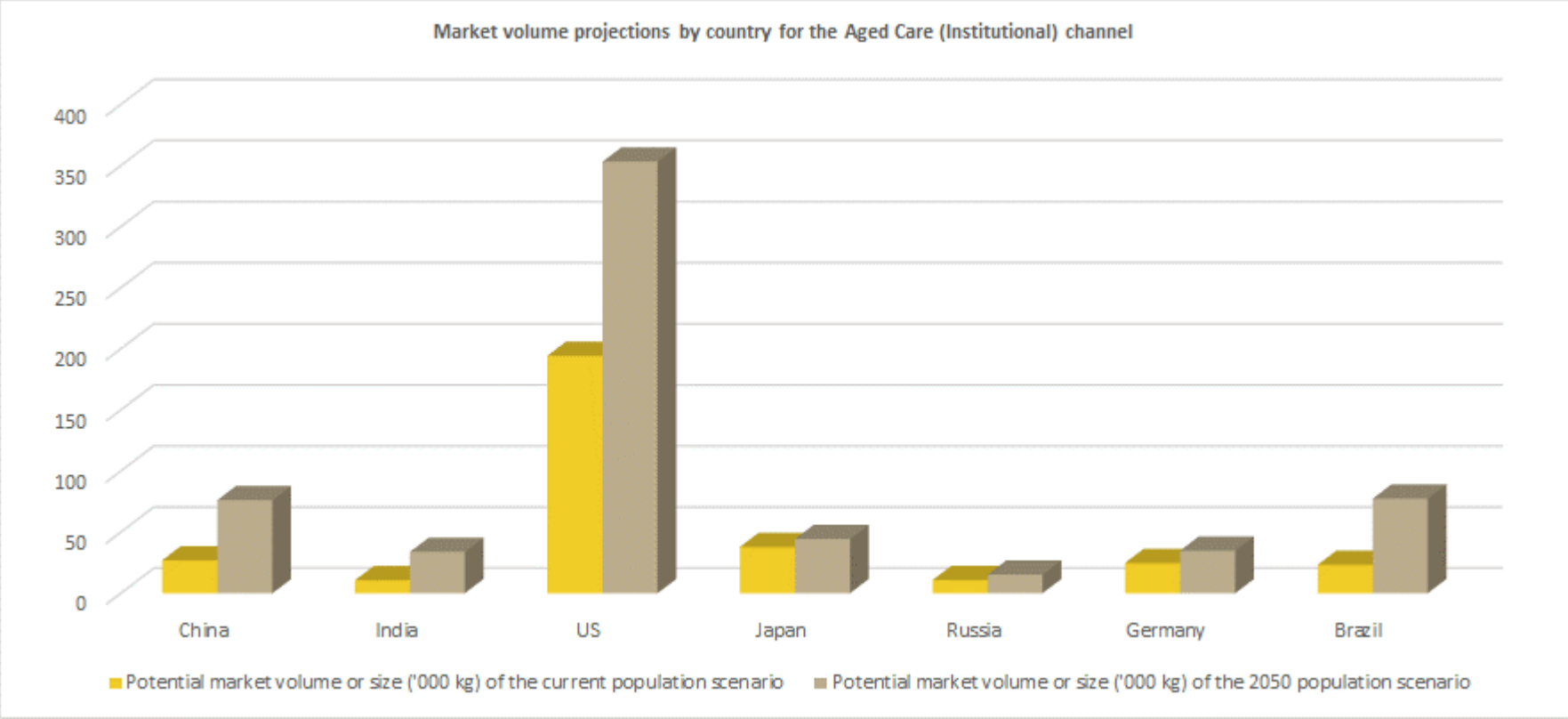

Figure 8: Market projection volumes by country for the Aged care (Institutional) channel

6 Lessons learnt from past technology platforms

A key aspect of this project is the employment of learnings from previous MLA technology platform projects that could not achieve full market adoption. Key learnings from each of these relevant to this project are described below.

Table 21: Previous project and applications for this project

Previous project	3DP Suggestion
P.PSH.0300 – Smart snack – fibre added red meat snack (Pommapalam, 2011)	
A red meat snack was developed, namely mince with fibre added. This product was tested in various supermarkets and was aimed at high school children, young students and aged consumers as a ready to eat snack. Various sources of fibre were added in various quantities relative to the meat component. The product was tested in the market and the additives were found to significantly impact taste, specifically oatmeal and curry was found to be a good combination.	1. Oatmeal could be used as a source of fibre that enhances flavour. 2. Fibre products suitable for 3DP food could be added to make meat products to be perceived as healthier.
A.RMH.0020 - Red Meat Innovation Insights Report: Food for Active Ageing (Jenkinson, 2015)	
The aging population is growing and present great opportunities in food because new aging generations have different demands. Food is more than nutrition, and is different things to different seniors, from opportunities to socialize to opportunities to be creative. The 65+ demographic is viewed as uniform, but in actual fact can be segmented and products developed to target even narrower segments' needs.	3. Segment the aged market further to zoom in on niche markets and niche consumer demands.
A.MPT.0049 – Evaluation and Development of High Moisture Extruded Red Meat Trim Products (Dahm, Evaluation and Development of High Moisture Extruded Red Meat Trim Products (Stage 2), 2014)	
Product flavour and presentation was an issue and with the help of a chef, the colour of the product was changed back to that of naturally cooked meat. The chef added some specialty flavours and worked on the presentation of the meat. He came up with products such as beef schnitzel, meat loaf sandwich, meat loaf parmigiana and beef pizza.	4. Specialised products (flavour, presentation, and implementation) are needed for specialised processing techniques to overcome colour and flavour barriers.
A.MPT.0036 – Powdered meat concept – product trials (Dahm, Powdered meat concept - product trials, 2014)	
For sensory acceptance, rehydrated powdered beef can replace up to 40% of fresh beef in specific products namely burgers and salami. Products with the rehydrated powdered beef were found to be browner and the rigidity was different to fresh beef products.	5. Rehydrated powdered beef is low in sensory quality and requires special flavours or products to make it more acceptable; however it can replace fresh meat successfully in small amounts.
A.MPT.0021 – Enzyme tenderisers for fresh meat (Geesink, 2012)	
Various different enzymes were injected into beef and then aged for 19 days, but none of the treatments improved the sensory quality score of grilled steaks. Experiments were conducted with enzyme concentrations higher than the manufacturer specifications, with success but it compromises the image of fresh meat, and adds salt to the product.	6. Enzymes present another method to tenderise meat, in competition with the approach of 3DP for aged care. However, enzymes also compromise the image of fresh meat and have further additives added to it.

A.MPT.0018 – Commercialisation of MSAT (Gutzke, 2008)	
MSAT steak samples were presented to a panel of Japanese chefs from different backgrounds, ranging from fine dining to quick service. Their feedback on the product was very different on aspects of eating quality and fat content and but they all thought the product was too expensive for a processed meat product at $8 to 9/kg.	7. Because the test panel couldn't agree on quality, plus it was found to be too expensive, MSAT shows that steak may not be the most suitable implementation of the processing technology. Experimentation with different product types, presentations and flavours is needed to exploit the technology and develop a matching product.
A.MPM.0033 - Impingement Oven – potential steak concepts (Austin, 2013)	
Pizza and pasta is a growing item on Asian menus, but doesn't include any beef in their meals as this market believes that a steaks needs to be only cooked on grills.	8. An opportunity exists to include meat to Asian pizza and pasta menus in the form of printed meats.

7 Recommendations and next steps

Considering the strategic benefits of 3DP technology (at present capability) for meat products, several market opportunities stand out based on consumer benefits:

- Healthy, premium prepared meals or 3DP raw material offered in the retail sector promoted for aspects related to disease prevention and personalised health.
- Direct to consumer promoted for aspects related to convenience.
- Personalised meals in the commercial sector promoted for aspects related to appearance and personalisation.
- Personalised food for the aged care market promoted for aspects related to texture and personal nutrition.

Opportunities that stand out based on market benefit, volume and risk are:

- The institutional aged care segment. This segment performance well on industry benefit against risk.
- The retail segment in total (convenience and healthiness and snacks). This market performs well on volume against risk index but specifically snacks do not compete well against existing ready-meal snack products currently available in the retail segment.

On an international level, the aged care segment shows promise in terms of volume in countries like USA and China. However, as stated above, the volume figures used in the model is highly dependent on the final execution and implementation of the product and consumer adoption depends on the perceived benefit, to name a few key factors.

Applying the lessons learnt to the identified market opportunities new product combinations can be discovered. For example, within the age care segment, consumers can be further segmented and oatmeal used to further enhance the “health” positioning of the product.

Depending on the raw material used, special care should be taken to develop products most suited to the technology but not at the risk of quality. To be specific, adding salt or flavouring to try to overcome the sensory barrier of powdered meat may not work as it is at the expense of the healthiness of the product in the mind of the consumer.

The following steps are recommended to further the development of 3DP meat product technology, not in order of importance:

5. Experimentation with final products is needed within each of the market opportunities highlighted above: retail (healthy), direct to consumer (convenience), commercial (appearance), aged care (sensory).
6. Consumer testing and adoption research is needed to assess potential market volumes.
7. Focus should be kept on **risk and consumer benefit** as opposed to potential quantified opportunity, because potential opportunity is highly dependent on the specific product implementation and that is the part that needs experimentation, trial and error to get it working.

8. Ways to experiment while minimising risk is what is needed as a next step. Fortunately, 3DP is modular and economical and thus easy experimentation is exactly what makes it such an alluring technology.

3DP presents a real opportunity for the Australian meat industry provided the time and effort and resources are invested to experiment and learn the technology and develop innovative products. The opportunity for beef is estimated in total at $3,900,000 per annum for beef, and for lamb the estimate is in the same range, based on the current level of skill and product opportunities and assuming the consumer adoption volumes as per the model.

As mentioned above, the consumer adoption volume is the strongest, most sensitive driver and is all dependent on the particular implementation of the product. The consumer volumes can potentially be 10 or 20 or 100 fold, depending on the user benefit offered, the product execution and the market positioning of the product, to name a few of the key aspects. Therefore the opportunity to the Australian red meat industry can potentially be 10 or 20 or 100 fold the estimated value, depending on the specific product offering.

Deloitte predicted that 3DP is the technology of the future, and that it is here to stay. Consumers will own more units than enterprises, but the bulk value will be generated by enterprises (Deloitte, 2015). The technology is still in its infancy, and the meat industry will be left behind if it doesn't put in the effort to experiment and develop products suited to the technology.

Bill Gates, together with other investors, pumped $108 million into Impossible Foods, a company making meat substitutes from plants with the health statement that it contains no cholesterol, no antibiotics, no hormones and no meat. It is very tasty and meat lovers cannot even tell the difference, as plant ingredients are specially selected and combined to create the meat taste (King, 2015). However, the concept is directly in contrast with the food trend of "naturally functional". Further, meat still has a lot to compete with, particularly, animal proteins are naturally satiating. Consumers will try and test and make their own conclusions. 3DP meat products can offer the Australian meat industry the opportunity to compete and if current consumer trends are applied, it can help the Australian meat industry to develop a distinctive competitive advantage.

8 Appendix: Stakeholder interviews

8.1 Technology and processing expert: Key messages from Chris Dahm

- The technology still has a long way to go. Technical issues include selection of the raw material and technique to achieve texture in the final product as well as getting the raw material to set. Because of the texture requirement, powdered meat or a liquid form of raw material could work. One way of setting would be heat, giving you a cooked final product.
- Dried powdered meat:
    - Up to 40% of dried meat can be used in a final product without a negative impact on the taste but the milling process would be expensive. Breaking down meat this way causes the proteins to be stretched and they snap.
    - The aged care market – where people struggle to chew and swallow – may be a potential market for a low-textured 3D-printed product using powdered meat as the raw material.
- Liquid raw material:
    - The great thing about meat is flavour and texture. Flavour you can also get in a soup, but texture is a big thing. If you are 3D printing, the powder won't give you that. The only way to get the fibre back in the process is with some more work. Provided the outlet velocity of a liquid raw material can be better controlled, fibres could effectively be printed to form the required texture.
    - Meat could be layered with cereal. Potentially any market could be catered for. You could do a range of products similar to those already available, from protein bars to roasts complete with fat seams.
    - Using the liquid form and high velocity extruder jets an entire roast could potentially be printed in 5 minutes.

8.2 Commercialisation expert: Key messages from Stephen Dunn

- Meat processors are not so interested in experimentation.
- Meat processors are interested in high-volume solutions and tend to lose interest if they find out the prototype equipment can only operate at a lower rate than their processing rate.
- There is a lot of work to be invested to get a concept into a prototype and into a semi-ready commercial product and it is often underestimated.
- A champion is needed to drive the experimentation, development and commercialisation process.
- Major commercial challenges for 3DP to be overcome are:
    - Expense (capital)
    - Low processing throughput capability
- Could be better suited to niche markets.

8.3 Target market expert: Key messages from

9 Appendix: List of Tables

10 Appendix: List of Figures

11 References

Austin, G. (2013). *Impingement Oven – potential steak concepts .* MLA.

Australian Bureau of Statistics. (2014, June). *3101.0 - Australian Demographic Statistics, Jun 2014.* Retrieved from Australian Bureau of Statistics: http://www.abs.gov.au/ausstats/abs@.nsf/0/1CD2B1952AFC5E7ACA257298000F2E76?OpenDocument

Branden, C. &. (1998). *Introduction to Protein Structures, 2nd edition.* London: Taylor and Francis.

Brunner, T. v. (2010). Convenience food products. Drivers for consumption.

CBS News. (2014). *Nursing homes in Germany serve 3D-printed food*. Retrieved from CBS News: http://www.cbsnews.com/news/nursing-homes-in-germany-serve-3d-printed-food/

Creighton, T. (1993). *Proteins, 2nd edn.* New York: Freeman.

Dahm, C. (2014). *Evaluation and Development of High Moisture Extruded Red Meat Trim Products (Stage 2).* MLA.

Dahm, C. (2014). *Powdered meat concept - product trials.* Sydney: October.

de Godoi, F. P. (2015). *Review of 3D printing and potential red meat applications.* Sydney: MLA.

Deloitte. (2015). *Deloitte technology predictions*. Retrieved from 3D printing is a revolution: just not the revolution you think: http://www2.deloitte.com/au/en/pages/technology-media-and-telecommunications/articles/tmt-pred-3d-printing-is-revolution.html

Deloitte University Press. (2015, June 18). *3D opportunity serves it up.* Retrieved from Deloitte University Press: http://dupress.com/articles/3d-printing-in-the-food-industry/

Dimmi: QLD >> Brisbane. (2016). Retrieved from Dimmi - Reserve the moment online restaturant reservations.

Fagain, C. (1997). *Protein Stability and Stabilization of Protein Function.* Georgetown, Texas: Landes Bioscience.

Fractals LAB . (2015). *TREND ALERT: 3D PRINTED FOOD*. Retrieved from Fractals LAB : http://www.fractals.it/en/trend-alert-3d-printed-food/

Geesink, G. &. (2012). *Enzyme tenderisers for fresh meat.* MLA.

Global Food Forums. (2013). *Protein Trends & Technologies Seminar.*

Gutzke, D. (2008). *Commercialisation of MSAT.* MLA.

Hobley, E. &. (2016, March). *Veggie is the most low-carbon diet, right? Well, it depends on where you live*. Retrieved from BeefCentral: http://www.beefcentral.com/news/veggie-is-the-most-low-carbon-diet-right-well-it-depends-where-you-live

Jenkinson, D. (2015). *Red Meat Innovation Insights Report: Food for Active Aging.* MLA.

King, T. (2015, October). *$108 Million Impossible Foods Investment: Bill Gates Backs Meat-Free Startup*. Retrieved from HNGN Headlines and Global News: http://www.hngn.com/articles/138206/20151008/108-million-impossible-foods-investment-bill-gates-backs-meat-free.htm

Mellentin, J. (2015). *10 Key Trends in Food, Nutrition & Health 2016.* London: New Nutrition Business.

OECD Data - Agricultural output: Meat consumption. (2014). *OECD Data - Agricultural output: Meat consumption*. Retrieved from OECD Data: https://data.oecd.org/agroutput/meat-consumption.htm

OECD/Food and Agriculture Organization of the United Nations. (2015). *, OECD-FAO Agricultural Outlook 2015.* Paris: OECD Publishing.

Pommapalam, E. &. (2011). *Smart snack - fibre added red meat snack.* MLA.

Rawstorne, T. (2013, December). *The future of cooking? PRINT your dinner: Don't scoff - but now 3D printers can make food*. Retrieved from Daily Mail: http://www.dailymail.co.uk/sciencetech/article-2530195/The-future-cooking-PRINT-dinner-Dont-scoff-3D-printers-make-food.html

Robinson, N. (2012, Sept). *German meat trade robust*. Retrieved from GlobalMeat news.com: http://www.globalmeatnews.com/Industry-Markets/German-meat-trade-robust

Scommegna, P. (2012, March). *Home > Publications > Reports > India's Aging Population*. Retrieved from Population Reference Bureau: http://www.prb.org/Publications/Reports/2012/india-older-population.aspx

Solomon, M. R.-B. (2012). *Consumer behaviour: buying, having, being.* Pearson Australia.

Spencer, S. &. (2012). *FOODmap: An analysis of the Australian food supply chain.* Canberra: Department of Agriculture, Fisheries and Forestry .

Sun, J. Z. (2015, January). An Overview of 3D Printing Technologies for Food Fabrication. *Food Bioprocess Technol*.

Thimmesch, D. (2015). *3D Printed Meat and the Future of Food*. Retrieved from http://3dprint.com/: http://3dprint.com/41988/3d-printed-meat-for-the-future/

United Nations- Department of Economic and Social Affairs, Population Division. (2015). *United Nations- Department of Economic and Social Affairs, Population Division.* Retrieved from World Population Prospects, the 2015 Revision: http://esa.un.org/unpd/wpp/Download/Standard/Population/

United Nations Department of Economic and Social Affairs/Population Division. (2005). *Living Arrangements of Older Persons Around the World .* Retrieved from United Nations

Department of Economic and Social Affairs/Population Division: http://www.un.org/esa/population/publications/livingarrangement/report.htm

Vikan, R. (2015). *Consumer response to genetically modified salmon: a study on benefit importance in the adoption process.* Dunedin: University of Otago, Dunedin, New Zealand.