final report

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Design and deliver novel meat extract concepts

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Executive summary

We have investigated what is desirable and feasible for extracts from red meat and organs and designed a low fidelity minimum viable product (MVP) concept. Meat-derived flavours that stimulate the gustatory senses and evoke memories of home-cooked meals were identified as strongly desirable, especially with umami and kokumi taste enhancers, roasty overtones, a slightly sweeter taste profile and an enhanced feel of creaminess.

To determine desirability, we explored the factors influencing the nutritional intake of older age New Zealanders as a model. Focus group interviews designed to discover flavour preferences were held at retirement villages with residents and staff responsible for the food served to residents. **A strong desirability for meaty savoury flavours was identified by the residents**. Participants positively associated meaty and savoury flavours to feelings of nostalgia for the savoury, meat-centric dishes of their youth, most notably the Sunday roast.

To gain an understanding of the **product feasibility,** flavour generation through protein-related reactions, composition of peptides influencing flavour perception, Maillard browning reactions and the contribution of volatile compounds were considered. Flavour extraction approaches that are proven and scalable (e.g. hydrothermal pressure processing, enzymatic hydrolysis, solubilisation) were considered for their yield, production cost, waste treatment, and regulatory and safety requirements.

An existing AgResearch annotated database of flavour compounds has been further improved by incorporating flavour peptides into a larger database of bioactive peptides and consolidating reliable data on tastants. The tastant database will be used as a cost-effective bioinformatic appraisal and screening tool for candidate flavourings during extraction procedures before proceeding further with sensory evaluation of promising candidates.

Data collected on the price of analogous products and the prices of raw materials and initial estimates on conversion efficiency (yield) indicate that **a minimum viable product concept, optimised through process and reaction flavours and in the form of table-top condiments such as a sauce, paste or free flowing powder, can meet or exceed the MDC target of raw material cost to product sales price ratio of at least 3.**

Our initial results suggest that an MVP could be a savoury-flavoured table-top condiments with popular umami flavours, to encourage bioavailable protein consumption. The MVP would not include excess saturated fat, cholesterol, or sodium. Such a product could also be fortified with important micronutrients or designed to be added to a range of nutrient-dense foods targeting a wider population demography.

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1 Background

An opportunity exists to increase the value of red meat offcuts and co-products by developing natural, intense and desirable flavour ingredients and sauces as high value seasoning or functionality-boosters for snacks. The concept is to capture the intense, delicious and satisfying flavour of well-prepared red meat and “bottle it”.

These natural meat flavour products can help expand the range and frequency of occasions to consume meat, by ensuring a premium consumer experience. Delivering authentic natural meat flavour (boosters) can help increase meat consumption. They can also be used in the formulation of foods designed for consumers who currently are not choosing to consume intact muscle (steaks, chops, roasts etc). The flavour market has been identified as a key growth target market to offset declining consumption of traditional red meat cuts.

Enhancing consumers’ sensory experience will help transform and deliver natural higher value meat solutions which could include meat analogues and stocks-sauces-gravies and snacks.

This Meat Extracts project investigates the opportunities for extracting and developing natural meat flavour products from low-value red meat cut and organs.

2 Project objectives

The overall objective of this phase of the project was to determine what is desirable and possible for extracts from red meat and organs and design and deliver low fidelity MVP concept. This was further detailed in milestone 2 as:

a) Identify key flavour principles to pursue, taking into consideration current and emerging competitor products, and the boundaries of acceptable industry methodologies
b) Decide on extraction approach(es) that are feasible, design-driven and scalable (e.g. hydrothermal pressure processing, enzymatic hydrolysis, solubilisation) and technical route to market
c) Decide on suitable meat, organ or co-product raw materials; consider NZ vs Australian sources.
d) Determine scale of a new annotated database of flavour compounds required to support bioinformatic screening.
e) Present first-draft options for prototype foods, and the types of benefits that might be measured in a human study. Describe planning and pre-scheduling requirements for food, recruitment and regulatory affairs.
f) List assumptions related to desirability- viability – feasibility in a business model canvas tool to validate and showcase value proposition
g) Present the market opportunity for red meat extracts

The project team was to *summarise these decisions and submit progress report to MDC to inform pending workshop in presenting final report.*

3 Methodology, results and discussion

3.1 Identify key flavour principles (literature and patent survey)

3.1.1 Literature review

3.1.1.1 Background

Extensive literature and patent searches were performed to gain an understanding of production, development and importance of flavour in food. Flavour perception is a multi-factor experience involving olfactory and gustatory responses, texture, mouthfeel and an integration of all these senses (Wang and Arntfield 2017). Aroma or smell is a very important component of perceived flavour and has been shown to influence consumer purchase intent and acceptance of food (O'Neill 1996). Foods are complex systems with diverse compositions contributed by proteins, lipids and carbohydrates. Understanding the behaviour of aromatic compounds and their interaction with major food components is becoming particularly important in improving the perception of taste (Wang and Arntfield 2017). It is generally recognised that fat, rather than proteins or carbohydrates, plays a more important role in the perception of flavour; as flavour compounds, particularly aromatic hydrophobic compounds, partition into the fat component due to their non-polar characteristics (Wang and Arntfield 2017). Carbohydrates also possess a diverse capacity to interact with flavour compounds based on their complexity which may range from simple sugars to complex polysaccharides (Wang and Arntfield 2017). Flavour-protein interactions are however most diverse due to the wide ranging chemical structures of proteins, including variable amino acid side chains, terminal ends of peptides and hydrophobic pockets within protein structures (Wang and Arntfield 2017). Interactions of flavour compounds may range from weak hydrophobic to strong ionic interactions and even irreversible covalent linkages (Zhou *et al.* 2006). Proteins and peptides, themselves have flavour attributes. Peptides with specific properties with regard to their amino acid composition and size, play an important role in the development and modulation of flavour. The influence of structural characteristics of peptides that have an influence on taste have been investigated by numerous researchers. Generally, taste peptide composition can be divided into taste precursor peptides and the peptide with characteristic taste properties derived from the precursors. Taste properties of peptides have been shown to be dependent on the length and sequence of amino acids in these peptides (Zhang *et al.* 2016). For example, an octapeptide (WVNEEDHL), a nonapeptide (NSLEGEFKG) and a decapeptide (KDLFDPVIQD) were shown to significantly increase meat flavour, umami taste and the kokumi sensation of thickness of chicken extract (Zhang *et al.* 2019). Studies conducted on isolation and analysis of meaty flavour enhancers from beef extracts have demonstrated that the macromolecular nature of these flavouring compounds are mainly peptides generated from collagen and tropomyosin, proteins that occur only in animals. A correlation has also been established between the flavour generation and lipid and sulphur containing amino acids in these extracts (Mabrouk *et al.* 1969). However, a high content of carnosine in the meat was associated with unfavourable sensory attributes mainly related to flavour and taste (Straadt *et al.* 2014).

2.1.1.1 Umami

Umami is recognised as the fifth basic taste and umami substances such as glutamate, 5’-inosinate and 5’-guanylate have been extensively studied. Three umami receptors in humans have been

identified, which led to further evidence that the umami taste is dependent on interactions between umami substances and umami receptors. Glutamate and 5'-inosinate are contained within various foods and the umami taste experienced through the consumption of such foods is induced by these synergisms (Kurihara 2015). Umami provides a pleasant savoury taste and enhances other flavours. Umami substances elicit enhanced appetite and increased food palatability and has been shown to play a role in increased satiety and reduce the post-ingestive recovery of hunger (Stańska and Krzeski 2016). Association of umami substances and management of obesity has also been found.

Studies conducted to understand the perception of consumers, especially in the United States, of umami rich products, indicate that addition of monosodium-L-glutamate (MSG) at low concentration of 0.1-0.5% alone or with 5'-ribonucleotides or inosine monophosphate (IMP) at 0.1% increases consumer acceptance and overall positive consumer perception of chicken soup. Addition of MSG and IMP, regardless of the concentration, were perceived to increase savoury, flavour, fresh, homemade and healthy wholesome attributes thus increasing the overall general satisfaction and positive emotions (Miyaki *et al.* 2016). Sensory perception of umami is also dependent on the concentration of umami imparting ingredients. Sensory intensity using an umami solution containing MSG and IMP was significantly higher compared to MSG alone when the concentration of MSG in the mixture was 0.05%-0.1%. This however plateaued when the MSG concentration was beyond 0.3% (Nishimura *et al.* 2016). Enhancement of umami flavours has been achieved by using cyclic oligosaccharides such as beta-cyclodextrin in the presence of hydrolysing enzymes such as Flavourzyme and Neutrase. Beta-cyclodextrin has been found to enhance umami taste in the hydrolysates by improving the solubility of proteins and forming inclusion complexes with the resulting peptides (Wang *et al.* 2016b). A recent study has shown that the structural differences of umami peptides contribute to their taste profile and thus can be categorised into two groups, Type I and II. Peptides categorised as Type I impart complex tastes and could be split further into two categories, bitterness and umami, whereas Type II peptides impart a strong umami taste at high concentrations that shows a linear relationship between peptide concentration and the development of umami taste intensity (Alim *et al.* 2019).

2.1.1.2 Kokumi

Kokumi is not considered to be a basic taste. It refers to a sensory feeling that is akin to mouthfulness, complexity of taste and the perception of feeling of continuity of taste, with an overall well-rounded and balanced sensation (Feng *et al.* 2016). Maillard reaction products (MRPs) generated through heat-driven reaction of peptides with reducing sugars such as xylose and amino acids such as cysteine increase the mouthfulness and continuity of taste. However, kokumi sensation is complex and various contributing factors are involved that are not restricted to only peptides. These contributing factors could be unhydrolyzed crosslinked products that are formed due to Maillard reaction (Karangwa *et al.* 2016). Peptides such as gamma-glutamyl peptides possess flavouring effects such as the kokumi sensory attribute, which can modify the five basic tastes when added to food. The positive correlation of gamma-glutamyl peptides and sensory attributes are due to the modulation of the calcium receptors (CaSR) on the tongue by these peptides.

2.1.1.3 Maillard Reaction

During the generation of Maillard reaction products, temperature plays an important role. High temperatures (over 100°C) can remarkably increase the formation of meaty aromas generated by

sugars such as xylose when reacted with meat extracts. Lower temperatures and longer heating generate umami and kokumi sensory attributes. Pyrazines were determined to majorly contribute to the roast and meaty aromas in MRPs while glutamic acid release under the low temperature heating contributed majorly to the umami taste. Low molecular weight peptides (less than 500 Da, approximately 5 maino acids or less in length) mainly contribute to the generation of pyrazines and 2-furfurylpyrrole possibly due to the high reaction activity of the amidogen (compounds derived from ammonia) in these compounds. It was also postulated that crosslinks contributing to the formation of compounds with molecular weight more than 1000 Da during the low temperature heating might be responsible for the formation of kokumi-active substances. However, if the crosslinks were allowed to form for a longer time to generate high molecular weight compounds above 3000 Da, these were very likely to contribute to the bitter taste (Liu *et al.* 2015a).

2.1.1.4 Volatile flavour compounds (aromas)

Perception of taste is heavily influenced by the presence of volatiles. Reaction conditions during flavour development influence the production of volatiles. Analysis of volatile substances produced during optimised roast beef flavour development, showed the presence of pyrazine, esters, ketones, alcohols, aldehydes and some heterocyclic compounds as the main aroma components (Liu *et al.* 2015b). Flavour generated from stewed beef using aroma extract dilution analysis (AEDA) indicated that 3-(methylthio)-propanal had the highest flavour dilution factor (FA) which is used as an indicator of the contribution of the identified compound to the overall aroma (Hou *et al.* 2017).

An important aspect of flavour perception is the retro nasal odour enhancement by certain tastes. It is now understood that corresponding food odours can be enhanced by the sweet taste but not by sour or bitter taste. This therefore raises important issues on underlying conditions of retro nasal odour enhancement by taste. For example sweet taste may signal the presence of beneficial substances whereas bitter taste can indicate potentially harmful substances. Saltiness and umami flavours can enhance food odour intensities, but the reverse was not found to be true. Therefore, the degree of odour enhancement was highly correlated with the degree of taste-odour congruency showing that the quality of taste can dictate enhancement of food odours (Linscott and Lim 2016). Characterisation of flavour compounds in chicken bouillon (stock cubes) indicated a positive correlation between favourable sensory attributes and the presence of sulphides, alkanes, aromatic compounds, ketones, alkenes and esters. For example, 2-propene-1-thiol, allyl methyl sulphide, 3,3'-thiobis-1-propene and (E,E)-2,4-decadienal contributed significantly to the characteristic flavour of chicken bouillons (Tian *et al.* 2016).

The loss of volatile compounds can negatively influence the quality of food and therefore consumer acceptability. The ability of proteins to interact with volatile flavour compounds and the nature of these interactions play an important role in the development of flavour. The affinity of flavour compounds to proteins is postulated to be multi-factorial, dependent on the protein source, protein conformation and stereochemistry of the flavour compound. The implication of flavour-protein interaction on protein functionality have also been studied, which show that flavour compounds are able to interact with proteins, supressing and unbalancing the flavour release thereby affecting the overall perception of flavour in food. Also, when flavour is added to low-fat foods, the interaction of proteins and carbohydrates (usually primary components of low-fat foods) interact differently than

fat with flavour compounds. Therefore, flavour systems that work in a full-fat food may not be able to deliver satisfactory results in a low-fat format (Wang and Arntfield 2017).

2.1.1.5 Flavour interactions

The interaction of volatile flavour compounds with proteins have been studied extensively using model systems, but the mechanisms of such interactions are still not clear (Wang and Arntfield 2017). The formation of volatile compounds can be achieved by the inclusion of yeast extract in various food formats, as shown by previous studies. Yeast extracts have been mainly used for their aroma active compounds to enhance flavour and freshness in food, particularly meat and meat products. Yeast extract at 2% concentration was shown to increase the formation of volatile compounds from amino acids and carbohydrate catabolism that also supressed any sensory-quality defects caused by the replacement of sodium chloride with potassium chloride in fermented sausages (Campagnol *et al.* 2011). Sodium chloride is the most widely used additive in food processing due to its essential function in food, influencing flavour, texture and shelf-life especially in meat products. Novel technologies to aid reduction of the use of salt such as high hydrostatic pressure processing and the use of ultrasound have been used to provide microbiological safety in low-sodium meat products. However, a lowering of the flavour component due to these treatments has needed to be compensated particularly by using yeast extracts and other enhancers such as monosodium glutamate (Inguglia *et al.* 2017). Volatile compounds together with sugars, amino acids, fat and nucleotides, determine the characteristic aroma and taste of food. Main aroma active compounds determined in yeast extracts are aldehydes, acids, ketones, furan derivatives, pyrazines and sulphur compounds. Volatile compounds such as 3-methylbutanal, 2,3,5-trimethyl-pyrazine, acetic acid ethynyl ester, 2-acetyl-1-pyrroline and (E,E)-2,4-decadienal have been shown to strongly influence flavour (Mahadevan and Farmer 2006; Lin *et al.* 2014). Yeast extracts also contain significant amount of glutamic acid, 5'-GMP and 5'-IMP nucleotides which interact synergistically with amino acids and peptides present in the extracts to enhance flavour (Rakowska *et al.* 2017). However, yeast extracts also have the disadvantage of yeasty off-odour. Some of these off-flavours have been identified using analytical methods and determined to be phenolic and pyridine compounds and carboxylic acids such as butanoic and propanoic acid (Zhang *et al.* 2017).

2.1.1.6 Protein hydrolysates as sources of flavour compounds

Flavour can be derived from protein hydrolysates. Protein hydrolysates from bovine and porcine sources obtained by hydrolysis using food grade enzymes such as Flavourzyme, papain, Protamex, Bromelain etc. indicated that strong relationships exist between the degree of hydrolysis, the molecular weight distribution of the peptides and the sensory characteristics of the hydrolysate. The nature of enzymes used for producing these hydrolysates also has a strong influence on the flavour profile. A mixture of exo- and endo-peptidases was found to generate hydrolysates with umami taste and low bitterness. Umami taste was positively correlated with molecular weight distribution of peptides between 500-1000 Da (Fu *et al.* 2018). Pre-treatment of proteins before enzymatic hydrolysis has also been shown to change flavour profiles. Studies have been carried to determine the effect of pre-treatments such as microwave and ultrasound followed by the action of proteases to enhance umami taste compounds in protein hydrolysates. Ultrasonication or microwave pre-treatment was found to increase the content of monosodium glutamate like amino acids and 5'-nucleotide contents increasing the umami properties of protein hydrolysates (Bruno *et al.* 2019).

2.1.1.7 Extraction of flavour compounds

Various technologies to extract flavour have been used in the food industry. Hot-pressure extraction technologies are used to extract nutrients such as proteins and minerals from bone residues. Hot pressure water extraction, regarded as a 'green technology', demonstrated high protein recovery from bones especially chicken at 135°C and 120 min extraction. High levels of essential amino acids, a decrease in the amount of bitter peptides/amino acids, and favourable flavour are some of the attributes of hydrolysates obtained using this technology (Wang *et al.* 2016a). Subsequent processing of the extracts using enzymes for the development of flavour compounds have been reported. Over forty different volatiles could be identified after 24 h hydrothermal extraction followed by enzymatic hydrolysis. An increase of almost 74% in the small molecular weight peptides (400-1000 Da), a contributory factor in flavour development, was observed after 8 h hydrolysis compared to 1 h hydrolysis time. This indicated that generation of taste active peptides is possible with prolonged hydrolysis time (Dong *et al.* 2014).

2.1.1.8 Other sources of flavour compounds

Another source of flavour compound are microbes. The microbial production of natural flavours during fermentation has been extensively studied and is currently being commercially exploited. However, lactones and some aromatic compounds from microbes that contribute significantly to the development of flavour need to be studied in greater detail as there is a lack of information on their metabolism and associated toxicity which is one of the barriers to industrial production of flavours from some microbial sources at present (Feron *et al.* 1996). With the current trend in using natural ingredients in food, there is renewed interest of using microbial sources such as bacteria, yeast, fungi and microalgae as producers of food ingredients and flavours. Microbially produced organic acids and hydrocolloids are also gaining traction as food ingredients (McNeil *et al.* 2013).

2.1.1.9 Off-flavours

Bovine bone extracts are sometimes associated with off-flavour. Simple procedures of using hot water washes have proved effective in the removal of off-flavour producing compounds. Steaming treatments have also been shown to produce compounds with favourable aroma such as 4-methylthiazole (Jang *et al.* 2014). Novel methods such as the use of lipase pre-treatment on bovine bone hydrolysates to favour the formation of MRPs have also been shown to be successful. Lipase pre-treatment before hydrolysis with proteolytic enzyme(s) significantly increased the degree of hydrolysis, the formation of low molecular weight peptides and free amino acid content, all of which contributed to the development of flavour. Maillard reaction carried out on these hydrolysates resulted in an increase of almost 78% of furans, pyrroles and thioesters which provided mouthfulness, umami taste and meaty flavour (Song *et al.* 2016). Maillard reaction on bone extracts have clearly demonstrated the formation of flavour forming free amino acids. Umami flavour increased initially during Maillard reaction but then decreased while equivalent umami concentration remained at a relatively stable level. Maillard reaction was also determined to reduce bitter taste in hydrolysed bone extracts and could be used as an effective process to change the flavour profiles by enhancing the meaty flavour (Sun *et al.* 2014).

2.1.1.10 Physiological activity of flavoursome extracts

The effects of bone and muscle extracts, especially from chicken, on cognition and mood have been extensively studied in human subjects. Extraction performed using hot water under high pressure was shown to result in high levels of proteins, amino acids, peptides and carnosine. Young adults tested after consumption of chicken extract were found to have quicker reaction times on focussed attention tasks, improved memory and quicker recovery of normal cortisol levels when subjected to stressful situations. The mechanism of physiological action of these extracts is postulated to be through the serotonin transporter (Benton and Young 2015). Although various tests have been performed to determine the physiological effect of chicken extracts it is also realised that further high quality randomized double-blinded controlled studies are required to arrive at stronger conclusions about these effects (Charernboon *et al.* 2016). Diketopiperazines (DKPs) are cyclic di-peptides which occur naturally in food and are particularly enriched in chicken extracts. DKPs are known to inhibit serotonin transporter and supress serotonin uptake. DKPs can increase extracellular levels of cerebral monoamines such as serotonin, norepinephrine and dopamine in rats and are thus suggested to abrogate the onset of depression and contribute to preventing the development of Alzheimer's and other types of dementia. This is of particular importance as senile depression is a risk factor for the development of dementia (Tsuruoka *et al.* 2012). Although extensive work has been performed to characterise chicken extracts, beef extracts are cheaper to produce than chicken extracts and may be used as nutritional supplements during chemotherapy procedures and to prevent fatigue. Beef extract has been shown in an animal model to increase endurance grip strength in a dose dependent manner. Beef extract significantly decreased lactate and blood urea nitrogen and glucose levels with a concomitant significant increase in muscle glycogen levels indicating an improvement in endurance when animals were subjected to prolonged physical challenges (Hsu *et al.* 2018).

2.1.1.11 Patents

Most patents returned by the patent search relate to methods of production of flavoursome products. Several disclose methods for production of simple meat extracts or stock (Howorth 1903; Marshall and Sutcliffe 1921; Iwamoto *et al.* 1996; Fujimoto *et al.* 2005; Okada 2010). The extraction of freshly slaughtered meat, prior to the onset of *rigor mortis*, is claimed to result in higher levels of 5'-IMP and a different flavour compared to standard meat (Stute and Seuss 1998; Seuss and Stute 2001). In one patent, the addition of an emulsifier prior to ultra-heat treatment (UHT) reportedly gave improved preservation of a meat extract (Nakayama *et al.* 2006). An early patent disclosed a method for preparing a dry meat extract, by pressing the meat to provide soluble and insoluble portions, followed by pepsin or papain solubilisation of the insoluble fraction, and finally freeze drying of the combined soluble portions (Chalas 1922). The use of enzyme hydrolysis is also claimed in a more recent patent; in this case hydrolysis using multiple enzymes comprising at least one endopeptidase (amino-endopeptidase and/or at least one carboxy-endopeptidase) and/or at least one exopeptidase (Scheide-Fischer and Scheide 2011). A product for rapidly producing a bouillon having "superior sensory quality" is described by Okada (2017); this consists of a water-permeable flexible container, designed to facilitate hot water extraction, which contains a combination of dried meat and meat extract (preferably from chicken). Apparatus for drying meat extract and other liquids is described in an early patent by Amundsen (1913). One patent discloses a soluble dried protein mixture comprised of meat extract and collagen that provides macro-and micronutrients in products

designed particularly to fortify the diets of patients or people who have difficulty swallowing (Bertin 2012).

Some patents relate to products in which other ingredients are included with meat. One includes aromatics from onions, vegetables, mushrooms, spices and/or other seasonings (Dragoco Gerberding Co GMBH 1975). Okada and co-inventors disclose a method for making a bouillon that involves the use of lactic acid fermentation and the addition of vegetables and/or spices (Okada 2004, 2011). Concentrates, gels or storage-stable stocks are the subjects of several patents (Staeger 1936; Melwitz *et al.* 2003, 2005; Achterkamp *et al.* 2013; Perrine 2018).

Preservation of flavour components in liquids with a high dry matter content is the subject of a recent patent by Aida *et al.* (2019); their process entails continuous heating at 130°C or above, performed for a short period of time by use of a direct steam-heating cooker.

Multiple patents specifically relate to the extraction of chicken meat to produce chicken essence (Ke 2008; Huang 2013; Wu *et al.* 2017). As for other meats, some disclosed processes involve the use of enzymes to affect solubilisation and flavour of the chicken essence (Tai *et al.* 2008; Yang and Tsai 2008; Yin *et al.* 2013a; Yin *et al.* 2013b). Flavour is enhanced in one process by combining chicken essence and soy sauce (Kuo 2010). In another process that utilises enzymatic hydrolysis the inventors claim the production of immunostimulating peptides that result in chicken essence with immunostimulatory activity (Lin and Tsai 2007). A machine specifically designed for production of chicken essence is described by Lin (2014).

Artificially generated flavours are the subjects of some patents. Galer *et al.* (2014) claim a natural biogenerated cheddar flavour component which is stabilised by the addition of a bacteriocin source (as a natural antimicrobial) to the fermentation mixture. A method for producing meat flavour by heating together amino acids and/or protein hydrolysates with a reducing sugar and a sulphonic acid component is detailed by Hack and Konigsdorf (Hack and Konigsdorf 1969, 1970). Yeasts extracts, which can impart or enhance meat flavour, are the disclosed in three other patents (Kengo and Akio 1970; Fujita *et al.* 2011; Horiguchi *et al.* 2016).

A number of patents and patent applications relate to compositions that impart kokumi and umami flavour to foods due to the presence of γ-glutamyl peptides, which are agonists of calcium receptor CaSR (Nisiuti *et al.* 2013; Mijaki *et al.* 2014; Miyaki *et al.* 2015; Futaki *et al.* 2017; Yamamoto and Imada 2018). The kokumi-imparting mixtures may be prepared using enzymatic methods (Hofmann and Dunkel 2012a, 2012b) or fermentation (Lee *et al.* 2018). Other patents describe the preparation of products providing kokumi from yeast extracts and vegetables or hydrolysed vegetable protein (Hayashi *et al.* 2005; Cepanec *et al.* 2017; Pluter-Schuddemat 2019). Ohsu and co-inventors claim a method for screening for kokumi-imparting ability, by measuring calcium receptor activity *in vitro* using cells transformed with a foreign calcium receptor gene, and processes and products developed using the assay are also claimed (Ohsu *et al.* 2016).

Several patents specify the use of specific compounds to enhance or modify the kokumi effect of gamma-glutamyl-containing derivatives. These modifiers include 1-octen-3-ol and/or 1-octen-3-one (Aso *et al.* 2014), pyridine derivatives (Delort *et al.* 2011; Rubin 2019), acrylamide compounds containing aromatic moieties (Billat-Rossi and Aeberhardt 2019), and cinnamides (Ley *et al.* 2015).

Sato *et al.* describe the synthesis of lanthionine derivatives that impart kokumi, one of which was found to have CaSR agonist activity about 9 times stronger than y-Glu-Cys (a well-recognised kokumi-imparting substance) (Sato *et al.* 2016).

3.1.2 Global food flavours market

Used in various products such as bakery, confectionery, meat, snacks, seafood, and poultry, "food flavours are used to alter the flavours of natural food product or creating flavour for food products that do not have the desired flavour". Food flavour is classed as a type of food additive, is generally marketed in powder form for easy storage, packaging and transportation (Jiang *et al.* 2013).

According to Allied Market Research, the global food flavours market was valued at US$13,172 million in 2017, and is expected to reach US$20,106 million by 2025, yielding a compound annual growth rate (CAGR) of 5.4% from 2018 to 2025[1]. Growth in disposable income and increase in demand for ready-to-eat meals are the main drivers for the industry, and Asia-Pacific market is forecasted to lead the market growing at a CAGR of 6% during the forecast period. Note that China represented 30% of the Asia-Pacific food flavours market in 2017.

Broadly, flavours can be classified into natural and artificial flavouring substances. In 2017, the natural flavours segment accounted for more than half of the global food flavours market share. Due to increase in health awareness in recent years, consumption of natural food flavours is projected to grow at a CAGR of 9%.

Based on end-user types, the market can be divided into:

- beverages
- dairy and frozen products (including meat)
- bakery and confectionery
- savoury and snacks
- animal and pet food

Among these, the beverages segment will continue to dominate the food flavours market, while the savoury and snacks segment is expected to grow at the highest CAGR of 6.3% during the forecast period due to the increasing demand for ethnic, spicy, unique and exotic flavours, and unusual flavour combinations.

Some of the key players in the food flavours market are:

- Kerry Group
- Givaudan
- Firmenich
- Symrise AG
- Sensient Technologies Corporation

[1] https://www.alliedmarketresearch.com/press-release/food-flavors-market.html

- Frutarom Industries
- Hasegawa Co. Ltd.
- International Flavors & Fragrances Inc.
- Takasago International Corporation
- Wild Flavors
- Huabao International

3.1.3 Global sauces, dressings and condiments market – an alternative market

While food flavours alter the flavour of food, sauces, dressings and condiments are flavour enhancers. This subtle difference results in the different product positioning and target market for these two product groups.

According to Prescient & Strategic (P&S) Intelligence, the sauces, dressings, and condiments market was valued at $US115.3 billion in 2017, and is expected to grow at a CAGR of 3.8% between 2018 and 2023. The main drivers for global market growth are:

- rising disposable income
- busy lifestyle of people
- launch of innovative and new flavours
- introduction of low-fat substitutes
- rise in use of natural and organic ingredients
- increase in consumer curiosity towards international cuisines

Based on the different product types, the market can be divided into:

- table sauces
- cooking ingredients
- dips
- pickled products
- pastes and purees
- others

The table sauces segment was the largest category in 2017, responsible for more than 30% revenue in the market, followed by the cooking ingredients segment as the second largest category. Again, Asia-Pacific was the largest market in 2017.

3.1.4 Regulatory landscape

Food Standards Australia New Zealand (FSANZ) is an independent statutory agency established by the Food Standards Australia New Zealand Act 1991 (FSANZ Act). FSANZ is part of the Australian Government's Health portfolio, and develops standards that regulate the use of ingredients, processing aids, colourings, additives, vitamins and minerals.

According to Australia New Zealand Food Standards code 2.2.1, offal is defined separately from meat, and includes blood, brain, heart, kidney, liver, pancreas, spleen, thymus, tongue and tripe, and excludes meat flesh, bone and bone marrow. The presence of offal in foods must be declared in the

list of ingredients, and such information must be declared to the purchaser if food labelling is not required. The labelling provisions suggested that brain, heart, kidney, liver, tongue or tripe must be identified as offal, or by the specific name of the type of offal. Any other type of offal must be identified by the specific name of the type of offal.

Published in February 2012, the International Organisation of the Flavour Industry (IOFI) Code of Practice version 1.3 defined different types of flavouring substances based on the current Codex Guidelines on the Use of Flavourings (CAC/GL 66-2008). A number of relevant definitions are provided below:

- Natural flavouring substances (CAC/GL 66-2008 item 2.2.1.1) are flavouring substances obtained by physical processes that may result in unavoidable but unintentional changes in the chemical structure of the components of the flavouring (e.g. distillation and solvent extraction), or by enzymatic or microbiological processes, from material of plant or animal origin. Such material may be unprocessed or processed for human consumption by traditional food-preparation processes (e.g. drying, torrefaction (roasting) and fermentation). This means substances that have been identified / detected in a natural material of animal or vegetable origin.
- Synthetic flavouring substances (CAC/GL 66-2008 item 2.2.1.2) are flavouring substances formed by chemical synthesis.
- Natural flavouring complexes (CAC/GL 66-2008 item 2.2.2) are preparations that contain flavouring substances obtained by physical processes that may result in unavoidable but unintentional changes in the chemical structure of the flavouring (e.g. distillation and solvent extraction), or by enzymatic or microbiological processes, from material of plant or animal origin. Such material may be unprocessed or processed for human consumption by traditional food-preparation processes (e.g. drying, torrefaction (roasting) and fermentation). Natural flavouring complexes include the essential oil, essence, or extractive, protein hydrolysate, distillate, or any product of roasting, heating, or enzymolysis.
- A thermal process flavouring (IOFI Guideline chapter 14.3) is a product prepared for its flavouring properties by heating raw materials that are foodstuffs or constituents of foodstuffs. This process is analogous to the traditional home cooking of ingredients of plant and animal origin.
- Smoke flavourings (CAC/GL 66-2008 item 2.2.3) are complex mixtures of components of smoke obtained by subjecting untreated wood to pyrolysis in a limited and controlled amount of air, dry distillation, or superheated steam, then subjecting the wood smoke to an aqueous extraction system or to distillation, condensation, and separation for collection of the aqueous phase. The major flavouring principles of smoke flavourings are carboxylic acids, compounds with carbonyl groups and phenolic compounds.

The Flavour and Fragrance Association of Australia and New Zealand (FFAANZ) is a member of IOFI and has adopted the IOFI Code of Practice. However, FSANZ has not included these detailed definitions into the Food Standards Code, thus there is no mandatory compliance date under Australian or New Zealand Food Law.

As well as meeting any New Zealand requirements, it is important to check any additional requirements set by the specific destination markets. It is advised to work with an overseas agent or importer to get advice on any regulatory requirements.

3.2 Decide on extraction approaches

There are numerous methods for extracting intact proteins and/or peptides (protein fragments) from meat and other materials. Regardless of whether the aim is to recover intact proteins or peptides, the methods predominantly have an extraction/digestion stage and a separation stage. During the extraction/digestion stage protein is liberated from the substrate, while in the separation stage, the solubilised protein is separated from insoluble residue and potentially other unwanted material that may also have been liberated from the substrate. Extraction is typically performed using water or aqueous salts, often at elevated temperature and pressure. Digestion steps break proteins into peptides or amino acids and include: acid hydrolysis, alkaline hydrolysis and enzyme hydrolysis. In some processes the residue from one extraction/digestion is used as the feedstock for another, thus different types of protein/peptide are extracted from the same feedstock material. The separation stage usually has a number of steps during which the liquid protein extract is separated from the insoluble residue by processes such as centrifugation, filtration, expanded-bed chromatography, and/or dissolved air floatation.

Similar to method selection at a laboratory scale, the most suitable commercial process depends on the nature of the feed stock and the desired end product. However, in addition to these, factors which are often of little consequence at laboratory scale must also be considered e.g. yield, production cost, waste treatment, and regulatory and safety requirements.

For our application of developing a flavour ingredient, until the feedstock has been selected and the final product specifications determined it is not possible to describe the envisaged process in detail. However, using the available information, and making a number of assumptions, we are able to outline a process and make some preliminary identifications of the unit operations that will be required. The assumptions made, which may change as the project progresses, are:

- The primary attribute of our product is that it will have a strong umami flavour
- The flavour will come from a mixture of peptides, lipids, and volatiles etc
- The feedstock will be a solid that is likely to contain muscle, connective tissue, arteries/veins, blood and possibly bone e.g. low value muscle, offal (kidney, liver).
- A hydrolysis method will be needed to turn the proteins in the feed material into flavour-rich peptides. Solutions, materials and handling will be food-safe.
- We may need to use additives e.g. anti-oxidants to preserve the flavour components during processing.
- There may be molecules that need to be removed e.g. ones that cause bitterness.
- The product will be either a liquid concentrate or dry powder.
- If the final product is a liquid, it should not contain lumps, particulates or settleable solids.

3.2.1 Process strategy

The envisaged process will use enzyme hydrolysis to produce flavour-rich peptides that will work in unison with other flavoursome components and volatiles present in the feed material to produce a desirable umami flavour. Unit operations will be required, prior to and after hydrolysis, to turn the enzyme hydrolysate into a final product. Unit operations that are before the hydrolysis will prepare the feed material for hydrolysis by removing contaminants or changings its size/form. Unit operations that follow the hydrolysis will remove unwanted components and/or alter the form of the process stream to that desired in the final product. These unit operations are discussed below.

3.2.2 Size reduction of feed material

Like most processes that act on a solid substrate, enzyme hydrolysis is greatly influenced by the physical size of the feed material. Due to relationships between size and mass and heat transfer, having a small feed size speeds up reactions and can increase yields. Therefore, prior to hydrolysis the feed material should be reduced in size as much as practical. For soft tissues this could be done by mincing, while for harder materials, or those containing bone, something more powerful may be required e.g. a hammer mill.

3.2.3 Pre-treatment

Depending on the feed material and desired product some pre-treatment may be needed to remove unwanted components prior to enzyme hydrolysis, or even prior to the size reduction step. The simplest form of pre-treatment is a water wash. A cold wash may be required to remove blood or extraneous material such as loose hair or bone chips. A warm wash might be used to remove these materials plus some fat; where possible it is beneficial to remove fat early in the process rather than later when a more complicated system, e.g. centrifuge, may be required. It is likely that some protein will be soluble in the wash water, and therefore lost with it. If it is crucial that these proteins are not lost then the wash conditions (e.g. temperature, pH, salt content) may need to be altered to minimise their loss. Conversely, the aim of the pre-treatment may be to remove certain components by intentionally altering the temperature, pH, or salt content so that they become soluble and are removed in the pre-treatment liquor.

3.2.4 Hydrolysis

For this application enzyme hydrolysis is favoured over other hydrolysis methods, e.g. acid or alkaline hydrolysis, as it is a gentler process (uses lower temperature and is closer to neutral pH) so is less likely to cause chemical reactions or modifications that could negativity affect flavour. Additionally, as the reagents used during acid or alkaline hydrolysis contain salt, these processes tend to produce salt-rich solutions which often need a unit operation to lower their salt content. Since different types of enzymes cleave proteins at different places, the enzyme used will determine which peptides are produced. Therefore, enzyme selection is critical, and it may be necessary to use a combination of different enzymes. The degree of hydrolysis also affects the nature of the peptides produced, so it is important that factors that affect this are controlled e.g. enzyme:substrate ratio, time, pH, and temperature. If the degree of hydrolysis is found to be critical then at a certain point the enzyme will need to be deactivated to stop the hydrolysis. The most common methods of doing this are to

denature the enzyme by increasing the temperature or altering the pH; how much these need to be altered depends on the enzyme being used. Some enzymes can also be deactivated by exposure to very high pressure. Considerations will need to be made to ensure the conditions needed to deactivate the enzyme do not damage the flavour components.

It is very likely that the feed material will contain endogenous enzymes, and therefore possible that during the enzyme hydrolysis step these enzymes will become active. If this happens the extract may contain peptides that do not match those predicted to be produced by the enzyme(s) used to perform the hydrolysis. It is also possible that the feed material will contain enzyme inhibitors that block the activity of the added enzymes.

3.2.5 Removal of particulate material

It is unlikely that all the solid feed material will be solubilised during the enzyme hydrolysis. Components such as connective tissue and bone are likely to remain, as may some of the soft tissue. If this remaining material is going to detract from the final product then it either needs to be removed or changed in form. Large particles (over 2 mm) can easily be removed by passing the process liquor through a screen or coarse filter. The best method for removing small (less than 2 mm) particles will depend on their abundance and the viscosity of the process liquor. If the small particulates are of low abundance and the process liquor is not overly viscous then they should be removable by dead-end filtration, or possibly sedimentation. If these processes are not practical, then centrifugation or pressure assisted filtration should be considered.

Removal of fine particulates may not be the best approach. If these particles are merely unhydrolyzed tissue, and they don't negatively affect flavour, then it might be better to further reduce them in size and leave them in the product. This would add to the dry-mass yield and prevent the generation of a waste stream.

3.2.6 Removal of fat

While the presence of fat can be beneficial to the product, as it can enhance flavour and mouthfeel, there will be an upper limit as to how much is acceptable. This limit will be lower if the final product is to be dry than if it is to be a liquid because fat can cause problems during drying and can cause rancidity in finished dry products. Fat can be removed by a number of means including (i) hot-wash pre-treatment, (ii) floatation (allowing fat to float to the top and then skimming it off), (iii) by centrifugation. How, and at which stage, the fat is removed (if necessary) will depend on what other unit operations are needed and what their operating conditions are. For example, if a hot-wash pre-treatment is needed to remove some other contaminant, then it makes sense to remove the fat at the same time. However, if the temperature required during the enzyme hydrolysis is high enough to melt the fat then it may be better to remove it by floatation after the enzyme hydrolysis. Given that our product could benefit by the presence of some fat, and that it could be technically difficult to remove a controlled fraction of the fat, the most practical option may be to remove all the fat and then add some back as required.

3.2.7 Concentration

Concentration may be required if the process stream is too low in solids content for the desired product, or if the product is to be in a dry form, e.g. a powder. The process cost of removing excess water during a concentration step is usually less than the cost of removing the same amount of water in a dryer.

Since many reactions that can alter flavour occur as heat is applied it will be beneficial to perform the concentration using a low temperature process, or at least one that uses a temperature no greater than that used during the enzyme hydrolysis. Possible options are evaporation under a vacuum or tangential flow membrane filtration. The former is preferred, as due to the multicomponent nature (e.g. fat) of the process liquor it could cause severe membrane fouling, which can be problematic.

If the issue is that the solution is too runny, as opposed to too low in solids, an alternative/supplementary approach to concentration is to add a thickener to achieve the desired texture.

3.2.8 Homogenisation

Since the process stream may contain a mix of soluble proteins/peptides, fat, and particulate material it could have a tendency to separate into different phases on standing. A homogenisation step would help prevent this; this may require the inclusion of an additive (e.g. an emulsifier).

3.2.9 Drying

If the final product is to be a powder, a drying step will be needed. Selection of the most suitable type of dryer will depend on a number of yet to be determined factors (e.g. heat liability of product, propensity of the product to oxidise in an air stream, etc.) as well as process economics (which are largely influenced by production rate), and the desired properties of the final product.

3.2.10 Alternate approach

The discussion above has treated the feed material as one process stream. To avoid some technical issues, it may be better to fractionate the feed material early on, process each fraction separately, and then recombine the fractions near the end of the process. However, working with multiple fractions is generally less desirable, as it leads to a more complicated process.

For example, if the fat is going to interfere with the enzyme hydrolysis or subsequent separation techniques it may be better overall to remove it first (e.g. hot wash minced feed) then add it back near the end of the process.

Similarly, if for optimum flavour development the enzyme hydrolysis needs to target one group of proteins, but other components in the feed are interfering with that targeting/hydrolysis, it may be necessary to remove the protein group of interest (e.g. by a pH shift), hydrolyse them in isolation, and then mix the resulting hydrolysate back into the main process stream.

3.2.11 Summary

Based on the available information, and the assumptions listed above, the concept process for producing a flavour-rich product from red meat/organs will resemble a process that is shown in Table 1.

Table 1. Process concept for producing a flavour-rich product from red meat (including organs).

Step	Purpose
Size reduction	To enhance mass transfer during hydrolysis
Pre-treatment	e.g. wash, if needed, to remove contaminants or unwanted (off-flavour) molecules e.g. heat treatment to expose more enzyme cleavage points
Targeted Enzyme hydrolysis	To liberate bioactive flavour-rich peptides May use a combination of enzymes and specific conditions (pH, temperature, time) to ensure correct degree of hydrolysis and cleavage points
Addition of anti-oxidants	To protect peptides during subsequent processing
Centrifugation/filtration	Removal of excess fat and particulate material
Concentration	Water removal
Homogenisation	To prevent separation on standing (if liquid product)
Drying	If required

Validation that the system of processes works together well, i.e. that the system is optimised for efficiency and consistency of production would be essential. If this technological hurdle is overcome, the technology should also be highly scalable, and could be utilised for generation of high value flavour ingredients for a wide range of applications.

Flavour technology involves the unit operations of extraction, chemical reactions, separation concentration and stabilisation. For production of specific flavours, the sequencing and conditions for each of the unit operations needs to be optimised. This could be implemented by combining several process unit operations into a system that amplifies flavour development and controls the physical properties of meat extracts.

While deciding on an extraction technology, the following needs to be considered:

1. The primary attribute of our products is that it will have intense umami and kokumi flavour.
2. The flavour will come from a mixture of peptides, lipids, and volatiles etc
3. The feed material will be a solid that is likely to contain muscle, connective tissue, arteries/veins and possibly bone e.g. low value muscle, offal (kidney, liver).
4. A hydrolysis method will be needed to turn the proteins in the feed material into flavour-rich peptides.

5. Additives may be required e.g. anti-oxidants to preserve the flavour components during processing.
6. There may be molecules that need to be removed e.g. ones that cause bitterness.
7. The product will be either a liquid concentrate or dry powder.
8. If the final product is a liquid, it should not contain lumps, particulates or settleable solids.

It is envisaged that the processing steps will use enzyme hydrolysis to produce flavour-rich peptides that will work in unison with other flavoursome components and volatiles present in the feed material to produce a desirable umami flavour. **Unit operation optimisation will be required to turn the enzyme hydrolysate into a desirable final product**.

3.3 Decide on suitable raw materials

3.3.1 Trade and production trends for meat and associated products

Global meat production has been growing at a 3% compound annual growth rate CAGR over the last 50 years. In 2018, the total raw meat production was 331m tonnes, which includes:

- Chicken (37%)
- Pork (37%)
- Beef and Lamb (26.2%)

New Zealand produced less than half a percent (i.e. 0.42%) of world meat supply with an overall production for all species of around 1.4m tonnes, while Australia produced just over 1.5% of the world's supply, about 5.1m tonnes.

Both countries produce a significant meat surplus (particularly beef and lamb) available for export. Out of 13 million tonnes of red meat exported globally in 2018, approximately 8% came from New Zealand and 19% came from Australia.

Generation of meat by-products is unavoidable, and these products may represent around 60% of the animal live weight. Some of these by-products are being further processed into co-products (i.e. edible and inedible). Note that the definition of the terms 'by-product' and 'co-product' can vary by country[2]. For example, in the United States (US) and many other countries, the term by-product is used to describe parts of the carcass other than dressed meat; whereas the European Union regulations specify it as "any part of the animal carcass or any material of animal origin not intended for human consumption", which means all co-products are intended for human consumption. For the purpose of this report, a looser US definition of co-product will apply, and the term 'offal' is referred to as edible meat co-products.

In New Zealand meat co-products include the following:

- hides and skins

[2] http://scitechconnect.elsevier.com/the-difference-between-meat-processing-co-products/

- edible offal
- prepared and preserved meat products
- finished and semi-processed casings
- meat and bone meal (MBM)
- tallow
- sinews and tendons
- pet food ingredients
- blood products for pharmaceutical or medical use

In the 12 months to June 2018, hides and skins were New Zealand's largest category of exported co-products, valued at $353 million. In second place was edible offal, with 63,106 tonnes exported, generating $227 million. Of this, just over a third (22,184 tonnes), was sheep offal worth $63 million, and the other two thirds (40,923 tonnes), were beef and veal offal worth $164 million (see Fig. 1).

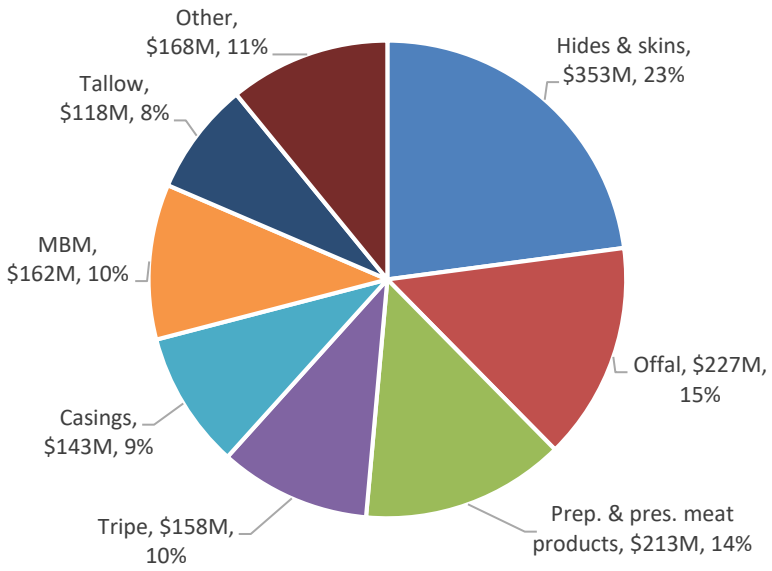

Fig. 1 Value of New Zealand meat co-product exports by type

In Australia, red meat and livestock exports (including co-products) peaked in the 12 months to June 2015 reaching A$15.7 billion before dropping to $13.3 billion in the 12 months to June 2017 (see Fig. 2). Fig. 3 reveals a similar trend for the total tonnes shipped weight for 'fancy meats' (i.e. offal). Please refer to Appendix 1 for more detailed statistics.

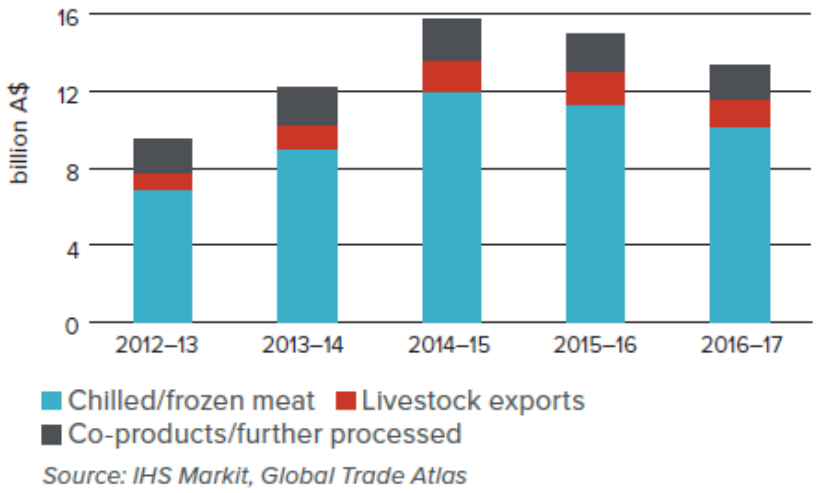

Fig. 2 Export value by product type – Australia, June year

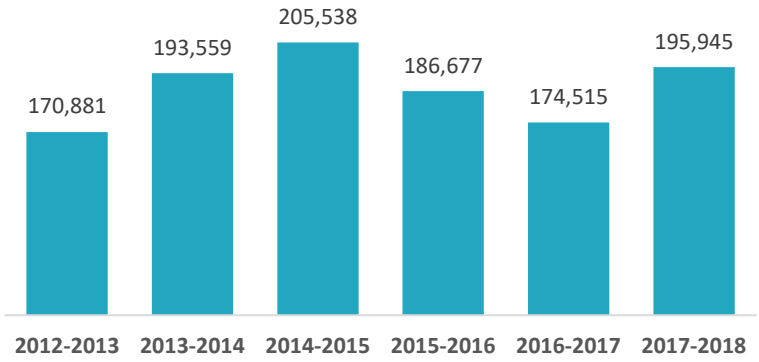

Fig. 3 Total fancy meats exported in tonnes shipped weight – Australia, June year

3.3.2 Market prices for beef co-products

Meat and Livestock Australia (MLA) conducts a monthly survey of approximately 25 meat processors across Australia and collates average prices and analyses trends on a range of co-products items. Its December 2018 report showed that despite a firmer Australian dollar beef offal prices were generally steady during November 2018, except cheek meat, omasum and tongues. In general:

- livers, kidneys and hearts were the cheapest, at approximately A$1/kg – A$2/kg
- tripe, beef lips and head meat were priced around A$3 – A$4/kg
- cheek meat, honeycomb tripe, aorta, and omasum were in the higher price bracket, around A$6/kg to A$8/kg

Interestingly, Australian beef offal products exported to Japan and Korea typically obtain a higher price. Heavy weight rumen pillars are currently the most expensive export to Japan, priced at A$21.2/kg, up by A$4.23/kg compared to a year ago.

Australian sheep co-products are primarily hearts, kidneys, livers, tongues and tripe, and average prices ranged between A$1/kg - $4/kg in December 2018. Compared to beef, sheep red offal and tripe was more expensive, however sheep tongues were significantly cheaper.

Based on current searches, no public pricing reports were found for meat co-products in New Zealand, however Meat Industry Association New Zealand may hold additional information in this area.

Assuming New Zealand domestic meat co-product wholesale prices align with international market prices, New Zealand beef and sheep offal prices have been estimated based on average prices obtained from online meat retailers and wholesalers in New Zealand. However, it is likely a retail mark-up has been added onto these prices, and a cheaper price may be obtained through bulk buying.

The preliminary results showed that offal prices in New Zealand are higher than in Australia. On average:

- beef co-product prices in New Zealand ranged from NZ$36/kg to NZ$19/kg
- livers, kidneys and hearts were the cheapest offal, at approximately NZ$6/kg – NZ$8/kg
- cheek meat, honeycomb tripe and beef tails also sit in the higher price bracket, significantly higher than Australia's at NZ$14/kg – NZ$20/kg

Average prices for New Zealand sheep livers, kidneys, hearts ranged from NZ$6 – NZ$14. In comparison to New Zealand beef, sheep hearts and livers are slightly less expensive than those from beef, whereas sheep kidneys are significantly more expensive, over double the price of beef kidneys. The most expensive New Zealand sheep co-product is sweetbread (thymus gland), with an average price of approximately NZ$23/kg.

3.3.3 Current uses of co-products

The meat industry generates large volumes of by-products, and a proportion of these are considered to be foods of interest depending on the country and local cultural traditions (Lynch *et al.* 2018).

Particularly,

- In **China**, **Korea** and **Singapore,** offal from bovine, duck, pork and chicken are widely used to make soups/broth or stew in soy sauce
- Liver from pork, lamb and beef is highly appreciated in **European countries**
- Bovine heart is used to prepare traditional **Peruvian** cuisine
- Beef tongue is commonly used in **Russia**, **Japan**, **Brazil** and **Uruguay**
- Kidneys from pork, lamb and beef are highly appreciated in the **United Kingdom**
- Beef tripe is used in traditional gastronomy in **Scotland**, **Rumania**, **Turkey** and **Spain**
- Edible offal is the main ingredient for traditional delicacies in **South Africa**

[3] 1 NZD = 0.95 AUD

At a very basic level, many co-products can be used as an extender in processed meat products. One study suggests that there is no significant difference in key quality characteristics when using pork tongue and pork head meat as sausage ingredients (Choi *et al.* 2016). While some co-products already command a reasonable price for direct human consumption, the majority are considered to be low-value products. There are even co-products which carry a neutral or negative value depending on the cost of disposal. It is generally difficult for industries to divert efforts into increasing the value of co-products. However, this readily available and under-utilised resource has the potential to provide high-value components to a variety of sectors.

Most meat co-products contain good amounts of protein, and many have protein levels comparable to that of standard cuts of meat. On-going efforts to recover protein from meat co-products have advanced technology that are used for the extraction and processing of these proteins (Gault and Lawrie 1980; Mullen *et al.* 2015). Some of the recovered proteins can impart special properties as food ingredients. For example:

- **Collagen**, a fibrous, structure protein, mainly extracted from skin and bones but also from other offal such as lung, tongue, trachea, large blood vessels, or tendons, is regularly employed in food production. Following extraction and hydrolysis it can be transformed to make gelatine, which is used in a wide range of products such as soups, gravies, desserts or dairy products due to its strong gelling properties. Collagen's excellent film-forming capacity also makes it ideal for casings and other novel packaging. Moreover, this natural biomaterial has great potential outside of the food sector, especially in the biomedicine and cosmetic industry.
- **Blood plasma**, containing blood proteins derived from meat co-products following centrifugation, is a versatile product commonly used as a food ingredient. It presents good emulsifying, gelling, foaming and solubility properties, and as a result its applications in the food industry include meat product binders, egg replacers, fat replacers, or even polyphosphate or caseinate substitutes.

In addition to their high protein content, meat co-products are well established as being rich in essential amino acids, minerals and vitamins, which provides additional opportunities for co-products as functional ingredients. More specifically, co-products can be used as raw materials for generation of biomolecules of interest like enzymes, or as extracts or protein hydrolysates with relevant functional properties or bioactivities (Lasekan *et al.* 2013; Chernukha *et al.* 2015).

Although the various types of application mentioned are mainly intended for human consumption, meat co-products have been traditionally used as ingredients in feeds and pet foods. Closely integrated with the meat industry, the rendering industry each year processes approximately 60 million tonnes of meat and animal by-products globally, of which renderers in North America process about 25 million tonnes and those in the European Union process around 15 million tonnes (Hamilton 2004). Meat and bone meal (MBM) is a rendered product primarily used as an ingredient in non-ruminant animal feed or pet food. New Zealand exported 153,106 tonnes of MBM in 2017/2018, worth $162 million. Indonesia is New Zealand's top export destination for MBM, responsible for 45% of total exports (Meat Industry Association 2018).

The composition and nutritional value of meat co-products make them highly suitable for companion animal diets. Inclusion of meat co-products can also serve as palatability enhancers, which is an important consideration in pet food formulation (Boskot 2009). In addition to being incorporated into pet foods, some products are also sold as pet treats, e.g. bone, hide, ears etc.

Other non-food applications of meat co-products include:

- Energy generation – low cost animal fats are commonly used as raw materials in production of biodiesel (Moreira *et al.* 2010).
- Mineral fertiliser – incineration of meat by-products generates ashes with a high content of phosphorus, which can be used as fertilizers (Bujak 2015).
- Medical and pharmaceutical applications – some animal issues, glands and organs are consumed for medical purposes or used as a source of particular pharmaceutical substances (Jayathilakan *et al.* 2012).
- Other chemical applications – for example, the cosmetic industry uses rendered fats for making lotions, creams, and bath products, and fatty acids are used in the chemical industry for rubber and plastic polymerisation, softeners, lubricants and plasticisers (Ockerman and Basu 2006).

Table 2 provides a summary of non-food applications and examples of high added-value products by co-product type (Mullen *et al.* 2017; Lynch *et al.* 2018).

Table 2: Potential uses of meat co-products and examples of high added-value products

Product	Industrial use	Pharma, veterinary and medical uses	Examples of high added-value products
Adrenal gland	Unknown	Corticosteroids, epinephrine, norepinephrine	
Blood	Glue/adhesive, fertilizer, feed, bio-plastics	Cell culture media, vaccine stabilizer, diagnostics, blood plasma, blood serum, blood albumin, fibrinogen films used in surgery, treatment of osteoarthritis and inflammation infection, wound healing, thrombin	Antioxidant, antibacterial, antihypertensive or iron-binding peptides Pre-digested peptides for animal and pet food; purified protein as food ingredient; peptides and bio-preserved blood; amino acids and peptides production
Blood vessels	Unknown	Used in surgery	
Bones	Mineral extraction, gelatine, pet food, collagen	Mineral extraction, gelatine	Hydroxyapatite and collagen; new kinds of sausages
Collagen	Cosmetics	Scaffolds for cell growing	
Ears	Pet food	Unknown	

Fat	Soap, lubricants, paints, emulsifiers, shampoo, ink, glue, solvents	Unknown	
Feet	Glue production	Unknown	
Heart	Unknown	Valves for surgery, pericardium used in surgery and for repair	High-value protein with low ash, fat and cholesterol; myofibrillar concentrate as texturizing agents
Hide	Leather, pet food, Gelatine for cosmetics	Unknown	
Skin		Gelatine collagen dressings, grafts initial treatment of burns	Barrier membrane, drug delivery, fibroblast scaffolds, bioengineered tissues; antioxidant peptides and liver protectors; antimicrobial or antihypertensive properties; biomimetic tissue
Intestines	Sausage casing	Mucosa used for the production of heparin, internal surgical sutures	
Kidney	Pet food	Unknown	
Liver	Pet food	Bile, heparin	Antioxidant peptides
Lung	Pet food	Heparin	Protein concentrates with good functional properties
Pancreas	Unknown	Insulin, glucagon, pancreatic enzyme supplements	
Stomach	Pet food, glue	Digestive enzymes (pepsin, rennin, lipase, trypsin), hormones	

3.3.4 Summary

The opportunity is to produce a meat flavouring extract from meat/offal that can be used as a condiment or as an ingredient with physical properties that maximise its flavour retention within other food formats, even during subsequent processing.

Haem has been identified as a key flavour component underpinning, and critical to, authentic "meaty" flavours. An alternative is to utilise red blood cells from the blood plasma industry. **Cheaper co-products from the meat industry such as liver, kidney and heart both from the sheep and beef**

industry could be used for the extraction of unique flavours. Meat based extracts have largely utilised extraction and concentration to capture flavour components. Flavour amplification can also be achieved using Maillard reactions. Lipids will also play an important role in the development of flavour. Aldehydes and carbonyls formed from the oxidation of lipids and their reaction with Maillard intermediates will be important to modify favourably the overall flavour profile. **Lipid (fat) replacers such as blood plasma could also be considered to lower the overall fat content in these products.**

Preliminary analysis indicates that if offal particularly liver, kidneys and lungs are used with an extraction process conversion efficiency of approximately 70%, then selling the final product as a liquid concentrate (e.g. with 10% solids content) would be more favourable than selling it as a dry powder (100% solids content).

The study should focus on combining simple readily available unit operations to add value to raw materials. The science and understanding of how the unit operations are combined will be the key Intellectual Property developed.

3.4 Determine scale of annotated database of flavour compounds

3.4.1 Introduction

AgResearch is involved in projects investigating the characteristics of food and their flavours and bioactive components. Much of the work relies on instrumental analyses that generate complex chemical profiles or signatures of the compounds in each sample. That information can identify materials and distinguish among treatments, but the actual human-perceived taste of the samples remains unknown. This limits our ability to screen samples for their desirability and progress them towards sensory analysis through consumer surveys or trained taste panels.

A link between lab chemistry and eating experience can be made through databases of flavour-related compounds. The term ‘flavour’ is often used loosely to encompass ‘aroma’, ‘taste’ and other hedonic attributes of food. Aromas from volatile compounds have long been the focus of flavour research, in part because they are relatively easy to capture experimentally. Published data on the flavour profiles of foods in peer reviewed articles and condensed within literature review articles and online databases (Minkiewicz *et al.* 2016) lean heavily towards volatiles. However, the non-volatile tastant compounds are equally important and the field is more open for exploration and discovery.

AgResearch is developing tools to help decode the chemical signatures of foods and ingredients in terms of their likely tastes, and to identify the presence or potential for release of bioactive peptides. In the Database of Tastant Compounds (dbTC) we are consolidating reliable data on chemical tastants into a searchable database built around consistent identifiers and descriptors. It will facilitate screening of novel food concepts, prototypes and processing. The Bioactive Peptides database (BPdb) also contains information on flavour peptides and amino acids but these comprise the minority of entries in the database. Most records in the BPdb instead relate to peptides purported to have physiological activity, which is outside the scope of the current project but could be of future relevance.

Some databases already exist in the public domain that relate taste to chemical compounds, proteins and peptides. However, these have significant limitations:

- They emphasise peptides, with limited scope for diverse chemistry and small molecules.
- While dairy foods are reasonably well represented, there is minimal information on meat and its derived products, especially red meat.
- Nomenclature is ambiguous; it is not systematic in terms of the identification of the food or source material, the compounds or their hedonic descriptors.
- The underlying research for the entries (the references) is sloppily curated. An entry might be logged as a taste, but the citation actually refers non-specifically to flavour. The citation might be to a review article that itself has misinterpreted the primary research. The true value of the original research result might be suspect, because methods appropriate for reliable sensory science were not used (this is common in papers about 'flavour' published in chemical and analytical journals.)

The dbTC and the BPdb fill knowledge gaps and are directly applicable to the kind of food-related research done by AgResearch. We expect to add to these databases over time and might make one or both publicly available.

3.4.1.1 The dbTC

3.4.1.1.1 Method

We initially searched for any databases that contained information on the chemical components of flavour. Substantive and useful examples included FooDB[4] and BitterDB[5]. Alternative consumer databases designed for professional chefs and the food service and perfume industries included Foodparing[6] and The Good Scents Company[7].

A literature search of peer reviewed articles of flavour compounds was conducted. Keywords of 'tastants', 'non-volatiles' AND 'meat', 'dairy' found 25 articles. Only 3 actually reported on the taste of food compounds while the majority focused on the chemistry and structure of the human taste system. Expanding the search to include volatiles and flavour found 221 articles. Amongst the flood of aroma and flavour- based research, several good review articles had links to experiments with taste profiles.

The search results were initially grouped on food type e.g. meat or dairy, then further refined by animal species. Our focus was on cattle and sheep, but pork, chicken and seafood results were retained if the data were of high quality.

[4] http://foodb.ca/

[5] http://bitterdb.agri.huji.ac.il/dbbitter.php

[6] https://www.foodpairing.com/en/home

[7] http://www.thegoodscentscompany.com/

Validation is central tenet of this project. Before including a compound from an existing database or a review article we tried to trace it back to original literature. Manual searching through these references (and their subsidiaries), with close attention to the chemistry and sensory science methods in use, yielded the most reliable tastant compounds for our database.

Where possible an experiment's sensory methodology was assigned a robustness score:

1 = a trained taste panel was used.

2 = a trained taste panel was used but the authors translated the results across species or results specifically from one species were called 'meat' generically.

3 = anecdotes or general opinions were collected from untrained consumers.

Experiments where taste was (mis)associated with merely hedonic liking as opposed to taste intensity were excluded.

3.4.1.1.2 Fields in the dbTC

Each record within the database is given a unique ID. To avoid ambiguity and lengthy groupings of chemical synonyms, the database uses CAS Numbers from the Chemical Abstracts Service Registry.

While aromas are not the focus of this database, they have been included when they were identified in the same experiment as taste compounds or if the research could not clearly discriminate. A field identifies records as being tastants, aromas or unknowns.

Where possible the primary taste descriptors are kept within the 5 recognised terms: sweet, sour, umami, salty and bitter. Many compounds used other terminology to describe taste. As these terms are rarely systematic or well defined, they are listed under a second field called "Alternative taste terms". There are also fields to identify compounds that have no specific taste of their own but are taste enhancers or taste suppressors, along with the primary taste that they impact.

Where possible each compound is annotated with the animal species and substrate that it was extracted from, for example: cattle, beef gravy.

The database includes links to the original research article describing the experiment, or to the review article or public database where it was subsequently mentioned.

3.4.1.1.3 Results and discussion

The purpose of the dbTC is to link food compounds with their associated tastes. It is not intended as a repository of information about each compound. Data on nutritional value, toxicity, metabolic pathways, mass spectra and other attributes are available online in databases related to food chemistry such as FooDB.

Currently the dbTC contains 307 records of minerals, phosphates, carbohydrates, carboxylic acids, ketones, nucleosides, nucleotides, peptides and amino acids. The substrates the compounds were collected from include minced beef, sheep and goat meats, chicken and beef broth/juices, mixed processed meats (salami), seafood and synthetics. The records comprise 251 tastants, 14 verified aromas and 42 that have yet to be confirmed as either. Of the tastants 16 are taste enhancers and 9

are taste suppressants. Some compounds have mixed attributes. A total of 66 are classified as 'odorants' because they can impart some smell.

Added to these, for the sake of completeness and cross-referencing, are some 561 peptides gleaned from the 91,544 entries in the BPdb. That database was compiled primarily for use in semi-automated annotation of peptides identified in complex mixtures by liquid chromatography-tandem mass spectrometry (LC-MS/MS). The peptides had been tagged as having the 5 standard taste profiles or the term 'astringent', or as having specific taste enhancing or suppressing properties. None were annotated with a source food material or species, and only 84 had references to literature. All were taken from two originating databases, BIOPEP[8] or EROP[9], both of which are known to reproduce incomplete and inaccurate data.

The dbTC can only reflect the quality of the underlying research. A limitation of some experiments is the lack of taste threshold data. Thresholds at which a given compound can be detected by analytical means or tasted by a trained panel offers valuable insight into the potency and balance of flavours in a food. Where such data are available, they may need to be added later but at this stage thresholds for taste are not considered fundamental to the goal of the database. Future considerations for the dbTC may be to expand beyond commodity food types like meat and dairy to accommodate interests in complex tastant profiles. Examples relevant to current AgResearch projects are 'Warmed-over flavour' and 'Fish sauce'.

3.4.1.1.4 Database usage

The dbTC has been applied in preliminary tests. Several recent AgResearch experiments used electrospray ionisation (ESI) mass spectrometry, *nuclear magnetic resonance (*NMR) and rapid evaporative ionisation mass spectrometry (REIMS) measurements of meat and derivatives to make tentative identification of interesting or treatment-related compounds. Any of those might be associated with flavour, so they were compared to the dbTC.

In one case, the database found hits on 38 peptides and could provide their putative tastes along with links to supporting literature. Of these records, there was 1 from sheep, 10 from cattle and 25 synthetic substrates. In a second experiment involving beef and lamb measured by NMR, 29 of the 56 metabolites were found in the database.

In an experiment about aromas, 37 volatile compounds were identified from meat and organ broth extracts. In this instance only 2 compounds were found in the dbTC. In an experiment studying the development of aromas during cooking of beef and lamb, a novel proof of concept approach used REIMS to capture volatiles in real time. Eleven compounds, each with several tentative identifications, were compared to the database. None were direct matches. However, the dbTC was a resource for suggestions on commonly identified compounds found in published articles on aroma

[8] http://www.uwm.edu.pl/biochemia/index.php/pl/biopep

[9] http://erop.inbi.ras.ru

experiments for both beef and lamb meats. This provided some insight into what kinds of measurement techniques are known to be successful at capturing flavour-associated volatiles.

3.4.1.2 The BPdb

The BPdb combines information from 14 public domain databases with entries obtained from peer reviewed scientific publications and other sources. It currently contains 91,544 records for 48,301 unique peptide sequences. Of these, 561 entries are tagged (although not verified) as having flavour-related activities (including 'bitter', 'umami', 'sweet' and 'sour'). The other 90,983 records relate to peptides with recognised or predicted physiological activity. Curation of those entries is performed when the specific peptide sequences are identified in samples by LC-MS/MS. The scientific literature is also the direct source of entries not contained in the online source databases.

A search to find scientific papers relevant to the current project was performed. This involved searching the OvidSP and Scopus scientific literature databases for occurrences of 'PEPTIDE*' within 5 words of one of the following: 'BITTER*' or 'UMAMI' or 'KOKUMI' or 'FLAVOUR*' or 'FLAVOR*' or 'TASTE' or 'TASTANT' (where the '*' allows for variants of the stub words). 1,807 references were returned by OvidSP and 703 by Scopus. If the next stage of the MDC flavour project proceeds, these papers will be manually inspected for any flavour-related peptide sequences that are not currently in the dbTC and BPdb and which are supported by acceptable evidence of activity.

3.5 Options for prototype foods and benefits that might be measured in a human study

3.5.1 Background

It is well known that population ageing is occurring in virtually every country in the world (United Nations 2017). This demographic trend is presenting many challenges, including meeting the basic needs of older adults, such as adequate healthcare and nutrition. Among the older adult population, health is known to both influence, and be influenced by, nutritional intake (Agarwal *et al.* 2013). As such, ensuring appropriate nutritional intake represents a critical component of caring for this section of the population.

This work was commissioned by the Meat and Livestock Australia Donor Company (MDC), with the purpose of better understanding the factors that influence decision-making surrounding older adult nutrition. This includes decisions made by older adults themselves, and by employees within, and contractors for, residential aged care facilities (RACFs), such as dietitians, kitchen managers, and care workers. This study aimed to unpack two main areas related to older adults' nutrition:

- Older adults' food preferences, and the factors affecting these
- Older adult's food choices, and the factors affecting these

Related to these areas were several further topics relevant to older adult nutrition, including changes in food preferences over time (and with age), barriers to consuming foods, and considerations regarding nutritional intake. The ultimate purpose of increasing understanding of these areas is to inform the potential development of a product to boost the nutritional intake of this sector of the population. It is therefore necessary to better understand the target market, to enable a fit-for-purpose product to be developed.

For the purposes of this report, it is important to clarify how the term 'older adult' was defined and applied. This research uses as a definition of older adults, individuals aged 65+ or, in the case of Māori and Pasifika persons, 55+. This distinction is made due to discrepancies in life expectancies between these ethnic groups within New Zealand (Statistics New Zealand 2015a).

This section of the current report first presents the findings from a review of the literature, into the factors affecting the health status of older adults, prevalence and effects of malnutrition, and its risk factors. The method is then presented, followed by a description of the high-level findings of the focus groups and interviews with older adults, dietitians, and kitchen managers and care workers at RACFs. These findings inform the two models which are presented; the first identifies factors influencing decision-making surrounding older adults in RACFs. The second examines in more detail the factors influencing how older adults themselves make decisions surrounding what they consume. This second model is informed by data from both the RACFs and community dwelling adults (elders who live in the community on their own), making it applicable to a wider cross-section of older adults in New Zealand. These models are accompanied by a description of the how these factors were articulated and understood by participants, in a thematic analysis of the data. Finally, the findings from this research are summarised, and conclusions are drawn, particularly surrounding how the results could inform product development to support older adult nutrition.

3.5.2 Literature review

Adults aged 65 years and over are the fastest growing sector of New Zealand's population (Bascand 2012), with the number of individuals in this age group predicted to increase from 635,200 in 2013, to 1,100,000 in 2030 (Dale 2015). Aside from the obvious benefits to the individual in terms of quality of life, healthy ageing has the potential to moderate the impact of this demographic shift on both the demand for, and cost of, healthcare services (Keene *et al.* 2016). Although the 65 year and over age group made up only 14% of New Zealand's total population in 2012/13, they consumed 33% of the health budget (Dale 2015).

There are myriad physiological, psychological, environmental, and socio-economic factors affecting the health status of older adults. Although the effects of genetic inheritance on health during the later years is largely non-modifiable (Sadana *et al.* 2016), the speed at which biological ageing progresses is heavily influenced by both the environment and lifestyle behaviours (World Health Organization 2015). Social engagement, socio-economic status, physical activity level, living situation, access to transport, access to health and support services, and even an individual's attitude towards ageing can impact their health (Dwyer *et al.* 2000). However, the influence of nutrition status on health and quality of life during the later years is consistently significant (Amarya *et al.* 2015; Leslie and Hankey 2015).

3.5.3 Assessing nutrition status

Nutrition status in older adults can be assessed using a variety of screening tools, which are designed to assess either the presence, or risk, of malnutrition. Stratton, Green and Elia (as cited in Cereda *et al.* (2016)) defined malnutrition as "a state of nutrition in which a deficiency or excess (or imbalance) of energy, protein, and other nutrients causes measurable adverse effects on tissue/body form (body shape, size and composition) and function, and clinical outcome". Reported rates of both

malnutrition and risk of malnutrition amongst older adults vary considerably, due in part to the screening tool used, living situation, and level of healthcare required.

3.5.4 Malnutrition

In their systematic review of 28 international studies, Verlaan *et al.* (2017) found a 2.3% prevalence of malnutrition amongst community-dwelling adults. In a New Zealand study using the same screening tool and population, Chatindiara *et al.* (2019) found a lower prevalence at 1%. However, as older adults require an increasingly higher level of care, both the prevalence and risk of malnutrition increases (Cereda *et al.* 2016). In a recent New Zealand study of older adults on admission to hospital (88% of whom were admitted from the community), the same screening tool found over one quarter were malnourished, with an additional half at risk (Chatindiara *et al.* 2018). This trend can also be seen within RACFs, where the prevalence of malnutrition may be between one-quarter and one-half of residents, with those requiring a higher level of care at a much greater risk (Gaskill *et al.* 2008; Kellett *et al.* 2014; Kellett *et al.* 2015). However, as the screening tool used in these studies differs from the one previously mentioned in the community setting, the direct comparison of prevalence and risk figures would be inadvisable.

Chronic malnutrition can affect both the structure and function of many systems in the body. Age-related sarcopaenia (loss of muscle mass and strength) can be accelerated (Robinson *et al.* 2018), leading to reduced mobility and stability, and an increase in falls risk (Agarwal *et al.* 2013). The body's ability to repair damaged tissue can be impaired, leading to longer wound healing times, longer stays in hospital, and greater risk of complications (Harris and Fraser 2004). Impaired immune system function can result in increased susceptibility to infections, and accelerated disease progression (Pae *et al.* 2012). Quality of life can also deteriorate, and overall mortality risk is significantly increased (Agarwal *et al.* 2013). As well as precipitating various health issues, malnutrition can occur as a result of pre-existing conditions, and as such can be described as both "a cause and consequence of adverse outcomes" (Agarwal *et al.* 2013).

3.5.5 Risk factors for malnutrition

There are numerous risk factors for malnutrition in older adults. Loss of appetite, dysphagia (difficulty swallowing), difficulties in chewing, and impaired physical and cognitive function are all strongly predictive of a decline in nutrition status (van der Pols-Vijlbrief *et al.* 2014). Psychosocial concerns such as depression and loneliness, and the loss of interest in caring for oneself are also recognised risk factors (van Bokhorst-de van der Schueren *et al.* 2013; Ganhão-Arranhado *et al.* 2018). Moreira and colleagues (2016) also found that polypharmacy (use of multiple medications) can affect nutrition status either indirectly, through altered appetite, nausea, dry mouth, or constipation; or directly, through interference with nutrient metabolism.

In addition, deficiencies in both vitamin B12 and vitamin D are common in older adults (de Groot 2016). Atrophic gastritis and pernicious anaemia are the most common causes of B12 deficiency in this age group, and the regular administration of intramuscular B12 injections is the standard treatment. However, in their review of the effectiveness of oral B12 supplements for the treatment of pernicious anaemia, Chan and colleagues (2016) found them to be a viable alternative, even with the decreased availability of intrinsic factor (required to absorb vitamin B12 in the stomach). A significant proportion of one's vitamin D requirements are met by regular, safe sun exposure

(Truswell 2002). However, this process becomes less efficient with age, and is exacerbated with less time spent outdoors and the inability of ultraviolet B rays to pass through glass (Duarte *et al.* 2009). Indeed, ageing itself is a significant risk factor for malnutrition as many of the factors mentioned above are a direct result of the ageing process (Moreira *et al.* 2016).

3.5.6 Changes in nutrition and diet with age

Many of the risk factors for malnutrition can result in significant changes in dietary patterns, in both the volume of food consumed, and changes in food preferences and choices. A gradual decline in the volume of food consumed, with a commensurate reduction in total energy, is the most frequently reported change (Whitelock and Ensaff 2018; Yannakoulia *et al.* 2018). This is mostly attributable to diminished appetite, but can be exacerbated by other risk factors, and coincides with a decline in energy requirements, due to a reduction in physical activity and resting metabolic rate (Yannakoulia *et al.* 2018). Other changes involve the avoidance of "heavy or acidic foods" to prevent digestive issues (Whitelock and Ensaff 2018); the avoidance of certain textures due to difficulties chewing or swallowing; the avoidance of certain textures due to dental issues; and the preference for healthier food choices due to the presence of one or more chronic health conditions (Kamphuis *et al.* 2015). Insofar as these health conditions are concerned, individuals may also alter their diet following advice from their health professionals to reduce the intake of saturated fat in the case of cardiovascular disease, reduce salt consumption for hypertension, and reduce the intake of free sugars to aid in diabetes management.

Changes in taste perception can also precipitate changes in dietary patterns that impact nutrition status (Amarya *et al.* 2015). For example, dysgeusia, or the distortion of taste, can occur as a result of medication side-effects, or as the result of disease processes (Schiffman and Graham 2000). Hypogeusia, or a reduction in taste acuity, has been shown to occur with advancing age (Ng *et al.* 2004; Kremer *et al.* 2007). However, how much of an impact age-related changes in taste have on dietary patterns is unclear. Barragán *et al.* (2018) demonstrated a decline with age in perception across all tastes; bitter, sweet, salty, sour, and umami. Interestingly, while Kennedy *et al.* (2010) found a significant decrease in the perception of sweetness intensity amongst older subjects, these subjects were far more likely to express dislike for an intensely sweet option, demonstrating that changes in taste perception may not translate into a desire for more intensity in flavour and changes in food choice. A similar result was found by Drewnowski and colleagues (1996) in relation to saltiness, where although older subjects demonstrated a slight decline in the perception of saltiness of a test solution, they preferred the less salty food option.

However, such age-related changes in taste perception may not be inevitable. In his examination of the assumptions around changes in taste perception with age, Mattes (2002) concluded that such changes are by no means consistent, and can vary considerably between individuals, and between taste stimuli. Mattes also challenged the assumption that such changes would lead to changes in food choices and dietary patterns, expressing the need for more research in this area.

3.5.7 Amount of food consumed

The risk posed by a decrease in food volume, and the avoidance of specific foods due to the various concerns listed above, is that the requirements for certain macronutrients (especially protein) and many micronutrients may not be met, unless the nutrient density of the diet is increased. Difficulties

accessing food, either due to economic or environmental reasons, can further exacerbate the effects of this reduction in food volume and/or quality, especially amongst adults of lower socio-economic status. Certain foods may be purchased less often due to their cost, or to avoid wastage from large package sizes. Fresh fruit and vegetable purchases are often impacted when an older adult is shopping for one, due to concerns over spoilage (Wham and Bowden 2011; Whitelock and Ensaff 2018). Issues with transport or lack of assistance with food shopping can also influence dietary patterns for community-dwelling adults (Wham and Bowden 2011; Whitelock and Ensaff 2018), however, the results varied between individuals due to personal circumstances.

Despite a relatively comprehensive literature review on older adult nutrition generally no studies were encountered of the combined impact of factors influencing older adult food preferences and choices, how these change over time, and how these affect nutrient intakes. This research therefore serves to address these knowledge gaps with data from the New Zealand context.

3.5.8 Aims and purpose of the research

The overarching purpose of this part of the study was to identify any changes in dietary patterns experienced by the older adult participants and determine the factors that had been influential in these dietary changes. To this end, we employed a qualitative research methodology to gain an understanding of the current nutritional intake of a diverse cross-section of older adults in New Zealand and any changes that had occurred in their diets, food preferences, and food choices, with advancing age (such as a reduction or alteration of flavour perception, changes in appetite, or difficulties digesting specific foods). The study also aimed to identify any dietary concerns or attitudes towards nutrition that the participants held.

The research methods (10.3.1.1) utilised within the project included focus group discussions with a diverse cross-section of older adult participants living in the community, and within RACFs, and interviews with those who develop and deliver menus to cater to the dietary needs of RACF residents.

The results of this study (10.3.1.2) may inform the development of natural products that enhance the appeal of meals and help improve the nutritional status of older adults, which may result in health benefits for this growing sector of the population.

3.5.9 Discussion

A key aim of this research was to inform the development of a potential food product to enhance older adult nutrition. To enable this, it is useful to consider which aspects of the factors related to decision-making surrounding older adult nutrition are modifiable. As indicated above in the proposed models, many of the factors which impact on food preferences and food choices amongst older adults occur due to the ageing process itself or are due to social and economic circumstances. Such factors are, by nature, difficult to modify. Given this, the flavour of foods may be the most substantially modifiable aspect within the model.

Enhancing the flavour of foods could, potentially, work to compensate for a decline in taste perception in older adults, and increase the intake of nutrient dense foods, thereby improving nutritional status. This is an emerging area of research, where results of flavour enhancement interventions have been mixed. For example, Schiffman and colleagues (1993) found an increase in

the volume of food consumed with a range of flavour enhancements, along with an improvement in immune system function and handgrip strength after a short, three-week intervention. Research by Mathey *et al.* (2001) found an increase in body weight and food intake, as well as an increase in feelings of hunger, following a 16-week intervention. This suggests a concurrent stimulatory effect on the appetite of the subjects. A further small study of hospitalised older adults (Henry *et al.* 2003) saw a significant increase in total energy and protein intake in only three days, with the addition of natural food flavours. However, in contrast, a 16-week intervention conducted by Essed *et al.* (2007) found no differences in energy intake and body weight, between the control group and the three flavour enhancement groups. It has been suggested by Sulmont-Rosse and colleagues (as cited in Boesveldt *et al.* (2018)), that one of the reasons for these mixed results is the lack of consultation with the target group in terms of preferred flavours. As detailed above, such an exploration of preferred flavours was a key part of the present study, establishing a strong preference for savoury flavours amongst our participants.

In addition to considering varied flavour preferences, Mattes (2002) has argued that there is considerable heterogeneity in the decline in taste perception, varying in both magnitude and in the specific tastes affected. This, therefore, could also impact the results of flavour-enhancement studies and results. One strategy for personalising the flavour enhancement of meals to allow for this heterogeneity is, as demonstrated by Divert *et al.* (2015), the provision of a variety of seasonings from which the subjects can choose. This strategy has been shown to improve meal satisfaction, feelings of autonomy, and overall food intake (Divert *et al.* 2015). Indeed, any development of flavour-enhancement products would arguably benefit from not only a consultation on preferred flavours, but also a thorough testing of any prototypes by a representative sample of older adults.

Insofar as savoury flavours are concerned, umami compounds may enhance consumer acceptability of flavour-enhanced foods. Research has demonstrated not only an impact on levels of acceptance, but an enhancement in feelings of satisfaction and positive emotions associated with an umami-rich meal, without any compromise in the perception of the health benefits of the meal (Miyaki *et al.* 2016). Moreover, the acceptability of a rich savoury beef flavour produced by Maillard reaction products was also found to be high, and may play an important part in the development of flavour-enhancement products (Kwon *et al.* 2011). Drawing from the results of the current project, our participants' positive associates with savoury flavours in food, reported above, may be linked to the feelings of nostalgia they expressed for the savoury, meat-centric, dishes of their childhood or young adulthood, most notably the Sunday roast. As such, including such flavours into natural flavour-enhancement products could prove popular with such groups of older adults in New Zealand.

The taste characteristics of any flavour-enhancement products are, however, only one of the considerations in their development. Texture also needs to be considered, as well as the ability to incorporate such products into texturally appropriate, easily digestible foods, especially amongst older adults with chewing and swallowing issues.

Medical advice can also affect both consumers' food choices and their perception of any enhanced food product, and its resultant acceptability. Van der Zanden and colleagues (2014) argue that medical advice to consume protein-enriched foods, as well as the sensory appeal of the foods, were both important facilitators of acceptance of such products. Health advice for those with cardiovascular disease, or at risk of developing cardiovascular disease, usually includes the

recommendation to cut back on the consumption of saturated fats, primarily in the form of meat and meat products (Paddon-Jones and Rasmussen 2009). Consequently, there may be an opportunity to develop healthier meat product formulations for use within the older adult population that not only address these concerns, but also provide important and highly bioavailable dietary protein along with various micronutrients of concern in the older adult population. For example, for those experiencing sarcopaenia, the regular consumption of adequate complete protein has been found to slow the condition's progression thus improving many aspects of health and in turn, overall quality of life (Gaffney-Stomberg *et al.* 2009).

Further modification and fortification of such products, reducing ingredients such as saturated fatty acids, cholesterol, and sodium, while introducing various vitamins and minerals, may further enhance the consumer acceptability of such flavour-enhancement products (Hathwar *et al.* 2012).

However, drawing from our findings, the origin of the ingredients in any such flavour-enhancing additive, and the associated perceptions surrounding them, would also arguably play a part in consumer acceptance. We encountered a strong desire for natural ingredients amongst our participants as well as a resistance to offal. This resistance was partly sensory and partly due to negative connotations associated with offal, essentially the 'yuck factor.'

Ultimately then, in order to improve the intake of nutritious food by older adults in New Zealand, our results suggest that the development of a savoury-flavoured food enhancement additive may be beneficial. Such an additive could be meat-based in order to gain the popular umami flavours, and encourage bioavailable protein consumption, without adding to the saturated fat, cholesterol, or sodium intake of individuals. Such a product could also be fortified with important micronutrients or designed to be added to a range of nutrient-dense foods. While involving older adults in all stages of the development of such products, has the potential to increase their acceptability.

3.5.10 Recommendations and conclusions

Based on the literature and the findings of the present study, two potentially modifiable scenarios have been identified within which older adults are not consuming enough nutrients. These scenarios are discussed below highlighting the possibility for intervention.

Firstly, older adults may experience a gradual, but potentially partially reversible, decline in the total volume of food consumed and consequently may not meet their protein and micronutrient requirements. This could be addressed via the addition of one or more natural, meat-derived, flavour enhancement products to a range of nutritious savoury meals, in order to stimulate appetite by increasing the sensory appeal of food. Such a strategy could potentially increase the likelihood of achieving nutrient adequacy by prompting an increase in the volume and variety of food consumed, with emphasis on foods rich in protein.

Secondly, older adults may experience an irreversible decline in the total volume of food they consume and consequently may not meet their protein and micronutrient requirements. In order to increase both the nutrient density and sensory appeal of food to such individuals, one or more natural, meat-derived, and micronutrient-fortified, flavour enhancement products could be added to a range of nutritious savoury meals. Such a strategy could potentially increase the nutrient density of the food consumed, with emphasis on foods rich in protein, and subsequently increase the likelihood

of achieving nutrient adequacy, with the potential to slightly increase the volume consumed also, through increased sensory appeal.

Given the potential for positive intervention in the nutritional status of older adults, the general recommendations resulting from this study are as follows:

3.5.11 General Recommendations:

- Create a low-sodium flavour-enhancement product (or ideally a range of products) that can be considered 'natural' and 'fresh,' as this is an important priority for older adults. These products could be fortified with nutrients, such as vitamin B12 and vitamin D, which are of particular concern.
- The ingredient list of any such product and what it is made from needs to be transparent, as older adults like to know what they are eating. However, be aware of the negative perceptions around the terminology used for offal.
- In light of this, consider formulating any products containing offal in such a way as to minimise the flavour notes and smells characteristic of these ingredients.
- Ensure cholesterol and saturated fat content of the flavour enhancement product is within current recommended ranges.
- Involve older adults in all stages of the development and testing of flavour-enhancement products, to increase the likely appeal to the target market.
- Avoid making food products highly seasoned or spicy, as many older adults appear to prefer simple, 'classic' foods such as casseroles, roast meats, and plain vegetables.
- Offer a variety of delivery methods for the flavour enhancement product/products:
- For RACFs: a product or products able to be easily added to bulk meals in the kitchen.
- For RACFs and those living in the community: a range of individual flavour enhancement products that can be added to a meal at the table to cater for individual tastes (or to the meal during cooking for those in the community if they prefer).

3.5.12 First draft options for prototype foods

A demographic trend towards aged population is presenting many challenges, including meeting their basic needs such as adequate healthcare and nutrition. Among older adults, health is known to both influence and be influenced by, nutritional intake. As such, ensuring appropriate nutritional intake represents a critical component of caring for this section of the population.

One of the aims of the study was to determine older adults' attitudes to meat consumption and whether there is potential to use meat as a flavour-enhancement product. The findings show an overall reduction in the intake of predominantly red meat. Although older adults were found to generally consume more fish and poultry, **the flavour profile of red meat is still the preferred savoury taste.** Most of the participants discussed their enjoyment of these flavours but due to health issues as well as economic barriers, they have chosen alternative options.

The factors that affect food preferences for older adults include dietary changes with age; formative experiences; social and cultural dynamics with food; and the sensory experience. These factors were expressed by the older adults as influencing their decision-making because of their connection to

previous life-experiences. However, consideration is needed for individual food preferences, which will differentiate based on socio-cultural backgrounds.

The results from the interviews and focus groups suggest that the development of a savoury-flavoured food enhancement additive may be beneficial. Such an additive could be meat-based to gain the popular umami and kokumi flavours, and encourage bioavailable protein consumption, without adding to the saturated fat, cholesterol, or sodium intake of individuals. Such a product might also deliver the important micronutrients of meat or could be designed to be added to a range of nutrient-dense foods.

3.5.12.1 Low fidelity Minimum Viable product

A new food or condiment must not only taste good, but also suit the other drivers of consumer demand, such as price, convenience, safety, wellness and provenance. A minimum viable product concept could take various forms depending on its practical application. For example, if used as table-top condiments, then it can be a sauce, paste or free flowing powder. If used as a flavour enhancement during consumer cooking, then cubes or granules could be some options. If intended for food manufacturing, then suspensions, emulsions or solutions might be easiest to introduce and disperse.

Ideally the product should behave as an efficient umami and kokumi taste enhancer with roasty overtones and a slightly sweeter taste profile and possibly enhanced feel of creaminess. To impart additional flavour notes further additions such as dried mushrooms, yeast extracts, and vegetables extract, along with a certain percentage of fat (animal or plant derived) might be used.

Three options of the packaging that may be used are shown in Fig. 4:

Fig. 4 Packaging options

If the product is formulated in the form of a table-top sauce, option 1 could be preferred over the other two options. Since elders are the target demographic for the product, considerations have been given to designing the bottle such as the weight (approximately 560 grams), the shape with ribbed edges, that will make holding the bottle easy and prevent slippage and the colour with the brand name which will not only make it stand out but also provide a clear message. If this product is to be used in bulk amounts, e.g. in kitchens, then a bigger pack size of the format shown in option 3 may be considered.

The following (Fig. 5) are some examples of simple beef extracts and condensates created by traditional processing, their retail price range and their claimed point of difference. This information could be used as a guideline for the pricing of our own beef-derived flavour enhancer.

Product	Price	Claimed point of difference
	NZ$ 0.72/100 ml	Real 100% natural No added MSG or preservatives
	NZ$ 4.01/100 ml	Stock pot
	NZ$ 5.05/100 g	Celebrity chef endorsement
	£ 1.50-0.33/100 ml	Slowly cooked for deeper flavour
	£ 1.50-3.00/100 g	Gluten free

Fig. 5 Commercial examples of beef extracts

4 Business model canvas

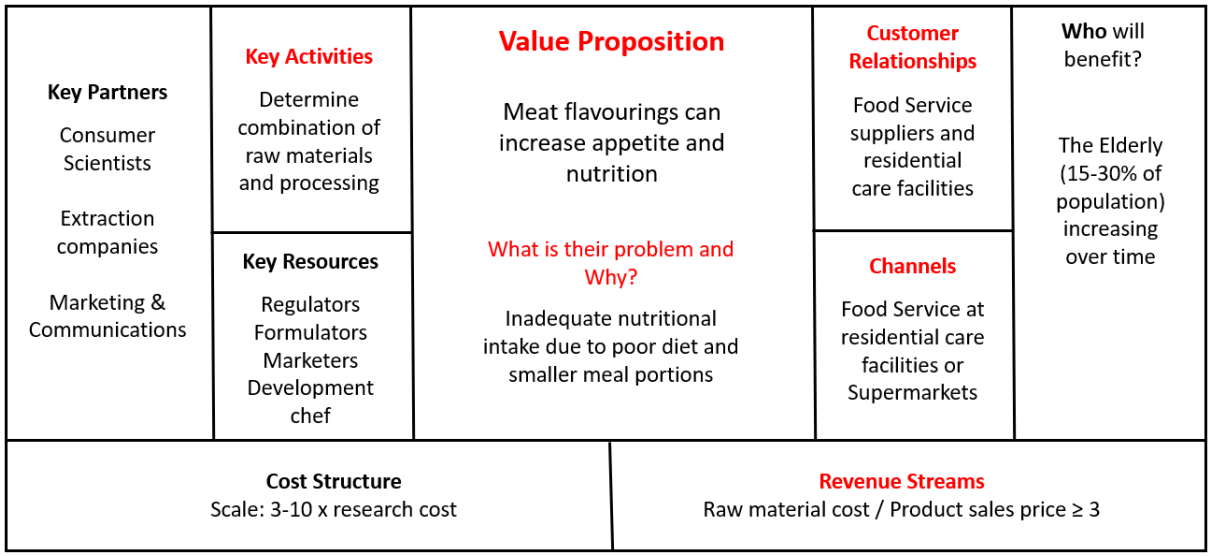

Fig. 6 Business Model Canvas

4.1 Who will benefit from flavour enhancement of food?

A rapidly growing demographic both within New Zealand and abroad is the elderly. Adults aged 65 years are predicted to increase from 635,200 in 2013, to 1,100,000 in 2030. Although this group makes up only 14% of New Zealand's total population in 2012/13, they consumed 33% of the health budget. Healthy ageing leading to quality of life is important. However, older adults are not consuming enough nutrients. Older adults may experience a gradual decline in the volume of food consumed leading to an inadequate protein and micronutrient intake. Meat derived, flavour-enhancement products added to savoury meals can stimulate appetite by increasing the sensory appeal of food leading to higher food intake and addressing nutrient inadequacy in older adults.

Although older adults were found to generally consume more fish and poultry, the flavour profile of red meat is still the preferred savoury taste. Due to health issues, economic conditions, accessibility and ease of use, alternatives to meat are sought.

From a manufacturing industry point of view, the work in this project will generate a technology that will enable the production of new high value flavour ingredients from streams that are currently of low value, but where specific processing conditions cause interactions with carbonyl, lipids, sulphur compounds and sugars with excellent potential for the generation of reaction flavours. This will result in protein derived ingredients with intense flavours.

The elderly population can benefit from meat derived, flavour-enhancement products added to savoury meals as these can stimulate appetite by increasing the sensory appeal of food leading to higher food intake and addressing nutrient inadequacy in elders.

4.2 What is their problem and why is it an issue?

The elderly population group faces a range of health issues ranging from age-related sarcopaenia to reduced mobility and stability and impaired immune systems that may be exacerbated by their inadequate nutritional intake. The risk posed by a decrease in food volume is that the requirements for certain macronutrients (especially protein) and many micronutrients may not be met, unless the nutrient density of the diet is increased. This makes nutrition an extremely important consideration for older individuals, as well as for those involved in their care. **A viable way of increasing the intake of nutritional foods by older adults could be through the development of a meat derived savoury-flavoured, food enhancement additive.** Meat based flavours that enhance the sensory appeal of meals and help improve the nutritional status of older adults, may result in health benefits for this growing sector of the population.

From a manufacturing industry point of view, current meat extracts are derived from streams that have low levels of flavour (being derived from myofibrillar and connective proteins) and therefore struggle to compete with high flavour meat extracts such as Brazilian meat extracts (derived from sarcoplasmic proteins lost during cooking). The technology proposed here will amplify the flavour of current meat extracts and thereby increase their value significantly.

4.3 Customer relationship

Older adults' involvement in all stages of the development of meat and offal based flavouring products, has the potential to increase their acceptability of the origin of the ingredients and the associated perceptions surrounding them. A strong desire for flavour derived from natural ingredients amongst participants in the focus group studies was seen, however, a resistance to offal was also encountered. This resistance was partly sensory and partly due to negative connotations associated with offal, essentially the 'yuck factor.' Drawing from the results, the participants' positive associates with savoury flavours in food, may be linked to the feelings of nostalgia they expressed for the savoury, meat-centric, dishes of their childhood or young adulthood, most notably the Sunday roast. As such, including such flavours into natural flavour-enhancement products could prove popular with such groups of older adults.

These flavour products would typically be available from retail or wholesale suppliers. If these products are targeted towards residents of residential aged care facilities (RACFs), important points to consider would be that there are various decision-making levels within RACFs and appropriate people must be made aware of these products for their inclusion in diets. For example, menus for the RACFs are ultimately controlled at the RACF management level, as it is the management who contract external dietitians to develop menus to suit each RACF site, or chain. More generally, RACF management determine the budget available to the RACF kitchens, and specify a budget per day, per resident. At the second level there are Dietitians, who either design menus for the RACFs, or analyse and approve menus designed by the RACFs. Kitchen Managers also can make decisions on menu options. Keeping the menu interesting, varied and appealing for the residents in question is a priority of kitchen managers, along with taking feedback from residents. People in these various tiers would need to have access to wholesale suppliers of these products. In contrast to this, older community dwellers tend to have more autonomy in their food choices, and therefore they should have access to retail suppliers.

4.4 Supply channels

These flavour products would typically be available from retail or wholesale suppliers. The supply channels could be multi-layered as shown diagrammatically in Fig. 7.

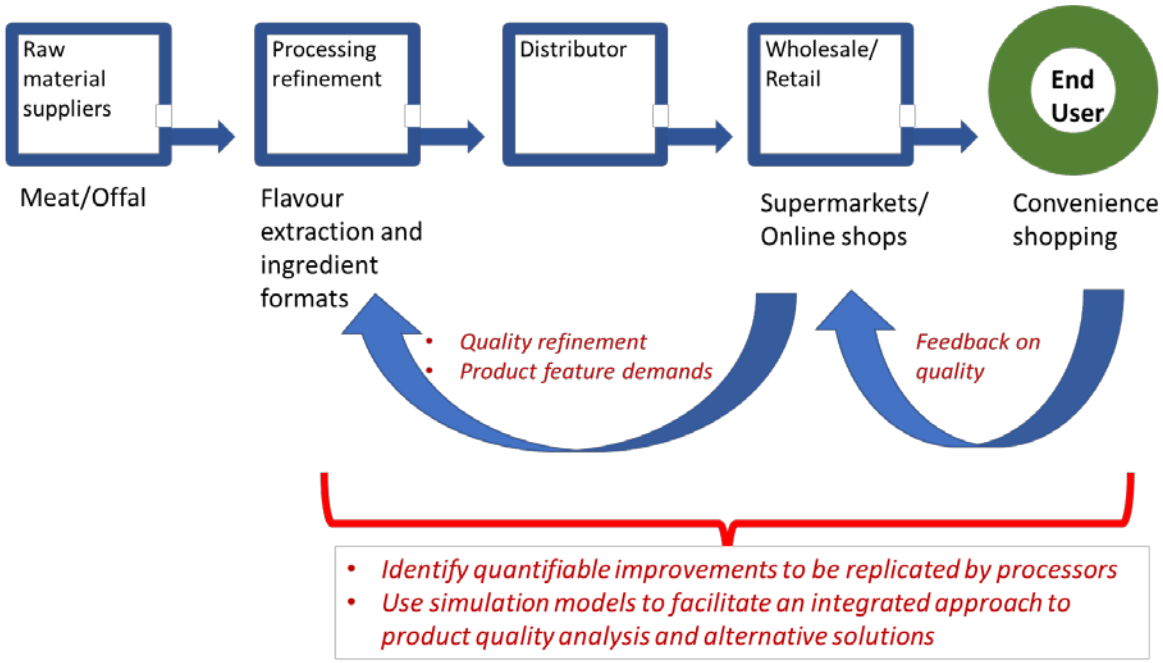

Fig. 7 A multilayered supply channel

4.5 What research needs to be undertaken and how novel is it?

The following requires consideration during the development and execution of the research into flavour development:

4.5.1 Technologies

Methods such as protein precipitation, lyophilisation, solvent extraction, isoelectric solubilisation have been traditionally used to extract and concentrate relevant flavour ingredients. The optimal techniques are dependent on the raw material and the final product. Typically, a combination of unit operations is required for optimal performance. However, some of these techniques may also have a negative impact on the final product, such as heat related destruction of peptides and formation of crosslinks, pH induced racemization and destruction of amino acids, increased oxidative modifications and changes in amino acid composition due to certain procedures. These changes can affect protein functionality and nutritive value thus limiting their application or reduce the final value of the product. Overall each combination of raw material and final product will require optimisation of the unit processes to be performed. Advanced phenotyping to gain a thorough understanding to optimise processing technologies is therefore of utmost importance.

4.5.2 Legislation

It is necessary to understand relevant legislation around access to animal derived raw materials. Information will be required on material collection, handling, storing and processing to ensure

compliance for downstream uses. These are standard controls on industrial food production, familiar to the meat industry and routinely implemented across the supply chain. Since these products are extracts and may be used as ingredients for export, country-specific regulations around declaring these on labels must be considered.

4.5.3 Consumer studies

It will be important to understand consumers' perspective (especially older demographic) on flavour enhancement, their likes/dislikes of certain flavours, intensity of flavours and how it may affect their nutritional intake. Consumers' reaction to offal-derived ingredients; negative ideas about offal consumption or positive acceptance because of 'de-animalising' offal due to further processing involved in obtaining flavour ingredients.

The research is novel in that heuristic evaluations will be used to arrive at combinations of meat and meat co-products to obtain flavour using specific processing conditions, that can be customised in terms of taste, intensity and form, providing unique flavour experiences. The development of flavour solutions may encompass various segments such as ingredients for food manufacturers, food services and nutritionists.

4.6 What needs to sit around the research to make it adoptable

We have identified the modifying factors that can affect food choices for older adults. These are mostly based around health, economic, environmental, and social considerations, and can be both enablers or barriers to food formats that are ultimately consumed. While formative experiences, socio-cultural dynamics and many of the dietary and sensory changes related to the ageing process are non-modifiable, we feel that there is potential for certain enhancements to the sensory properties of food to compensate for some of these factors influencing food preferences.

To ensure the products are affordable, accessible and easy to use, and are formulated and aligned with traditional values and perceived as "natural", we recommend the following:

- Establish an advisory group providing guidance on the feasibility of the various approaches that may be used to develop and implement research in the flavour space
- Increase the awareness of decision makers, established through closer interactions, on the benefits of using meat-based extracts to manipulate flavours such as umami and other desirable attributes and encourage bioavailable protein consumption, without adding to the saturated fat, cholesterol, or sodium intake of individuals.
- Involve older adults in all stages of the development of such products, as this has the potential to increase their acceptability

4.7 Who would we need to work with to adopt the solution?

From the focus group studies, five key roles were identified as being critical in the chain of decision-making relating to nutrition of residents within the RACFs. These are RACF management, Dietitians, Kitchen Managers, Care Workers, and Residents themselves.

The research team from AgResearch have identified that low-sodium flavour-enhancement products that can be considered “natural” will resonate well with older adults. These could also be fortified with nutrients such as vitamins B12 and D. There must be enough transparency regarding the make-up of these products, as older adults like to know what they are eating. Also, highly seasoned or spicy flavouring are not preferred. The research team, including meat scientists and social scientists, nutritionists and marketers, with support from MDC/MLA will need to work together to best support this work. For example:

- Marketers can provide insight into how to address the flavour space and drive the point home that unique and enhanced flavours would be of benefit to the elderly by addressing pleasant sensory experiences that will be of further benefit from an increased nutritional intake and better health.
- Social scientists will help bridge the gap between the actual science and communicate the requirements of the stakeholders, in this case the decision makers as stated above. They will help in engagement ‘with’ and not ‘at’ stakeholders. Communicating separately with each type of stakeholder (segmentation), starting with management through to the residents themselves, and giving specific examples of benefit, will help with success. They will also ensure seamless integration with the current situation with very little disruption which will help in the adoption of these flavour formats.
- The meat scientists along with social scientists will decide on how implementation is managed. Stakeholders must be provided opportunities for feedback, with implementation adjusted accordingly to achieve greater adoption. Metrics to assess implementation success will be needed.
- Retailers will also play an important role in the adoption of the products. They should be involved in the later stages of the concept development so that products may be available in retail shelves that are easily accessible to residents and to the general public.

There is a clear role for a food manufacturing company that has the expertise and equipment required to manufacture the products developed in this project. Smaller quantities will be manufactured initially to allow trial marketing and consumer acceptance studies.

The research team at **AgResearch is also engaged with a New Zealand based concept development chef** who brings experience from working with world-renowned celebrity chefs such as Heston Blumenthal and Gordon Ramsay. This chef can help us understand the multi-sensory attributes of flavour, obtaining unique flavour profiles, and how chefs manipulate flavour.

4.8 How much could be gained if others adopted it (Time/$/Growth/Trust)?

In 2017, the natural flavours segment accounted for more than half of the global food flavours market share. Due to increase in health awareness in recent years, consumption of natural food flavours is projected to grow at a CAGR of 9%. According to Prescient & Strategic (P&S) Intelligence, the sauces, dressings, and condiments market valued at $US115.3 billion in 2017, is expected to grow at a CAGR of 3.8% between 2018 and 2023.

Based on the different product types, the table-top sauces segment was the largest category in 2017, responsible for more than 30% revenue in the market. This was followed by the cooking ingredients segment as the second largest category.

Meat and Livestock Australia (MLA) December 2018 report showed that in general (all values in Australian dollars):

- Livers, kidneys and hearts were the cheapest, at approximately $1/kg – $2/kg
- Tripe, beef lips and head meat were priced around $3 – $4/kg
- Cheek meat, honeycomb tripe, aorta, and omasum were in the higher price bracket, around $6/kg to $8/kg
- Australian sheep co-products are primarily hearts, kidneys, livers, tongues and tripe, and average prices ranged $1/kg - $4/kg in December 2018

Offal prices in New Zealand were higher than in Australia. On average:

- Beef co-product prices in New Zealand ranged from $ 6/kg to $18/kg
- Livers, kidneys and hearts were the cheapest offal, at approximately $6/kg – $8/kg
- Cheek meat, honeycomb tripe and beef tails also sit in the higher price bracket, significantly higher than Australia's at $13/kg – $19/kg
- Average prices for New Zealand sheep livers, kidneys, hearts ranged from $6 – $13.

While some co-products already command a reasonable price for direct human consumption, the majority are low-value products, there are even products which carry a neutral or negative value depending on the cost of disposal.

A preliminary cost model is presented below to test economic feasibility, and several scenarios have been developed using this model (Table 3). When setting up the model four main factors were found to influence viability. These were: raw material cost, conversion efficiency (yield), final product concentration, and final product cost. In the table the extremes (high/low) of these factors have been used to compare the raw material cost with the expected revenue; the following assumptions were used in the calculations:

- Raw material price will be between $1/kg and $8/kg
- Raw material has a solids content of 25%
- A conversion efficiency of 70%
- Product will have a solids content of between 10% and 100%
- Product will sell for between $6/kg and $15/kg

Table 3. Preliminary cost model

Description		Scenario							
		A	B	C	D	E	F	G	H
Raw material cost	$/kg	1.00	1.00	1.00	1.00	**8.00**	**8.00**	**8.00**	**8.00**
Raw material IN	kg	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Raw material solids content	%	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Extraction process conversion efficiency	% of dry solids	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
Dry solids out	kg	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Product solids content	%	10.00	**100.00**	10.00	**100.00**	10.00	**100.00**	10.00	**100.00**
Mass of Product OUT	kg/kg wet feed	1.75	0.18	1.75	0.18	1.75	0.18	1.75	0.18
Mass of raw materail needed to make 1 kg product	kg	0.57	5.71	0.57	5.71	0.57	5.71	0.57	5.71
Cost of raw materail to make 1 kg product	$	0.57	5.71	0.57	5.71	4.57	45.71	4.57	45.71
Revenue from 1 kg of product	$	6.00	6.00	**15.00**	**15.00**	6.00	6.00	**15.00**	**15.00**
Revenue less raw material cost	$	5.43	0.29	14.43	9.29	1.43	-39.71	10.43	-30.71

Note that this evaluation does not include any manufacturing or other costs. Once the extraction process has been decided and more is known about the required unit operations and operating conditions (e.g. temperature) this model can be expanded to include additional costs.

Data in the table show that selling the product as a liquid concentrate (e.g. with 10% solids content) is more favourable than selling it as a dry powder (100% solids content). If it is believed that conditions similar to those used in scenarios A, C, D, or G can be replicated in the real world then it is worth gathering more information and progressing with the next level of coast estimation, which should include manufacturing cost.

Extraction of flavouring compounds from meat/offal will involve industry scalable procedures with minimal number of steps. However, obtaining the desired flavour profiles will be highly dependent on the development of integrated process unit operations and manipulation of these to produce flavour enhancing ingredients with sensory and processing characteristics. These will pose considerable processing challenges that need to be addressed. However, the science and understanding of how the unit operations are combined will be the key valuable Intellectual Property developed.

Overall selling the product as a liquid concentrate (e.g. with 10% solids content) is more favourable than selling it as a dry powder (100% solids content).

4.9 What is the cost to undertake the research and cost to scale?

Typically, the cost to scale is between 3 and 10 times the research cost, which is difficult to estimate at this early stage of the project.

4.10 Desirability

The focus group studies to determine if there was desirability of enhanced meat derived flavours to compensate for a decline in taste perception in older adults, and increase the intake of nutrient dense foods, thereby improving nutritional status. A strong desirability for savoury flavours amongst the participants was established. Participants were found to positively associate meaty and savoury flavours to the feelings of nostalgia they expressed for the savoury, meat-centric, dishes of their childhood or young adulthood, most notably the Sunday roast.

Therefore, including meaty flavours into natural flavour-enhancement products should prove popular with older adults. Our initial results suggest that the development of a savoury-flavoured food enhancement additive to gain the popular umami flavours, and encourage bioavailable protein consumption, without adding to the saturated fat, cholesterol, or sodium intake would be a desirable product. Such a product could also be fortified with important micronutrients or designed to be added to a range of nutrient-dense foods.

4.11 Feasibility

Flavour extraction processes that are suitable and scalable include combinations of thermal, evaporative, pressure, enzyme hydrolysis, ultrasound assisted extraction, and solubilisation. All these processes are well known and therefore are eminently feasible. The final unit processes and their parameters will depend on the nature of the feed stock and the desired end-product and this is where the IP will be concentrated. Other factors that will impact feasibility include waste treatment, regulatory and safety requirements.

4.12 Viability

A preliminary model has been developed to test economic potential, and several scenarios were explored. Four main factors were found to influence viability, namely; raw material cost, conversion efficiency (yield), final product concentration, and final product cost. Extremes (high/low) of these factors were used to compare the raw material cost with the expected revenue from retail prices of flavouring ingredients presently available to consumers.

The model outputs indicate that there are combinations of raw material and final product form that meet and exceed the MDC target of raw material cost / product sales price ≥ 3.

5 Value proposition

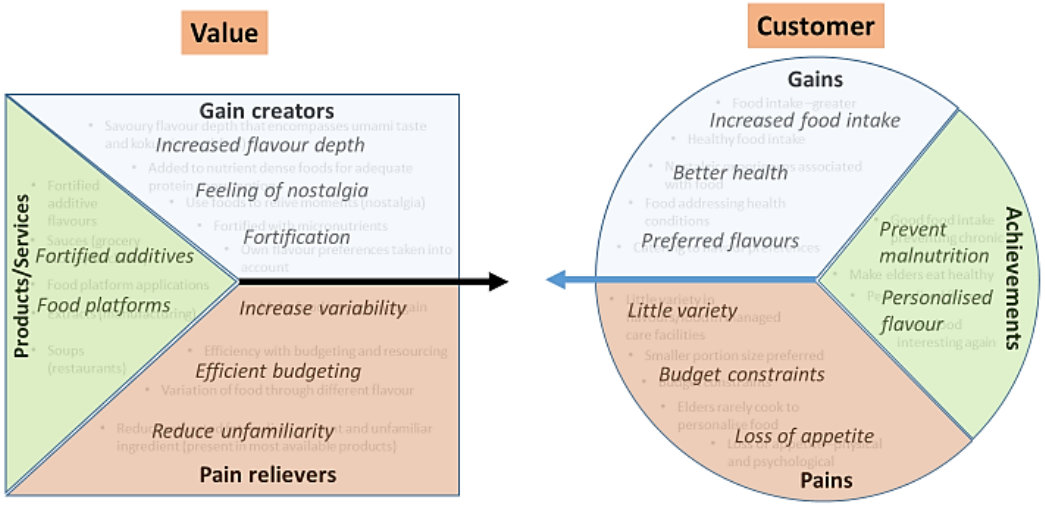

Fig. 8 Value Proposition Canvas

Low value processing streams from the meat industry may be used for extraction of proteins. These initially may not have intense flavour profiles due to the nature of the proteins. The flavour can however be amplified by increasing interaction with lipids, carbonyl and sulphur compounds.

In the flavour industry, the focus is on low inclusion rate, high value of the product and low transportation cost. There needs to be a change in focus on flavour (intensity), in the form of ingredients, rather than volume.

One of the major trends in flavour industry is the role of taste. Just having the volatiles without having the supporting base for other taste components do not provide the overall flavour impact. A value proposition where it is a one whole flavour component should be considered.

Table 4 demonstrates the gain creators for customers (elderly consumers) from product/services covered in this report.

Table 4. Gain creators for customers

Customer	Value
Pain points: • Little variety in flavour/food in managed care facilities • Smaller portion size preferred by residents • Budget constraints that limit variety in food • Elders rarely cook to personalise food • Loss of appetite due to both physical and psychological reasons	**Pain relievers:** • Make food interesting again • Efficient budgeting and resourcing • Variation in food using different flavours • Reduce saturated fat, sodium content and unfamiliar ingredients (present in most available products)
Gains: • Increase in food intake due to greater variety in taste • Healthy food intake • Nostalgic experiences associated with food • Food addressing health conditions • Catering to personalised flavour preferences	**Gain creators:** • Savoury flavour depth that encompass umami taste and kokumi mouthfeel • Added to nutrient dense foods for adequate protein consumption • Use foods to re-live moments (nostalgia) • Fortified with micronutrients • Own flavour preferences considered
Achievements • Good food intake preventing chronic malnutrition • Healthy eating experience for elders • Personalised flavour • Make food interesting again	**Products/services** • Fortified additive flavours • In the form of sauces/soups available in grocery stores and for use in kitchens and restaurants • Can be used in various food platforms • Extracts made by various manufacturers

Although the focus of this study is on elderly consumers who have specific nutritional and digestibility requirements, but who desire traditional flavours, there is significant opportunity in targeting a wider global consumer base, including flexitarians and other future consumers who will use factors such as sustainability considerations in making purchasing decisions.

A minimum viable product concept could take various forms depending on its practical application. For example, if used as table-top condiments, then it can be a sauce, paste or free flowing powder. If used as a flavour enhancement during consumer cooking, then cubes or granules could be some options. If intended for food manufacturing, then suspensions, emulsions or solutions might be easiest to introduce and disperse. **Ideally the product should behave as an efficient umami and kokumi taste enhancer with roasty overtones and a slightly sweeter taste profile and possibly enhanced feel of creaminess.** To impart additional flavour notes further additions such as dried mushrooms, yeast extracts, and vegetables extract, along with a certain percentage of fat (animal or plant derived) might be used.

6 Market opportunity for red meat extracts

When incorporated into a food formulation, flavourings and flavour enhancers are classed as a type of food additive. Requirements for labelling will reflect their origin and composition. According to Allied Market Research, the global food flavours market was valued at US$13 billion in 2017, and is expected to reach US$20 billion by 2025, yielding a CAGR of 5.4% from 2018 to 2025. Growth in disposable income and increase in demand for ready-to-eat meals are the main drivers for the industry, and Asia-Pacific market is forecasted to lead the market growing at a CAGR of 6% during the forecast period. China represented 30% of the Asia-Pacific food flavours market, in 2017.

The flavour of any food can also be altered or enriched externally, through condiments, sauces and dressings. This is a separate opportunity for new product positioning. According to Prescient & Strategic (P&S) Intelligence, the sauces, dressings, and condiments market valued at $US115.3 billion in 2017 is expected to grow at a CAGR of 3.8% between 2018 and 2023.

7 Gap analysis

The value proposition identifieds the gain creators for customers through the development of one whole flavour component in the form of an MVP. Various issues have been identified through a gap analysis that could affect future viability of the value proposition. It is evident from Table 5 that placing these issues in the right context would prevent holding back innovation. The value proposition clearly identifies a route to market while addressing future growth opportunity spaces.

Table 1. Gap analysis

Issue	Current state	Future state	Comments (gaps)
Market Analysis	Feasibility established	Target market identified and profiled	Use cases for novel products. Where is growth occurring in markets?

Extraction techniques	Some processes defined for extraction of meat and offal (n = 1 combination)	Optimised extraction of meat and offal including interaction with other processes (e.g. fermentation)	Offal:Meat:Other ratio, extraction procedures (e.g. hydrothermal enzymatic etc.). Distillation? "Other" ingredients need to be defined.
Fermentation of Meat:Offal:Other	Fermentation is commonly used to produce flavour in food	Meat:Offal:Other combinations optimised	Little known about the impacts of fermentation in the context of meat and offal extracts.
Ultimate flavour/taste profiles defined	Partially defined (*in silico*) Peptides	peptides, volatiles and lipid profiles defined	Define flavours in a by lipids, peptides, volatiles. Mouth feel, Appearance.
Rapid analytical techniques for flavour	Lab-based techniques are established but expensive and time consuming	Real-time techniques calibrated for predicting flavour profiles.	Calibration/validation of rapid techniques such as Rapid Evaporative Ionisation mass spectrometry, spectroscopy.
Scale-Up	Lab-scale partially defined	Industrial process and process costs defined	Optimised extraction needs to be completed first. Costs defined.
Business Model	Processors focussed on meat processing	Integrated food companies	Pathway to customer/ consumer-driven integrated food companies Feedback loop to producers.

8 MDC Workshop

On 17th July 2019, the project team presented their findings to date at an MDC workshop held in the MLA Brisbane office. The meeting accepted the broad project findings and MDC staff requested that the final report include a Value Proposition Canvas and a Gap Analysis.

9 Conclusion and recommendations

Based on the literature surveys, interviews and focus group studies, two scenarios have been identified within which older adults are not consuming enough nutrients and flavour can play an important role in higher food intake. The focus group studies were designed to determine the desirability of enhanced meat derived flavours to compensate for a decline in taste perception in older adults, and increase the intake of nutrient dense foods, thereby improving nutritional status. **A strong desirability for savoury meat flavours amongst the participants was established.** Participants were found to positively associate meaty and savoury flavours to the feelings of nostalgia they expressed for the savoury, meat-centric, dishes of their childhood or young adulthood, most notably

the Sunday roast. Overall, we feel that desirability of meat-based flavours that may be used to stimulate appetite by increasing the sensory appeal of food has been demonstrated.

Flavour extraction approaches that are **feasible** and scalable (e.g. hydrothermal pressure processing, enzymatic hydrolysis, solubilisation) and technical route to market are being investigated. The flavour extraction processes being reviewed with emphasis on large-scale commercial procedures considering yield, production cost, waste treatment, and regulatory and safety requirements are well known and well proven, therefore extraction is feasible. **From initial estimates of a few different scenarios of extraction technologies and raw material use, a product with a minimum value multiplier of three times the input raw material cost may be possible.** However, further analysis is required considering manufacturing and other costs associated with unit operations.

We have already identified combinations of raw material and final product that meet or exceed the MDC target of raw material cost / product sales price ≥ 3.

Finally, the team at **AgResearch made contact with a New Zealand based concept development chef** who is keen to be involved should this project progress to research and prototyping. Such experience will help us understand flavour interactions, the multi-sensory attributes of meat-based flavour, and what formats of new foods, condiments and enhancers will be most convenient for them.

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11 Appendices

11.1 Appendix 1: Detailed statistics

Supplementary Table 1 Global total meat production volume (thousand tonnes), includes beef, veal, pork, chicken, lamb and mutton, NZ / AUS position. Source: OECD-FAO Agricultural Outlook 2018-2027 – 2018 forecast (stats.oecd.org).

Production ('000 tonnes)	World ('000 tonnes)	NZ % World	NZ ('000 tonnes)	Australia % World	Australia ('000 tonnes)
Beef and veal (cwe)	71,724	0.90%	643.07	3.64%	2,612
Pigmeat (cwe)	120,708	0.04%	49.00	0.36%	430
Poultry meat (rtc)	123,205	0.19%	229.37	1.04%	1,287
Sheepmeat (cwe)	14,872	3.09%	459.81	5.11%	759
Total Meat	330,510	0.42%	1,381.26	1.54%	5,088

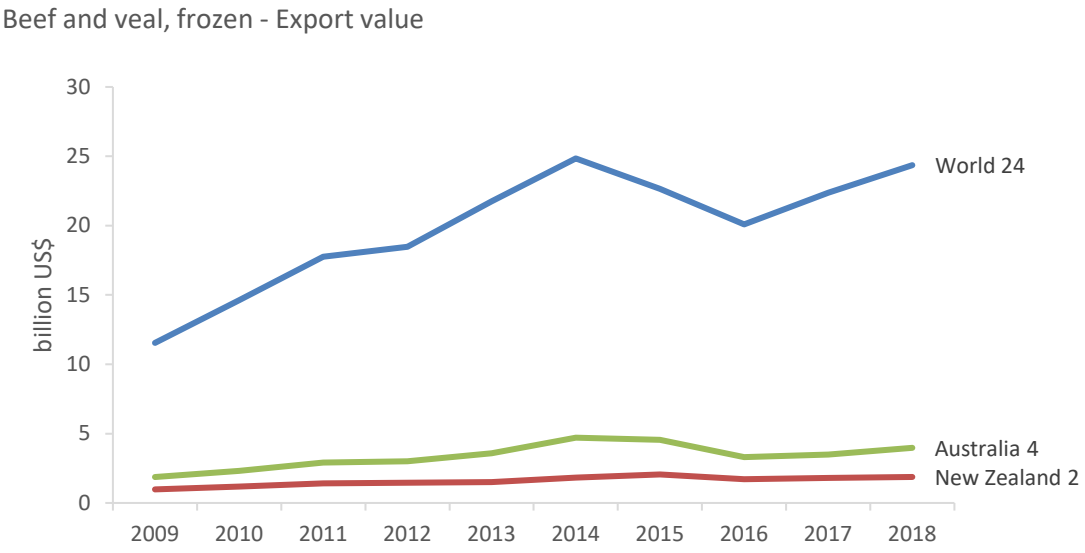
Supplementary Table 2 Global red-meat production volume (thousand tonnes), includes beef, veal, lamb and mutton, NZ / AUS position. Source: OECD-FAO Agricultural Outlook 2018-2027 – 2018 forecast (stats.oecd.org).

Production ('000 tonnes)	World ('000 tonnes)	NZ % World	NZ ('000 tonnes)	Australia % World	Australia ('000 tonnes)
Beef and veal (cwe)	71,724	0.90%	643	3.64%	2,612
Sheepmeat (cwe)	14,872	3.09%	460	5.11%	759
Total Red-Meat	86,597	1.27%	1,103	3.89%	3,371
% of Total Meat	26.20%				

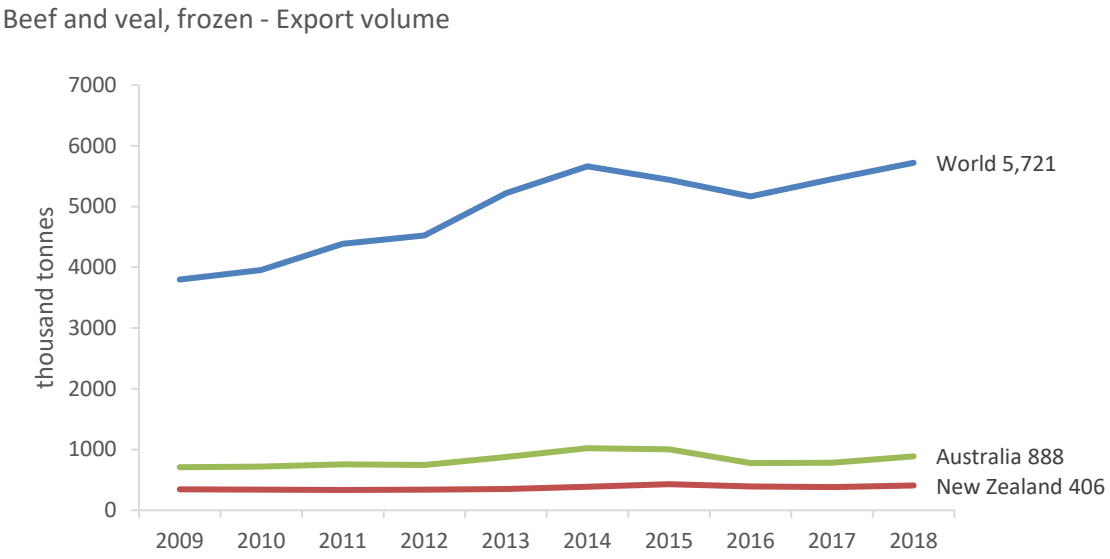
Supplementary Table 3 Global red-meat exports volume (thousand tonnes), includes beef, veal, lamb and mutton, NZ / AUS position. Source: OECD-FAO Agricultural Outlook 2018-2027 – 2018 forecast (stats.oecd.org).

Exports ('000 tonnes)	World ('000 tonnes)	NZ % World	NZ ('000 tonnes)	Australia % World	Australia ('000 tonnes)
Beef and veal (cwe)	11,357	4.98%	566	16.60%	1,885
Sheepmeat (cwe)	1,334	32.87%	439	39.18%	523
Total Red-Meat	12,691	7.91%	1004	18.97%	2,408
% of Total Meat*	37.37%				

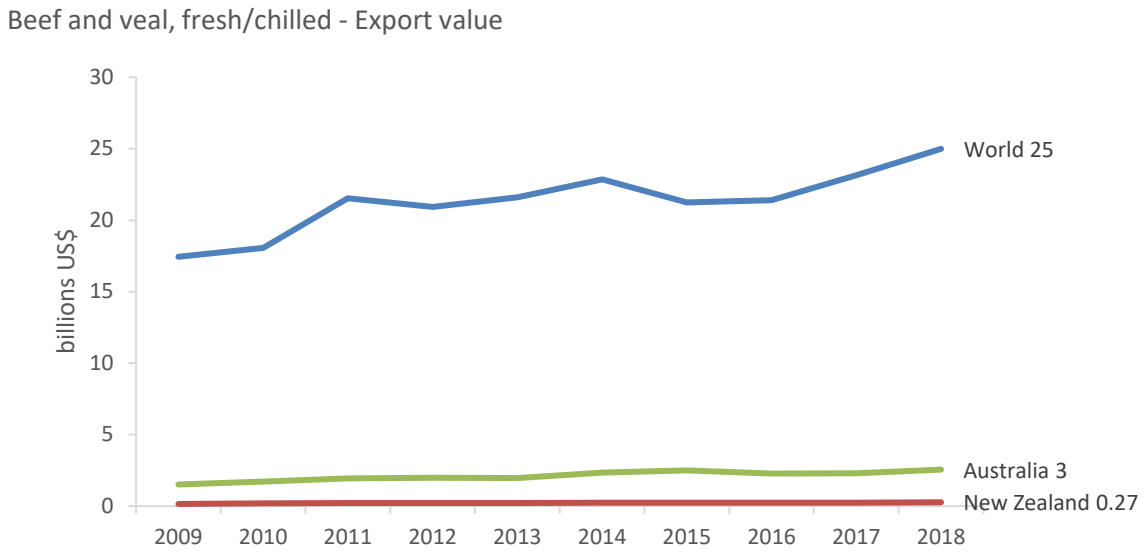
*Global total meat exports = 33,961.48 thousand tonnes



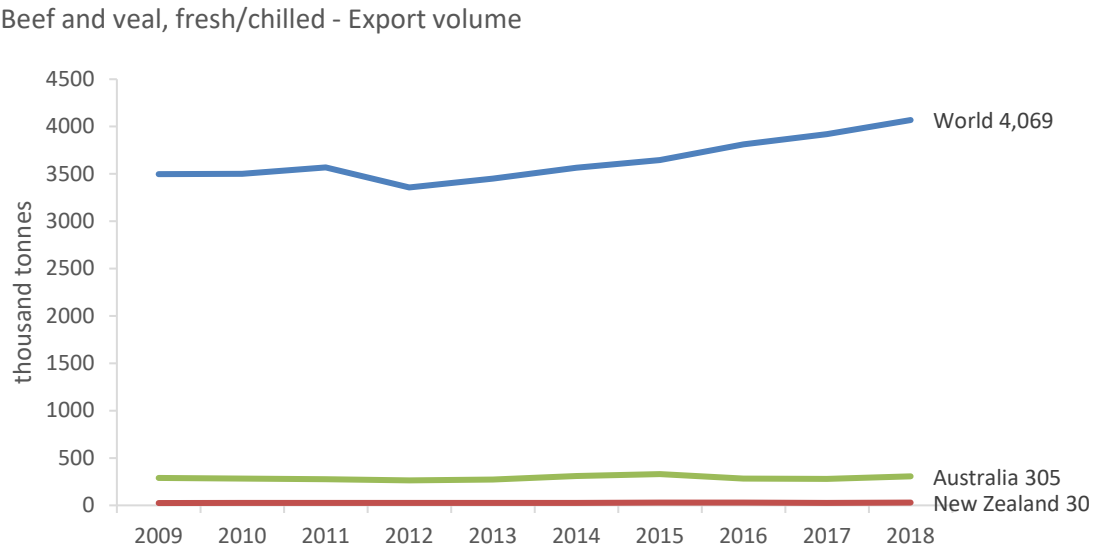
Supplementary Fig. 1 Global frozen beef and veal export value (US$), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0202, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



Supplementary Fig. 2 Global frozen beef and veal export volume (tonnes), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0202, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



Supplementary Fig. 3 Global fresh/chilled beef and veal export value (US$), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0201, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).

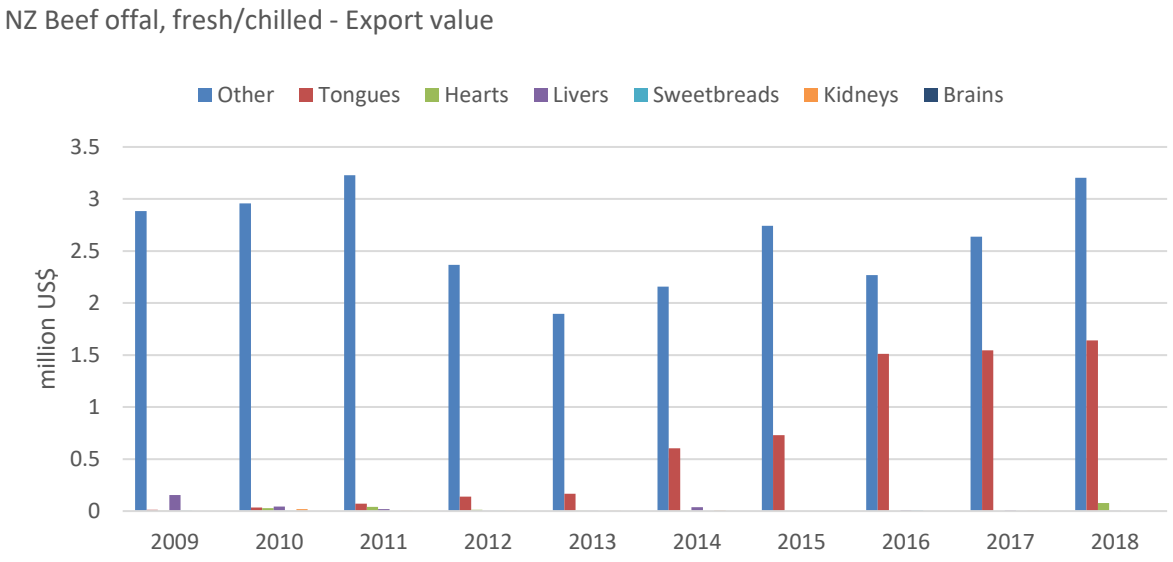


Supplementary Fig. 4 Global fresh/chilled beef and veal export volume (tonnes), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0201, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).

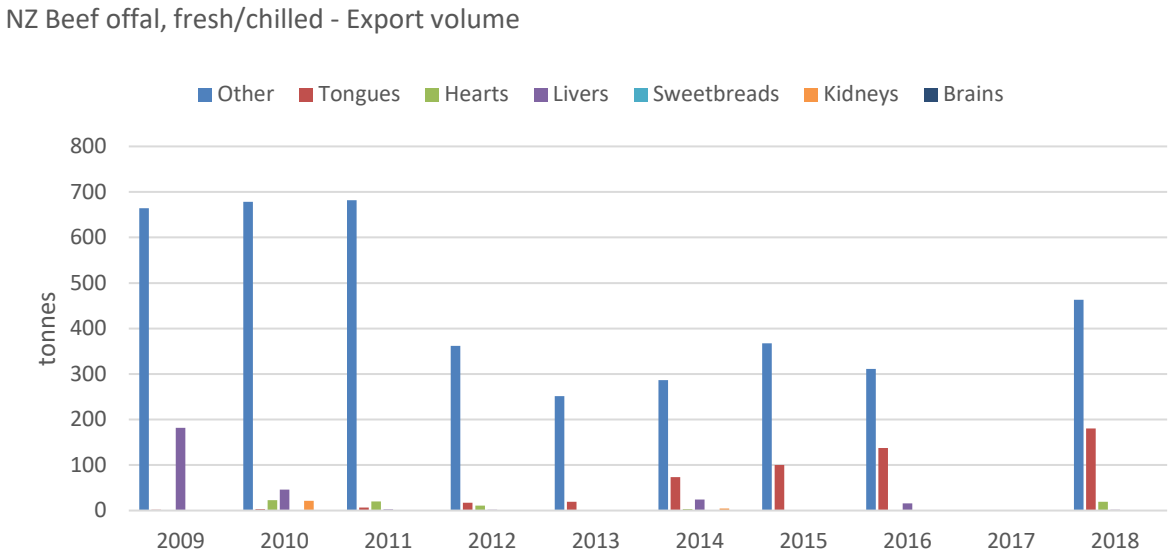
Supplementary Table 4 Global fresh/chilled beef offal export value (thousand US$), 2018, NZ / AUS position. Sources: HS (2012) 020160, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).

Exports ('000 US$)	**World ('000 US$)**	**NZ % World**	**NZ ('000 US$)**	**Australia % World**	**Australia ('000 US$)**
2018	967,369	0.5%	4,936	9.3%	90,414
Annual growth rate 2014-2018 (%)	3%		14%		18%
Annual growth rate 2017-2018 (%)	7%		18%		11%

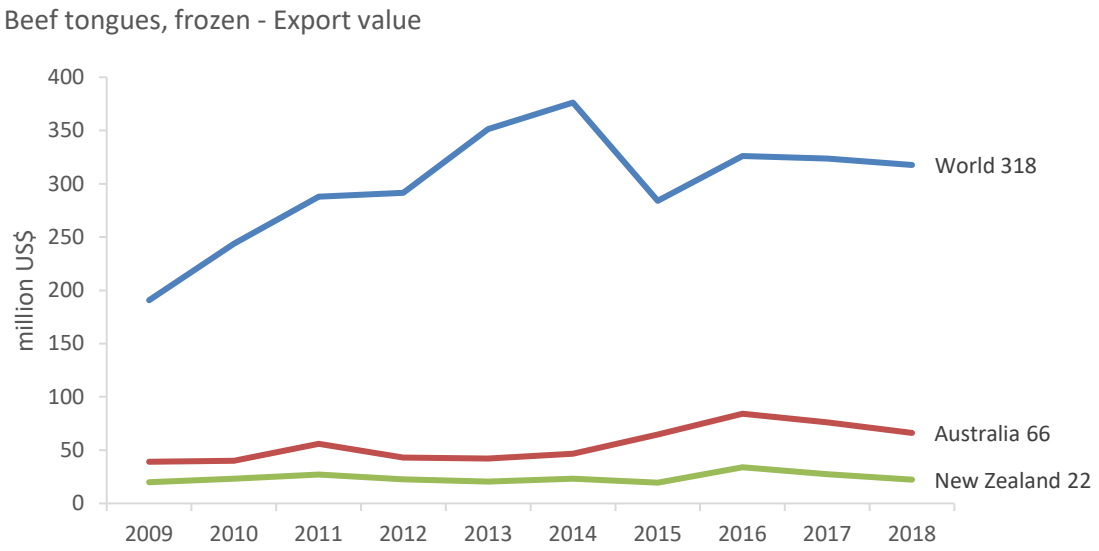
Supplementary Fig. 5 Global fresh/chilled beef offal export volume (tonnes), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 020610, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



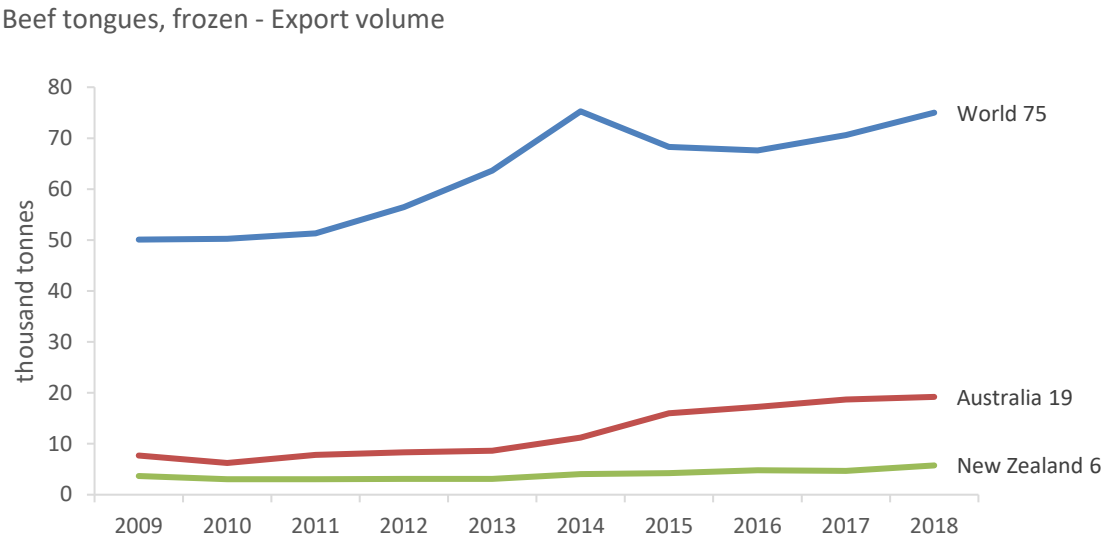
Supplementary Fig. 6 NZ fresh/chilled beef offal export value (US$), 2009 – 2018. Sources: HS (2012) 020610, ITC calculations based on UN COMTRADE and ITC statistics *(http://www.trademap.org).*



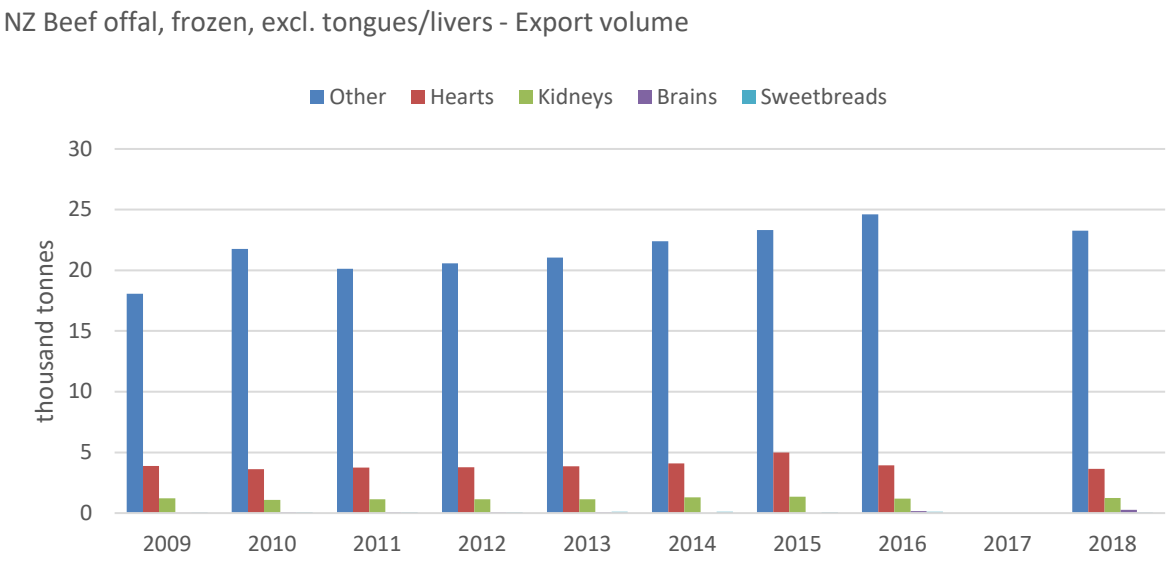
Supplementary Fig. 7 NZ fresh/chilled beef offal export volume (tonnes), 2009 – 2018. Sources: HS (2012) 020610, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



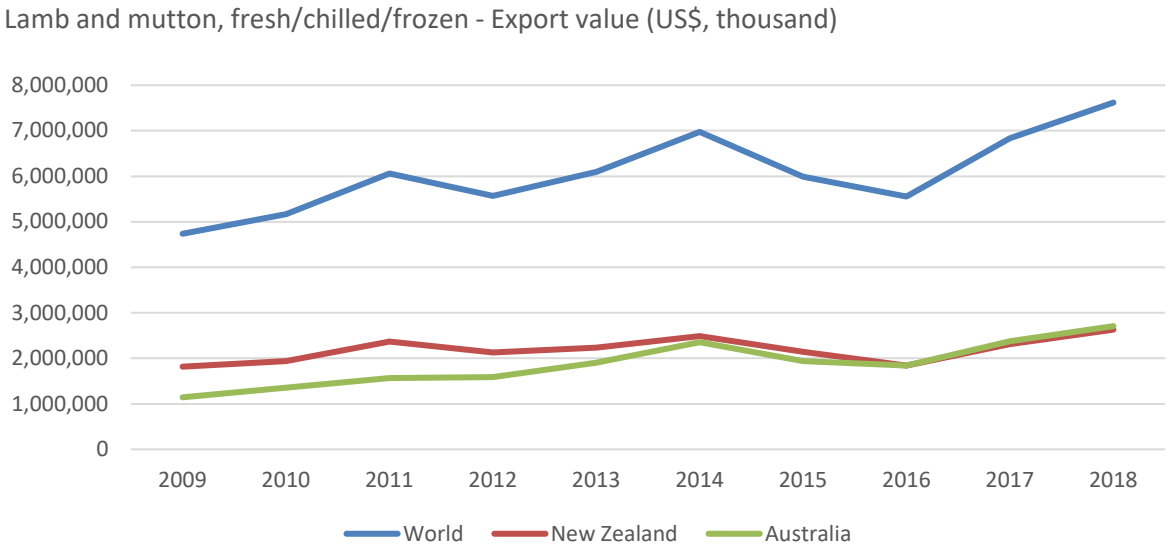
Supplementary Fig. 8 Global frozen beef tongues export value (US$), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 020621, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



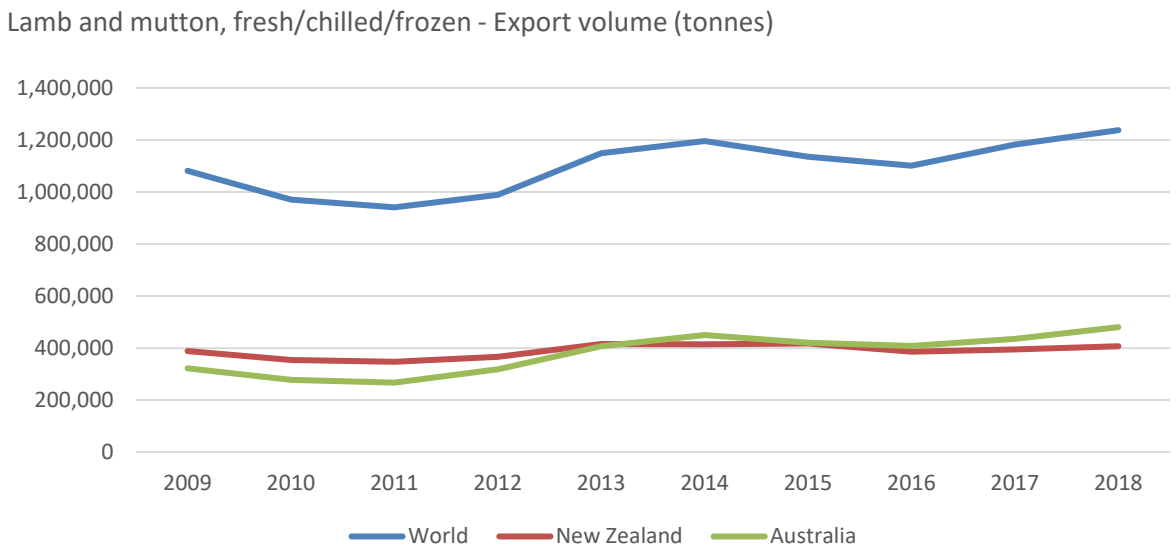
Supplementary Fig. 9 Global frozen beef tongues export volume (tonnes), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 020621, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



Supplementary Fig. 10 NZ frozen beef offal excluding tongues / livers export volume (tonnes), 2009 – 2018. Sources: HS (2012) 020629, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).



Supplementary Fig. 11 Global lamb and mutton export value (US$), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0204, ITC calculations based on UN COMTRADE and ITC statistics *(http://www.trademap.org).*



Supplementary Fig. 12 Global lamb and mutton export volume (tonnes), 2009 – 2018, NZ / AUS position. Sources: HS (2012) 0204, ITC calculations based on UN COMTRADE and ITC statistics (http://www.trademap.org).

11.2 Appendix 2: Nutritional intake of older adults - survey

11.2.1 Methods

11.2.1.1 General method

In undertaking this study, we employed a qualitative methods approach to explore the factors influencing the nutritional intake of older adults. With a focus on the lived experiences of a socioeconomically, culturally, and ethnically diverse group of older adults in New Zealand, participants were accessed through RACFs and community groups in Canterbury and the Waikato. While the RACF sites were selected to be as geographically and socio-economically diverse as possible, the residential population of RACFs in New Zealand is predominantly, and disproportionately, Pākehā. In 2013, 93.4% of the 65+ population in residential care were Pākehā (New Zealand Census 2013). As such, we also approached Marae, Pasifika groups, and the Citizens Advice Bureau to assist us in accessing non-Pākehā participants and expand the diversity, and therefore representativeness, of our sample. The Citizen's Advice Bureau subsequently put us in contact with the Senior Chef programme and the Appetite for Life programme, who were running a group for Mandarin-speaking older adults.

With the permission of the management at the RACFs, Marae kaumatua, Pasifika group leaders, and Senior Chef and Appetite for Life programme coordinators, we employed a range of research methods in order to gain an understanding of the factors surrounding decision-making regarding nutrition for older adults in New Zealand, and any changes that might have occurred with advancing age. These research methods included focus group discussions with older adults (55+ for Māori and Pasifika, and 65+ for non-Māori/Pasifika), as well as a series of face-to-face and telephone interviews with those who develop and deliver menus to cater to their dietary needs, and who assist older adults with their meals.

11.2.1.2 Ethics

Ethical approval for the study was granted through the AgResearch social research ethical review process. Following these guidelines, participants were provided with information about the nature and purpose of the research. They were informed that their participation was entirely voluntary, and that they were able to opt-out at any point during the research. They were also informed that they could withdraw their responses up to 14 days after their focus group/interview, with no detrimental impact to themselves. Furthermore, participants were assured that their confidentiality, and that of the RACFs, would be maintained throughout the project and in any resulting publications. Those residing in, or working with, the RACFs were also guaranteed that their statements regarding the food and service provided by the RACFs would not be fed back to the care, kitchen, or management staff. In line with the requirements of Archives NZ, the anonymised project data files will also be stored securely for a minimum of seven years before being destroyed.

11.2.1.3 Data collection

11.2.1.3.1 Interviews with Dietitians, Kitchen Managers, and Care Workers

As a first step, the project team contacted the kitchen managers at the four participating RACF sites, as well as the care workers who provide personal assistance with meals. These staff members were given an information brief explaining the purpose of the project, and what participation involved.

Staff who agreed to participate in the research were interviewed in-person, using an in-depth, semi-structured interview schedule :

1. What is your role here?
2. What are your responsibilities within that role?
3. How long have you been working in this role, or similar roles elsewhere?
4. Can you talk me through how a menu is planned here?
    a. Who plans it?
    b. Who has input into the planning process?
    c. What are the key things that need to be considered when planning a menu for older adults?
5. What are the kinds of challenges residents here face with eating and nutrition?
    a. Are there any particular foods that residents struggle with?
    b. Are there any particular textures of foods that residents struggle with?
    c. How do you take these challenges into account with the menus you plan?
6. Do you try to enhance the flavour of the pureed meals you prepare?
    a. If so, using what ingredients?
    b. Do you ever use offal to improve/enhance the flavour of meat dishes?
7. Do you worry about the nutritional intake of the residents?
    a. If yes, what in particular worries you?
    b. If no, what gives you confidence that residents are getting all the nutrition they require?
    c. Are there any food groups or nutrients that you worry the residents don't eat enough of?
8. What strategies do you think help, or would help, older adults to eat a well-balanced diet?
9. From your perspective, what are the key dietary changes that older adults experience as they age?
10. Are there any particular dishes or foods that are popular with your residents?
    a. Why do you think that is?
11. Are there any particular dishes or foods that are unpopular with your residents?
    a. Why do you think that is?
12. Do the residents eat much in the way of meat?
    a. If yes, which meats and in what forms, are popular?
    b. If no, why do you think this is?
13. Are there any particular flavours that you find are popular with residents?
14. Are there any particular textures that you find are popular with residents?

Interviews were undertaken with two members of the research team present, in private and quiet spaces within the RACFs. Informed consent was gained prior to the interviews commencing, and staff

were provided a written description of the information brief and asked to sign a consent form to indicate that they understood the purpose and conditions of involvement.

A total of six RACF staff were interviewed, including four kitchen managers and two care workers. These interviews lasted approximately 30-45 minutes and were audio-recorded and transcribed by an independent stenographer. Staff members were anonymised during the transcription phase of the research.

During these interviews we became aware that the base menus for the RACFs were being planned by dietitians who were contracted by the RACFs. Thus, in order to gain an understanding of the process and priorities that underpinned the development of such menus for RACF residents, we contacted two dietitians who work in this capacity for informal telephone interviews. Following a description of the project, and of their right to withdraw from the interview at any time, their anonymity was assured, and their verbal consent was acquired. The dietitians were then asked about their role in the decision-making surrounding the nutrition of residents of RACFs by a member of the research team, who recorded the dietitians' responses by hand, and where possible, verbatim.

11.2.1.3.2 Focus groups with older adults

Secondly, with the assistance of the RACF staff and community group coordinators, older adults were invited to take part in a series of focus groups. Staff and coordinators who assisted with recruitment and selection of focus group participants were informed that participants needed to be able to speak in a group setting and answer the questions guiding the research. Within the RACFs, staff approached residents who were known to be able to participate, and who were interested in participating. Among the broader community groups, coordinators sent an invitation to members of the groups, where all were invited to participate. Eleven focus groups were undertaken, with a total of 59 individual participants.

Older adults who were interested in participating in the focus groups were informed of the purpose of the research through the RACF staff and community group coordinators. A private room was organised for each focus group where all participants could sit around a table. Upon arrival, focus group participants were provided with a written information sheet. The facilitators then verbally explained to participants the purpose of the research, what an individual's involvement would entail, and answered any questions participants had. Before the focus groups commenced, all participants were required to sign a consent form to indicate that they provided their informed consent. One participant was unable to provide written consent due to eyesight and physical coordination difficulties; thus, verbal consent was obtained instead.

With the exception of one of the marae focus groups, which due to its size was split into two smaller groups, each focus group was facilitated by two members of the research team. A laminated sheet listing a range of general flavours (spicy, sweet, sour, savoury, salty, and bitter), was used during each focus group to prompt participants about their flavour preferences, but otherwise the researchers used verbal prompts where necessary.

Given that the participants in the Appetite for Life group were not competent English speakers, Mandarin translators were used for this group. Each focus group lasted approximately one hour, and

as with the interviews, the focus groups were audio recorded and transcribed verbatim by an independent stenographer, with all identifying information for the participants anonymised.

The interview schedule which guided the focus groups was:

1. Firstly, can we go around the group and can you each tell me your name, your age, and what your favourite food was when you were a child?
    a. What is it about that food that made it your favourite?
2. What was your favourite food when you were a young adult, and why?
    a. What is it about that food that made it your favourite?
3. What is your favourite food now?
    a. What is it about that food that made it your favourite?
4. How often do you get to eat your current favourite food?
    a. If not very often, why not?
5. Can you tell us about the role of food within your family life and your community?
6. What would you say are your favourite types of flavours? – for example sweet, sour, savoury, salty, or bitter?
7. How often do you eat meat?
    a. What is your favourite meat, and what do you like most about it? – anything about the flavour or the texture?
    b. How do you like your favourite meat to be cooked?
8. In what ways has your diet changed as you have gotten older? – be it the foods you eat, when you eat, how often you eat
    a. Are there flavours you like now but didn't use to, or used to like but don't now?
    b. Has the amount of food you eat changed as you have gotten older?
9. Why do you think your diet has changed?
10. Are there any foods that you no longer eat that you wish you did or could eat?
    a. Why don't you, or can't you, eat them?
11. Do you like to try new foods or do you prefer to stick to what you know you like?
12. Do you feel like you currently have a well-balanced diet?
    a. If yes, how do you achieve that?
    b. If no, what do you think you might be missing out on and why?

11.2.1.3.3 Data analysis

The notes from the two dietitian interviews, and the transcripts from the six RACF staff interviews and eleven focus groups, were uploaded into NVivo (QSR International Pty Ltd) where they were coded for emergent themes, using open coding and a thematic analysis approach (see Braun and Clarke (2012)). The emergent themes were independently reviewed and validated by all members of the research team before being analysed further. In conjunction with findings from the literature, this analysis was used to construct two models of decision-making surrounding older adult nutrition; within the RACF context, and among older adults more broadly. These models were successively revised by the project team with each iterative analysis of the data.

11.2.1.3.4 Results and Discussion

Following an overview of the participants' demographics, the results from the focus groups and interviews are presented below in two sections. Firstly, an exploration of the decision-making process related to older adult nutrition within RACFs is presented in a model and discussed. Within this context, RACF managers, dietitians, kitchen managers, care workers, and residents are involved in decision-making related to food. This is then compared and contrasted with the experiences of older adults residing independently in the community. Secondly, the factors influencing older adults' food preferences, and the modifying factors that turn food preferences into actual food choices, are presented as a model and explored.

11.2.1.3.5 Demographics

Basic demographic data were collected from the focus group participants, indicating that 37 (62.7%) of the participants were women, and 22 (37.2%) were men. Part of this gender discrepancy can be attributed to the longer life expectancy of women in New Zealand, and thus the greater percentage of older adults in New Zealand who are women (Statistics New Zealand 2015b). Participants were ethnically diverse, with 26 (44.1%) being Pākehā/New Zealand European, 21 (35.6%) Māori, 7 (11.9%) Pasifika, and 5 (8.5%) Chinese or Singaporean. Seventeen (28.8%) of the participants lived in RACFs, and 42 (71.2%) lived independently in the community. For the interviews, one of the Kitchen Managers was male, while all other interviewees were female.

11.2.1.4 RACF model of older adult nutrition decision-making

Data from the focus groups and interviews were used to construct a model of decision-making surrounding older adult nutrition within the RACF context. This includes identification of the different people involved in the 'chain' of decision-making within the residential facilities chosen for this research, the factors influencing the decisions these people make surrounding older adult nutrition, and the factors which each person is able to control. Finally, 'priorities' are identified for each of these people, as 'drivers' of decision-making regarding older adult nutrition, in their role. This model looks at nutrition from preparation and meal planning, through to food consumption.

Five key roles were identified as being critical in the chain of decision-making relating to nutrition of residents within the RACFs, as identified in Fig. 9. These are RACF management, Dietitians, Kitchen Managers, Care Workers, and Residents themselves. Each of these roles is further explored below, with a description of the factors each role prioritises, and an exploration of how these factors are prioritised and seen by each role. This is evidenced by quotes from individuals who participated in the research, which illustrate different perspectives regarding the factors identified in the model.

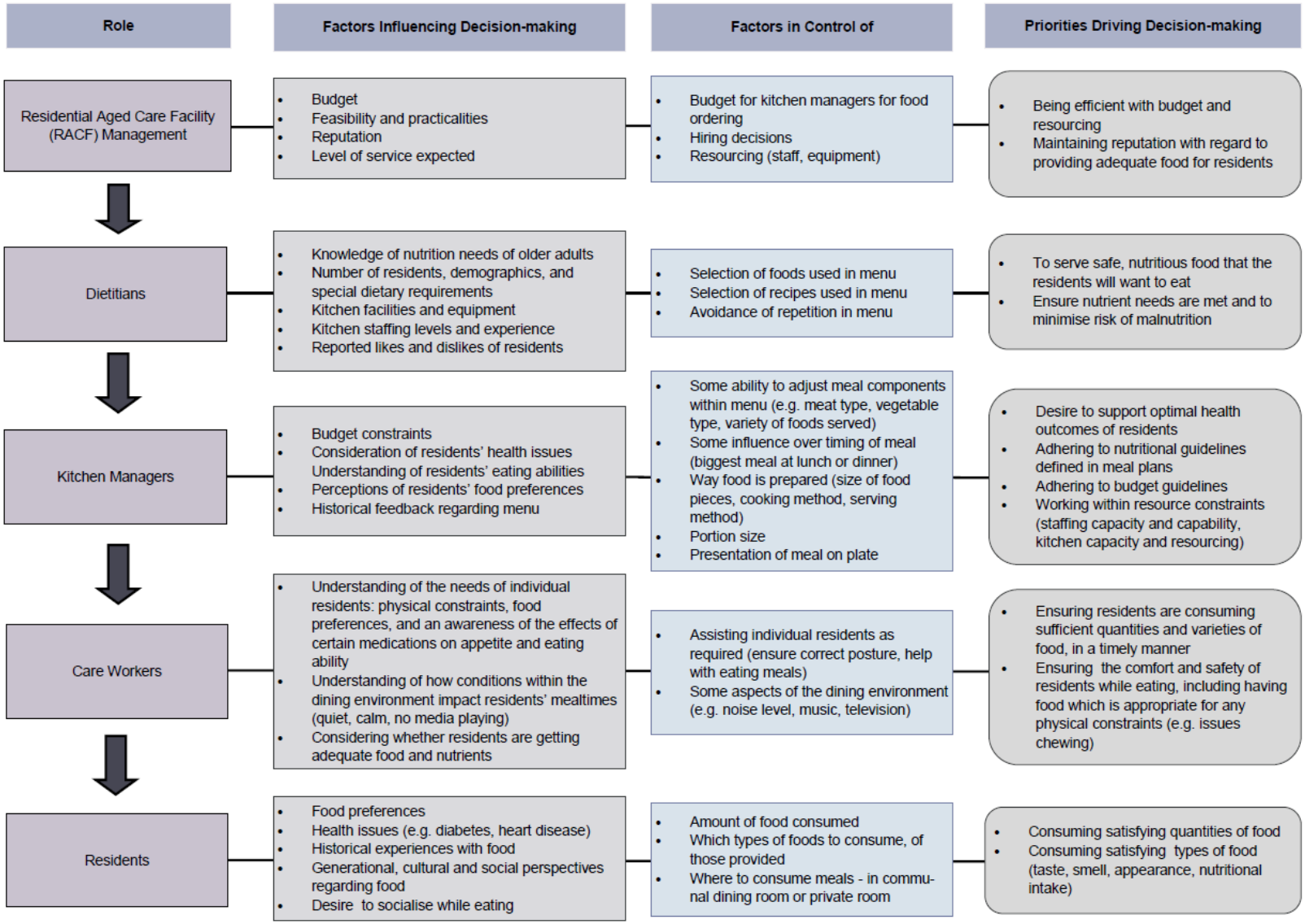


Fig. 9 Model of decision-making surrounding older adult nutrition in RACFs in New Zealand

11.2.1.4.1 RACF management

Menus for the RACFs included in this research are ultimately controlled at the RACF management level, as it is the management who contract external dietitians to develop menus to suit each RACF site, or chain. More generally, RACF management determine the budget available to the RACF kitchens, to order food and resources (such as kitchen equipment), and specify a budget per day, per resident. Management are also in charge of hiring decisions, and therefore the skill level, number of staff, and role of other key members in the decision-making chains. This arguably has a significant effect on the quality of the food provided to residents. For example, in the RACF where the Kitchen Manager had previously worked as a professional chef, residents received a four-course meal every night, whereas in the RACFs where the kitchen managers had a background in commercial food production environments, the meals were comparatively modest. Finally, RACF management specify preferred food suppliers for the facilities, thereby limiting the decision-making capacity of Kitchen Managers, in terms of which brands or suppliers they can order food from.

The control that RACF management have over the menus provided for RACF residents, and the financial constraints they apply, are evident in the following quotes from kitchen managers:

"our Head Office plans the menu, we don't have anything to do with that." - Kitchen Manager 4

"Well, we get a four-week rolling cycle for the menus. So all [RACF] homes all have the same menu. And we're all on the same week at the same time. And we can only purchase preferred items off the grocery list... like you go to the website to order our food, but if it is not a preferred item then we can't buy it." - Kitchen Manager 2

"[Residents] might pay $1,000 a week to be in a home but we only get like $7 something a day for them [to provide their meals]."
- Kitchen Manager 2

It is important to note that RACF management did not participate directly in this research, and their role in the proposed model is based on data collected from other participants in the research. This data suggests that budget considerations are key in the decisions made by RACF management, in relation to residents' nutrition within the facilities. However, the authors of this report are also aware of the legal requirement to meet the standards set out in the Health and Disability Services (Safety) Act 2001, which involves regular auditing of RACFs, including certain standards for the provision of meal services.

11.2.1.4.2 Dietitians

At the second level there are Dietitians, who either design menus for the RACFs, or analyse and approve menus designed by the RACFs. This process takes into account the number of residents and any special dietary requirements, the kitchen facilities and equipment available at the RACF, kitchen staffing levels and expertise, and information concerning the food preferences of the residents, as conveyed by the kitchen managers. The overall aim is to include a wide variety of foods that appeal to the residents, while ensuring their nutritional requirements are being met. Dietitians also assist with weight management of residents, providing individual nutrition advice to mitigate weight loss

when the weight-monitoring programmes of the RACF identify a resident requiring such intervention. The Dietitians involved in the research were not members of the RACF staff, but were contracted from private practices to provide Dietetic consultation services to aged care facilities.

Dietitians clearly identified their priorities when designing menus for RACFs:

"To serve safe, nutritious food that the residents want to eat."
- Dietitian 1

"Malnutrition is the prime concern in aged care." - Dietitian 1

The Dietitians also emphasised the importance of monitoring the residents' weight status, to identify those at risk:

"Everyone [RACFs] weighs monthly [at least], some fortnightly".
- Dietitian 2

A role which was further discussed by several of the kitchen managers and care workers:

"So if a resident's losing weight or something like that the nurses ring the Dietitian up and she'll come in and she'll look at what they've been eating and she'll add an ice cream to all their desserts or ice cream at supper time and put them on Ensure or offer them poached eggs for breakfast just to, you know, try and build them up."
- Kitchen Manager 2

The Kitchen Managers, such as the one quoted below, also identified the role that Dietitians play within the RACFs in terms of setting the base menus with which they subsequently must work:

"A meal is planned; we have a four-week cycle. And a summer and winter menu. They've certainly been approved by a Dietitian. And we follow them as best as we can. Sometimes there's stuff residents don't like so we take them off and replace with something they do like." - Kitchen Manager 1

Based on the data collected, the key priority driving decision-making for Dietitians appeared to be ensuring residents had their nutrition needs met within a varied and appealing menu.

11.2.1.4.3 Kitchen Managers

At the third level, there are Kitchen Managers, who prepare the food for the residents. As noted above, Kitchen Managers are provided a detailed, rotating menu from the Dietitians, however they are able to modify these menus to a degree; swapping protein options or vegetable options, provided they have similar nutritional value. Kitchen Managers can also alter the timing of the main meal (to be at either dinner or lunch time), and menu options from one day to another (if meals are becoming repetitious), so that residents have more variety. Kitchen Managers are also responsible for ensuring the format of food (e.g. bite sizes, texture) is appropriate for older adults.

Kitchen Managers described time and budget constraints, which they were required to adhere to. In some cases, this meant they could not cater to all residents to the extent they desired:

"There is a lot of labour goes into [moulding pureed foods]. Whereas we've only got a very small staff. We're not -- you know, we haven't got a lot of labour in our kitchen." - Kitchen Manager 1

"Because they pay so much to live here, the odd one that is ... quite capable, they sort of think they should be having steak and salmon steaks and -- because of the money they pay. But they just don't realise how much breakdown it is and how little the kitchen actually get for their budget." - Kitchen Manager 2

Kitchen Managers were, however, able to influence the timing of the main meal of the day, and are responsible for staff and budget management:

"And what they serve in the dinner we serve in the lunch. So they serve light meals in the dinner mainly, and I serve the main … heavy portions at dinner mainly, just because ... we have our special meats and other stuff" - Kitchen Manager 3

"So I'm responsible for the diets, their nutritional requirements, I'm responsible for the ordering. I'm responsible for the six staff that work in the kitchen. I'm responsible for the all food that comes out of the kitchen, all the ordering and the budget." - Kitchen Manager 4

Kitchen Managers described that a key part of their role was to make food appropriate for residents to eat, in terms of practical eating considerations, nutritionally, and to cater to dietary preferences:

"[Residents] can end up malnutritionised [sic] so easily with just the quantity of food that you can get into them sometimes. Especially the frailer ones that just refuse to eat. That's hard. And we do put like cheese sauces and gravies and we do smoothies and there's always ice cream on hand for those ones, but that's not good nutrition." - Kitchen Manager 1

"[For] our pureed meals and that, at night we give them more protein again. We give them a leftover meat...but a lot of them don't eat a lot" - Kitchen Manager 1

"I just go and talk to them or see them in the mornings, whenever I ... have the time or if they ask for the special food. Like one of the persons here, she got some cancer in her mouth, she can't eat anything so she asked for this small cheese and macaroni...She wasn't able to sit and just eat but I requested a nurse, then a nurse has sent the caregiver there and they start feeding her and she had a little bit. She said, "Especially tell the chef that I had a little"." - Kitchen Manager 3

"Behind the door in the kitchen we have big lists of all the [residents] that won't eat chicken, all the [residents] that won't eat fish, the [residents] that won't eat mince.

And so then when we cook something we have to see how many don't eat it and we have to send substitutes." - Kitchen Manager 2

Keeping the menu interesting, varied and appealing for the residents in question was also a priority of kitchen managers, along with taking feedback from residents into account:

"I might just swap the [menu] day over to ... space it out."
- Kitchen Manager 1

"Presentation of the food. Because you eat with your eyes. If it looks good they're going to eat it, or they're going to at least give it a try."- Kitchen Manager 4

"If they don't like pork and apple meatballs, give them pork and apple casserole because that's what they relate to, this age group, that's what they relate to; a casserole" - Kitchen Manager 4

"Now we've all got these new moulds [for the moulied food] that we mould the food into the moulds and pop them out onto plates and they look like normal food. Yeah, no, they like it. Even like when we had a barbeque not long ago ... well I made mouli sausages and made spray stuff so it looked like they had charcoal on them, so they looked like they were cooked, you know, browned on a barbeque." - Kitchen Manager 2

Finally, Kitchen Managers were also aware of the physical and health constraints of residents, including their psychological health:

"And they want thinly … very thinly sliced...I already get my meats already sliced ...and ... we have the caregivers there ... they go and help them in cutting to bite size." - Kitchen Manager 3

"We have like normal stuff then we have like a soft option but a lot of the time because ... we steam all our meat in the casseroles it comes out nice and tender anyhow". - Kitchen Manager 2

"We had plates of sandwiches in the fridge for the ones that are diabetes [sic] ... if they need them through the night." - Kitchen Manager 2

"If it's somebody I know that is a bit depressed because of their family -- or their family have come in after six months because they're overseas and then they've had to go home again, they're depressed, so it's basically give them what they want to make them feel better, then we'll get back to the normal diet. And giving them what they want for a couple of days is short term. They know it's not a long-term thing." - Kitchen Manager 4

Overall, the key priorities for Kitchen Managers appeared to be producing nutritious meals which are enjoyed by, and can be consumed by, residents, within the budgeting and resource constraints of the RACF.

11.2.1.4.4 Care workers

At the fourth level, there are Care Workers, who assist with serving meals and aiding the residents who require help in eating the meals. The Care Workers who participated in this research aimed to make sure residents are eating food which is appealing (appearance, smell, taste, seasoning, texture), eating sufficient amounts, and that the environment in which they are eating is appropriate (quiet, good posture and support while eating).

Care workers indicated a high degree of awareness of the importance of the sensory aspects of the food:

> *"Ideally the meal has got to look good, okay, because we eat with our eyes so if it doesn't look good then that's when we have a lot of trouble. It's got to look good on the plate. It's got to be the right temperature." - Care Worker 1*

> *"And just making sure that, yeah, it's presented nice and -- which I do the dishing up at lunch most days so I just make sure that it is presented nice and make sure they have plenty of gravy or whatever on the top of it for those that need it." - Care Worker 2*

> *"The most important thing for me is that it tastes good and it looks good. And I think that tasting is actually – this should be paramount to when you're actually preparing that meal...I taste it...to actually see what they're eating, and sometimes, it's salty. It's so salty, and I keep thinking, "they don't need this amount of salt"." - Care Worker 1*

While Care Workers were aware of the importance of taste, it was perceived that residents preferred simple, traditional foods:

> *"[Residents] don't like spicy food. You can guarantee that you're going to have a lot of food thrown out if its spicy. They just like the bland, good old, you know, kiwi food; the mashed potato, the peas, the mince" - Care Worker 1*

> *"(If something was meaty flavoured) [residents] would enjoy that more [than spicy flavours]." - Care Worker 1*

Care Workers were sensitive to the needs of residents who may have difficulty eating their meals, and identified that some residents struggle with chewing meat:

> *"The other thing that can also stop somebody from eating is, you know, whether they can cut it up by themselves. And some people ... find it difficult to ask for help so they'd rather sit there and struggle, than to actually sit there and enjoy their meal. So if we are aware of their limitations, and making sure that, you know, we*

are delivering their meal -- to how they can eat it without having to be embarrassed or asking or anything." - Care Worker 1

"They can't pick up a spoon or a fork or a knife so we assist, yeah. ... and we feed them their breakfast and their lunch and their dinner" - Care Worker 2

"[Residents] definitely struggle with the meats. In fact that's a high percentage of our residents here struggle...it's just sometimes they can get meat where its actually been cut wrong. And that's not our kitchen. That's coming from the supplier...And they chew and chew and chew." - Care Worker 1

Care Workers were also aware of health issues and interactions with medications, which affect the residents' ability to consume food, and the quantity of food they consume:

"Well obviously, as [they're] aging ... their taste buds are changing and things. Their appetite changes, the size of their meals." - Care Worker 1

"Especially like I say if you're dealing with loose dentures, or broken teeth ... or any other thing, that's going to sort of not help in the eating process." - Care Worker 1

"We do have a list in our servery when people come to us we get their nutrition needs and then we make sure that we write down what they dislike and what they don't eat and what they do eat and yeah, so that's all done as soon as they arrive. ... we just work to their needs ... and we have alternatives." - Care Worker 2

"If medication is making them drowsy it's probably too close to when their lunch is going to be, or breakfast or whatever, then it's going to play a huge role in how much they're actually going to be able to eat." - Care Worker 1

However, responses from the Care Workers who participated suggested that they felt the nutrient requirements of residents were being met within the RACFs: enough quality food being provided:

"I think residents here eat a well-balanced diet." - Care Worker 2

"Quite a few of our weight loss people, you know, where we've noticed that there's been like a 4 or 5% weight loss or anything like that, we encourage ... the food intake, the cream on the porridge in the morning, you know, all of the extra protein and things like that." - Care Worker 1

Nevertheless, it was acknowledged that there are ethical and moral considerations around assisting with nutritionally supplementing residents' food as they reach the end of their lives:

"Saying that, we have to be careful because family members might not want us to help [nutritionally boost] them, like for instance we were giving Ensure to a particular resident for quite a while and the family member just wanted us to stop." - Care Worker 2

Finally, Care Workers noted the importance of the environment in affecting residents' eating habits:

"The environment plays a huge role in eating. I don't have loud music on when – and I do not have the TV on [in the RACF dining room]." - Care Worker 1

"The posture. The way they've been put at the table. Are they sitting straight? Are they on the lean? The plays a role with them...they [might be] in a massive big armchair and they're leaning back, but they can't get under the table properly. So they're far away from their meals." - Care Worker 1

For Care Workers then, decisions related to resident nutrition appeared to be driven by a desire to ensure residents were presented with food that was appealing, while ensuring that residents received the physical support required to enable them to consume as much of the food as they wanted (while taking into account the potential effects of medication on appetite) within a safe and pleasant environment.

11.2.1.4.5 Residents of RACFs

After going through these four higher levels, the food reaches the residents in the RACFs. Though residents are given a set menu and served their meal by Care Workers, residents are able to decide both how much they decide to eat, and which of the foods provided they choose to eat. Health issues and ability to consume food were identified as factors influencing decision-making among residents.

Residents noted the role that the Dietitians and Kitchen Managers played in ensuring their diet was nutritionally balanced, and that the diet and cooking varied depending on which staff member was in the kitchen:

"I suppose you [the residents] rely on the people here to give us a balanced diet" - Participant in RACF Focus Group 2

"[The way the meal is prepared] depends who's the cook for the day probably" - Participant in RACF Focus Group 2

"Basically, we all have ... different meals over the weeks and months...it didn't be [sic] repetitious necessarily" - Participant in RACF Focus Group 2

Overall, residents who participated in the research felt that the quality of the food was good, despite the constraints of catering for large numbers, and that some personal preferences were catered for:

"I haven't got any complaints about the standard of food here. I think they're very good in comparison to other places I've heard. I would readily admit though it's very difficult catering for a large number or in a hospital." - Participant in RACF Focus Group 3

"To be quite honest with you I feel that this staff know exactly what they're doing and they do give you a pretty good variation. Every day when ... you're having a

meal they bring a little booklet with them with a little place to order ... what you would like the following day." - Participant in RACF Focus Group 4

"You ask the chef the day before he will do it for you." - Participant in RACF Focus Group 3

However, residents did identify personal preferences which were not met, regarding the food provided by the RACF, in terms of certain foods, tastes, textures, and portion sizes:

"There is variety [at the RACF]. The only thing I would complain about is too much lettuce salad." - Participant in RACF Focus Group 2

"[The meals are] sometimes a bit bland" - Participant in RACF Focus Group 2

"Some of [the meals] are a bit dry" - Participant in RACF Focus Group 2

"We get sloppy food a lot" - Participant in RACF Focus Group 2

"We could do with a bit more of just plain eggs, a poached egg at night on bread and butter"
- Participant in RACF Focus Group 2

"Eggs and mandarins and bacon cooked properly [are things in my diet that I want more of]" - Participant in RACF Focus Group 2

"And I don't like too much mince meat" - Participant in RACF Focus Group 4

"A few carers here that sort of like to fill the plate and they don't realise that we can't consume large portions. We like smallish meals." - Participant in RACF Focus Group 1

"They give us coleslaw or lettuce. And it's not quite right. It should have a bit of potato with it" - Participant in RACF Focus Group 1

"The turkey we had at Christmas was processed, you know, it was not turkey. It's bits of turkey smashed together." - Participant in RACF Focus Group 3

Finally, residents identified health or physical constraints which influenced their dietary preferences and choices:

"There's a lot of food I can't eat now, I've got a lot allergies." - Participant in RACF Focus Group 1

"I for one have got a hiatus hernia and I've had a bit of a peptic ulcer. So ... you don't like strong flavours and I think where that's the peak of them at the moment. We wouldn't want anything stronger. - Participant in RACF Focus Group 1

"They bring fruit round every teatime and its good fruit, but an orange is too difficult to peel when you haven't got a vegetable knife, and – so you choose a banana because it's the easiest thing to peel." - Participant in RACF Focus Group 2

"[The RACF] gave me sirloin. It's got too many sinews in it." - Participant in RACF Focus Group 3

Overall, priorities for residents therefore appeared to be driven by a desire to eat food which they enjoyed, in a quantity which they preferred, while being cognisant of any health or physical constraints they might have.

11.2.1.4.6 Summary

This model of factors influencing decision-making regarding older adult nutrition within RACFs highlights several key ideas. Firstly, that there are a number of people who play a key role in influencing nutrition and the food provided in RACFs, who are each guided by different priorities. Second, that there are varying degrees of communication within the decision-making chain. This was evidenced by the disconnect between perceptions of residents' preferences and their actual preferences, as seen in the following example:

"No one liked baked beans. Baked beans was a national thing that no one likes it so they had to take it off the menu." - Kitchen Manager 2

"Well, we have had spaghetti here quite a lot, but we've never had baked beans. And I would quite like a meal of baked beans." - RACF Focus Group 2 resident (at the RACF where the above kitchen manager works)

This statement by the resident regarding a preference for baked beans was enthusiastically supported by most within the focus group.

There was also evidence of limited communication between the Dietitians and Kitchen Managers, with some Kitchen Managers being unsure of exactly how the RACF menu had been constructed. A third finding from the model and associated analysis was that there are trade-offs between priorities among the different roles. For example, there is a trade-off between RACF management resource constraints, and Kitchen Managers desire to provide appealing food, and diverse foods, such as the moulded mouli food for those residents on a 'soft' diet. There is also a need to achieve a balance between catering to residents' personal preferences, and catering for the preferences of most of the group. This highlights a key conclusion from the RACF model, that residents within an RACF context have a high degree of food security and food access, however they have lower levels of autonomy in deciding which food to eat, and in which form. This is a critical distinction identified between the older adults living in a RACF context and those living outside of RACFs which is discussed in greater detail below.

11.2.1.4.7 Autonomy and food security

This research was focused on older adult nutrition decision-making, which is not just exclusive to RACFs. Older adults who live in communities were also invited to participate in focus groups to bridge the divide between decisions made within the RACF setting, and those made by older adults

living outside the aged-care sector. As discussed above, the results show that RACF older adults experience, and benefit from, food security and oversight for their nutritional intake, but due to various levels of decision-making above them within the 'chain' of roles, older adults often experience diminished autonomy over their diet. However, in contrast, our findings show that older adults in the community tend to have more autonomy in their food choices, but unlike those within RACFs, they were vulnerable to food insecurity and were not often subject to the same level of oversight of their nutritional intake.

During the focus group sessions, the older adults living in RACFs discussed the food security they experience by highlighting the options available to them, but also point out that the options available to them are not necessarily aligned with their individual preferences:

"I mean we're regimented – we're in a sort of regime here. I mean, we have to accustomise ourselves to that rather than our personal likes and dislikes" - Participant in RACF Focus Group 1

"When you're in an establishment like this, you usually have – how many [options] do we have to choose from [resident's name redacted]? Two?" - Participant in RACF Focus Group 1

"Because we are in here [the RACF], we can't be quite as fussy about what we eat and don't eat. And probably eat some things that we may not have been too fussed about in the past" - Participant in RACF Focus Group 1

The lack of autonomy of RACF residents expressed in the above quotes was also addressed by some of the RACF staff:

"The structure must be a huge thing to go from being from their home and then coming in here and all of sudden they don't have a fridge in their rooms or any other facilities to prepare food, it's all taken care for them. So I think the restrictions would be the hardest things ... I mean they must come in here and think, "Oh, am I allowed to do this?" So it's almost like a permission" - Care Worker 1

The dietitians elaborated on this by explaining the role food has for personal autonomy and how in the RACF context food often becomes an aspect of their lives that older adults voice their opinions on as a way of attempting to maintain some control:

"Food is a very personal thing...most people like some control over what they are eating. When they are in an environment where they have lost control over most things...[the food is one thing they can voice opinions about with the aim of achieving change]" – Dietitian 2

However, in some cases, losing the responsibility which came with the autonomy of living in the community, was seen as a positive. One RACF participant explained that her medical condition left

her struggling to manage simple tasks in the preparation and cooking of meals, and as a result the overall nutritional intake for herself and her husband was affected:

> *"I have to confess that I was suffering from Parkinson's Disease and I didn't know it, and I got less and less able to put together a meal. And so we ate less and less and we lost weight... I was quite proud how skinny I'd got, but I realise that it was a false pride because it wasn't 100% healthy and they sent us into respite care and it was what I needed because I just couldn't cook the same food. My condition left me unable to get the plates down from the shelves and all sorts of things I had to get my husband to help ... and I just couldn't keep up … with the demands."*
> *- Participant in RACF Focus Group 2*

Having less autonomy but more food security, as well as the support of Dietitians and Care Workers through a RACF can, therefore, be seen as a beneficial trade-off by older adults. However, by contrast, for some of the community dwelling participants, being able to enjoy the autonomy of eating what they like and when they like, was one of the great joys of living independently. Yet, without the nutritional oversight experienced by those within an RACF, such autonomy can result in individuals' chosen diets not meeting their required nutritional needs:

> *".. when you're on your own you just eat what you like. If you don't feel like cooking you don't cook. You just -- just go and have -- what do you call it -- cornflakes for tea, or whatever." - Participant in Community Dwelling Focus Group 3*

Nevertheless, in some cases, making their own food choices allowed the older adults to express their social and cultural traditions by opting to go to stores and make food they are accustomed to. For example, one Chinese participant explained how since moving to New Zealand they have become a part of the Chinese community through meals, and thus they choose to purchase Chinese foods, rather than conventional New Zealand supermarket options:

> *"After I moved to New Zealand and I get Chinese food from Chinese grocery shop and for Chinese and gathering together to have meals is important." - Participant in Community Dwelling Focus Group 4*

Either food autonomy or food security can be limited as the power to make decisions shifts between RACFs and individuals living in the community. Within RACFs, older adults experience more food security, with meals specifically tailored to their needs in order to ensure their sufficient nutrient uptake. However, they have less autonomy over what they can eat as the meals are prepared based on the RACF criteria and meal plans. Whereas older adults living in the community have more autonomy over their food choices but that can occur in tandem with a reduction in food security. The main factors that increase such vulnerability to food security is socio-economic status, physical access to food, and health issues. These factors will be discussed below.

11.2.1.4.8 Nutrition decision-making by older adults

Data from the focus groups were also used to construct a model of decision-making for older adults more generally, considering those living both within and outside of the RACF environment. Older adults identified many factors which affect their choices related to nutrition and food consumption,

which have been organised into themes. These focus around food choices and preferences, food access and preparation, and the social and cultural aspects of eating food. The themes are summarised in the model in Fig. 10, and then further described and explored using evidence (quotes) from the participants.

11.2.2 General model of older adult nutrition decision-making.

Based on the discussions with older adults, food preferences and food choices were two distinct components that frame the decision-making process for older adult nutrition. The two components provide the basis for understanding how food choices are made, by identifying which factors are linked to personal preference, and which factors are modifiable. The first tier of Fig. 10 outlines factors that shape food preferences by addressing norms, customs, formative experiences and socio-cultural aspects, along with the effects of ageing itself, most notably food volume and the impacts of sensory change. Many of these factors are ingrained and based on an individual's life experiences, however, the sensory characteristics of food can potentially be modified to at least partially compensate for some of these age-related changes. The second tier of Fig. 10 outlines factors that can influence whether older adults' food preferences are translated into food choices: which food options are available and accessible, both physically and economically; health concerns that may override preferences; and the impact of social circumstances. Some of the factors share similarities and can overlap, but these discrepancies will be unpicked below.

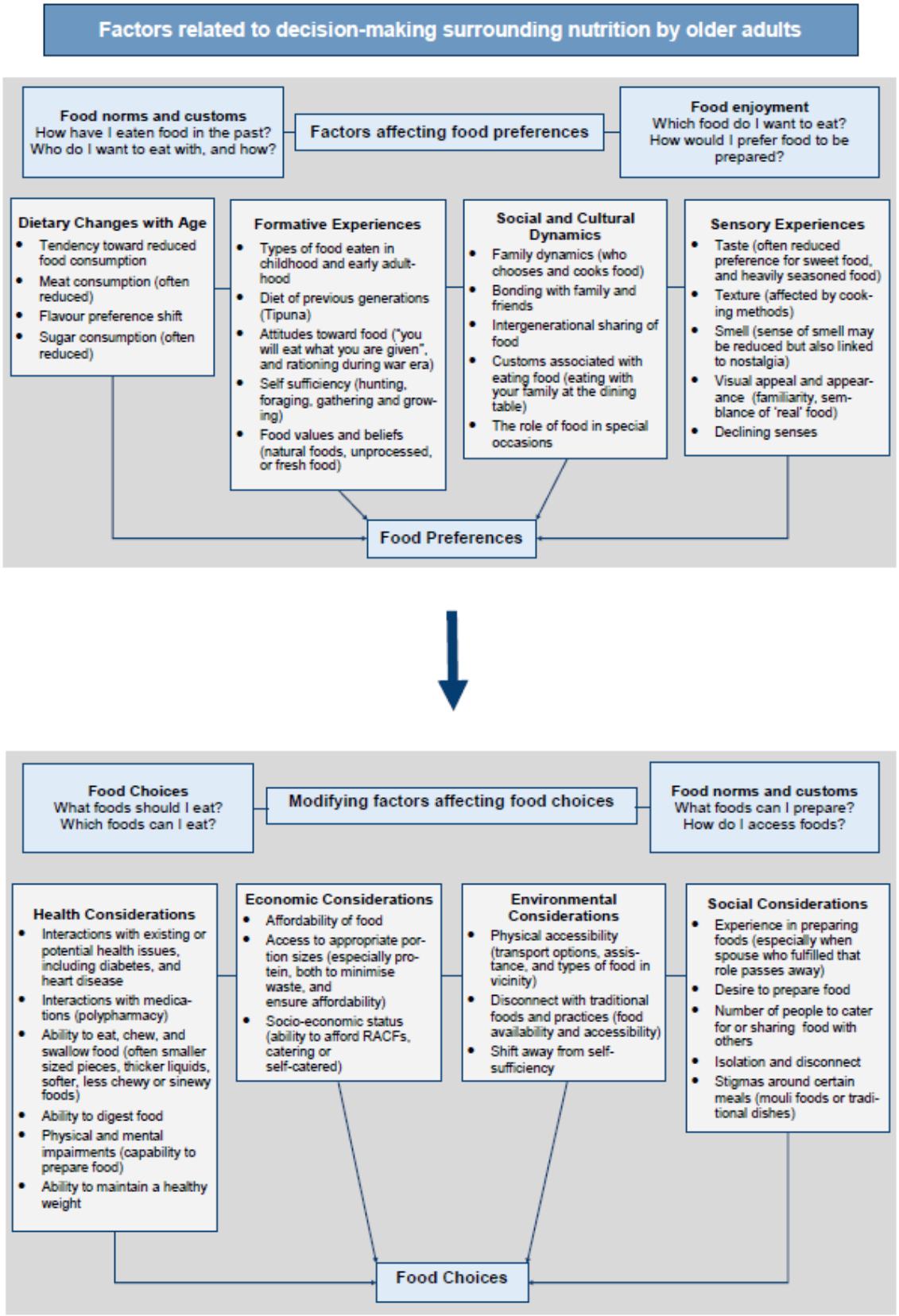


Fig. 10 Model of decision-making surrounding food preferences and food choices for older adult nutrition, both in RACF and Community Dwellings.

11.2.2.1 Factors affecting food preferences

Food preferences relate to the factors that influence personal experiences with food, particularly through the context of food norms, customs, and overall enjoyment. The factors affecting food preferences for older adults are the dietary changes with age; formative experiences; social and cultural dynamics with food; and the sensory experience. These factors were expressed by the older adults as influencing their decision-making because of their connection to previous life experiences. However, consideration is needed for individual food preferences, which will differentiate based on socio-cultural backgrounds. Each of these factors will be unpacked and supported through quotes from older adult participants below.

11.2.2.2 Dietary changes with age

Food that was consumed previously, may no longer appeal or be appropriate as overall food needs have shifted with age. The older adults discussed the quantity of food they consume and most agreed that they have reduced how much they eat:

"I don't eat as much. Smaller meals." – Participant in Community Dwelling Focus Group 6

"We don't eat so much. You know we eat small amounts. And we get full quickly so yes, we have changed." – Participant in Community Dwelling Focus Group 1

The participants explained that they have a decreased appetite because they are no longer as active, thus not needing to burn as much energy:

"Lack of work -- you can't eat so much."
– Participant in RACF Focus Group 1

Part of these changes in food preferences include a reduction in meat consumption in favour of vegetables:

"I don't eat nearly as much meat as what I used to. And probably my quantities have changed. So I eat less than probably what I used to."
– Participant in Community Dwelling Focus Group 6

"I eat more vegetables, potato and a mixture. I have meat but it is moderate amount." – Participant in Community Dwelling Focus Group 4

"As I've got older I don't eat a lot of meat. I eat a lot of vegetables, so I'm quite fussy about what I eat now. I'm not a cake eater and bread is toast mainly but that's about it. More fruit, more veges, not a lot of meat." – Participant in Community Dwelling Focus Group 1

"I like vegetables now, you know, not that fussed -- I used to eat a lot of meat before when we lived on a farm, but I live on my own now and it doesn't really bother me." – Participant in Community Dwelling Focus Group 3

Many of the focus group participants also noted their flavour preferences have shifted away from seasoned and sweet foods:

"As you get older you don't eat so much of those sweet things." – Participant in Community Dwelling Focus Group 3

"When you get older -- I don't like seasoned stuff. I just like the plain old -- I love my vegetables." – Participant in RACF Focus Group 1

"I'd rather have a savoury than a piece of cake." – Participant in RACF Focus Group 3

Our findings therefore indicated that as our participants had aged many had experienced a reduction in their appetite, as well as a shift in their diet away from meat-heavy meals and towards vegetables. However, this reduction in meat consumption was accompanied by a preference for savoury, rather than sweet, flavours.

11.2.2.3 Formative experiences

Past life experiences can shape older adults' perceptions of food as they draw on memories and emotions that are associated with a meal. Positive and negative connotations around certain foods can influence the decision-making process as to whether someone will prefer different types of food based on the nostalgic value. Formative experiences, such as the types of foods previously eaten can influence the foods liked in the present:

"I spent time in Vietnam with the surgical team, and that had a profound effect on my liking for food. And it was the whole variety of things, and the way they cook them. But I ate things that I wouldn't have thought of. But life experience has a lot to do with our dietary likes and dislikes I think." – Participant in RACF Focus Group 1

Part of this is the nostalgia around the meal process and the memories linked with different types of food you liked in earlier life. Often, the older adults would reminisce about their parents' cooking, which suggests that diets are influenced by previous generations:

"Well it was quite good when mum used to do the stews and that. And I used to like the stews she used to make."- Participant in RACF Focus Group 2

"Mum did a beautiful roast, of particularly lamb, and I meant on the odd occasion I do roast." – Participant in Community Dwelling Focus Group 6

"I loved rabbit stew when I was a child. But we don't have it now. I can't remember the last time I had a rabbit stew. I used to love it when mum cooked it." – Participant in RACF Focus Group 1

Additionally, the older adults have a strong attitude towards food consumption and eating what you are served because of the effects of war. A dominant attitude throughout the focus groups was the sense of appreciation for food as this generation had personally experienced rationing:

> *"There was a certain amount of bartering that went on. That's during the war because things were rationed. But one thing I really remember is somehow we got an orange and there was six of us and mum cut it into six pieces for us to have a piece each. Because it was such a rarity ...and we enjoyed that. But just to let you know that fruit wasn't available like it is these days."*
> *– Participant in RACF Focus Group 2*

> *"I think we've all been through a period where you ate what you could get. And you ate what you were given." – Participant in RACF Focus Group 1*

Another important aspect that has an impact on older adults, is the concept of self-sufficiency. Previous life experiences often include memories of collecting and harvesting food, and having access to food sources when desired. The older adults reflected on times when they were self-sufficient and how that affected their individual food values and beliefs:

> *"I like homekill. I was brought up on homekill. And my favourite foods are mum and dad's cooking and my grandparents cooking. So it was always fresh, it was straight from the sea onto the plate, out of the hen and onto the plate."*
> *– Participant in Community Dwelling Focus Group 1*

Furthermore, as alluded to in the quote above, many of the older adult participants stressed the importance of foods being natural, unprocessed, and fresh:

> *"A lot of the food, way way back, didn't have the additives, today, you know, you could pick anything up in the supermarket or anything like that, there's additives." – Participant in Community Dwelling Focus Group 5*

This was often discussed in the context of wanting to know what food you are consuming and where it came from. Thus, despite the value placed by participants on 'eating what you are given,' there was a clear preference for natural, fresh, unprocessed foods that were reminiscent of the foods consumed in one's childhood.

11.2.2.4 Social and cultural dynamics

The findings from the focus groups suggest that the act of meal-making and dining can directly affect how food is enjoyed. While the customs surrounding food can impact the memories and associations a person has with food. Older adult participants discussed the role food had in bringing the family together and how meal times would include aspects of the intergenerational sharing of food:

> *"It's a social rather than a nutrient aspect of eating that's pretty important. In fact, it's the only time families get together during the course of the day and it's an important occasion on which to communicate."- Participant in RACF Focus Group 1*

"Our family together to have meals is to represent that is happiness and that's traditional so we like to sit around to have meals together as a family... For our family, we always eat together, like elderly -- we eat together – and when children come along, the children eat with the whole family as well." – Translation for Mandarin-speaking Participant in Community Dwelling Focus Group 4

"When I was a kid we used to live in Samoa with my Grandfather and where we lived they grow a lot of grapefruit all round, and bananas and coconut trees. And that's how he fed us. And down the bottom there, where the beautiful beach is, and we go fishing every day." – Participant in Community Dwelling Focus Group 2

Many of the older adults emphasised their preference for sharing meals with others, whether that was with family (as highlighted above) or with friends:

"We have dinner with friends at least once a week. Sometimes two or three times a week we have people come for a meal. We like to do the socialising a bit over a meal which is good." – Participant in Community Dwelling Focus Group 5

Additionally, the custom of eating at the dinner table resonated with the older adults as it was an important part of their day-to-day formalities, which also lends itself to different family dynamics:

"I miss being with the family and just sitting at your table having a conversation." – Participant in Community Dwelling Focus Group 2

"Yeah, you had to wear a tie at the evening meal. You had to get dressed up." – Participant in Community Dwelling Focus Group 5

However, not all participants shared the sentimental value of food. One participant highlighted that food is just sustenance and the role of food consumption does not have a significant impact on their life:

"To me it's just a function. You eat to live. I don't live to eat. As others might really enjoy their food and they like trying new things, well, I don't really care. Me, I just eat because it's a necessary part of life. I'm indifferent." – Participant in Community Dwelling Focus Group 5

Yet, despite this response, the social importance of food was expressed by participants across all the different ethnicities represented in this study. Moreover, from a cultural perspective, participants across all ethnic groups noted that food can play an important role during special occasions and traditions, as it allows people to connect with their heritage:

"My mum comes from a family of 18 and so we always had get togethers and you know like -- we'd go out with our grandfather and we'd get pipis, we'd dive for mussels. You know, for these occasions, and then we'd have a hangi and that's when steam pudding would come out afterwards." – Māori Participant in Community Dwelling Focus Group 5

"Culture is broad things and meal time is important, particularly dinner is important because everyone in a family will ... get together. Usually we wait for everyone to be home to have our meals. Celebration; we usually cook special food for special festivals. Like moon festival; we have moon cakes and for spring festival we have lots of things because suppose is harvest. After our autumn and celebrate a new year, so lots of food." – Chinese Participant in Community Dwelling 4

"I think my favourite food as a child was the old Sunday roast, a leg of lamb, and you know, couldn't beat that aye I don't reckon." – Pākehā Participant in Community Dwelling Focus Group 5

Interestingly, the concept of Sunday roast and fish 'n' chip Friday were common aspects of meal time traditions for the participants, that are entrenched in New Zealand's socio-cultural norms. Many participants from RACFs and Community Dwellings emphasised the importance of those particular meals, which would often facilitate the social aspect of gathering people together to share a meal.

11.2.2.5 Sensory experiences

Food preferences are heavily influenced by the intrinsic properties of foods themselves. Taste, texture, smell, and the appearance of food can be adapted to an individual's preference and can be used as an insight into how they view different types of food. However, many of the older adult participants discussed how their senses were declining due to age related reasons:

"I'm losing my sense of smell." – Participant in RACF Focus Group 2

"We've got no sense of smell. I've got no sense of smell." – Participant in Community Dwelling Focus Group 3

"As far as the reduction in senses and taste, yes, I think they do deteriorate over the years but again, that's life." – Participant in Community Dwelling Focus Group 5

"I can't taste, not to any great extent. I haven't completely lost my sense of taste, but it has deteriorated over the years." – Participant in RACF Focus Group 3

"Yeah, it's got to be something really powerful for me to actually pick that taste up." – Participant in Community Dwelling Focus Group 2

"Well, my sense of taste has -- is practically nil so I eat because I keep alive and I can't taste much now." – Participant in RACF Focus Group 3

With a reduction in taste and smell the food experience is shifted. Older adults therefore emphasised the importance of ensuring food is appetising through colour and presentation:

"So now I'm still eating the same thing, mainly vegetables, but I like colour when I cook. I cook all the different colour; white, dark green, light greens and yellow. So -- or purple, whatever. Whatever is available and cheap." – Participation in Community Dwelling Focus Group 2

"If it's a new food he'll look at the presentation and then ... based on that he will decide whether he will try or not." – Translation for Participant in Community Dwelling Focus Group 4

Colour and presentation are variables that can also impact an individual's willingness to try new foods. Participants discussed whether they would try new foods, and stressed they would be willing if the food was presented in an appealing manner. Another key aspect that was found to impact food preferences is the texture of the food. The participants expressed a strong preference for food that is soft and easy to chew:

"We do a boil up once a week. We eat everything but it gets back to texture. Because I use my pressure cooker a lot aye, and so it's pretty soft. And we like brisket for a boil up, just the flavour. The bacon bones and that can be, I don't know the textures not -- it's a bit too tough a little bit." – Participant in Community Dwelling Focus Group 3

"It was cooked quite nice and soft."
– Participant in Community Dwelling Focus Group 3

"Some of the soups are like porridge. It's too thick for us."
– Participant in RACF Focus Group 2

As mentioned above, among the older adults who can still appreciate different food tastes, there was a preference for savoury flavoured foods rather than spicy or sweet:

"Yeah, that sort of plain flavour is really appealing."
– Participant in Community Dwelling Focus Group 3

"We don't always have anything to eat when we have our coffee, but if we do I usually go for a savoury type thing."
– Participant in Community Dwelling Focus Group 4

"My taste buds have gone all changed a lot. I don't eat so many -- I used to be a big eater, I used to love my sweet cakes and biscuits and chocolate, but now I don't fancy them anymore."- Participant in Community Dwelling Focus Group 1

"I don't like spicy stuff as I got older." – Participant in RACF Focus Group 2

Thus, like their social and nostalgic importance, the intrinsic properties of the foods themselves were found to influence the food preferences of the focus group participants. Indeed, despite the diminishing senses of smell and taste experienced by some participants, across all groups a preference for both savoury flavours, and for visually appealing meals, was clear.

However, as shall be discussed below, we found that the food preferences expressed by participants did not dictate what individuals actually consumed. Rather, a series of factors, that we have termed modifying factors, interplayed with participants food preferences to shape their food choices.

11.2.2.6 Factors affecting food choices

Food choices relate to factors that influence personal experiences with food, particularly through the context of foods that are appropriate and accessible. The modifying factors we have identified as affecting food choices for older adults are health, economic, environmental, and social considerations. These factors were experienced by the participants as enablers or barriers, and determined which foods were ultimately consumed. Similar to food preferences, individual choices will differentiate based on socio-cultural backgrounds. Each of these factors will be unpacked below and supported through quotes from the focus groups.

11.2.2.7 Health considerations

As evident in the quotes below, many older adults discussed the impact of health considerations as a significant factor in their decision-making regarding food:

"[I have] Haemochromatosis. Which is too much iron in your blood... And it just got picked up with a ... routine blood test, but I have other issues, other problems as well, but that it is the main one which changed my diet dramatically...
So I'm very aware of too much -- especially red meat. And I don't eat poultry, which is a wee bit sad. I don't eat poultry in any shape or form."
– Participant in Community Dwelling Focus Group 6

"I've had diabetes for about 25 [years] -- I've cut back on the sugar -- and I don't eat a lot of meat now. Mainly vegetables, a lot of vegetables." – Participant in Community Dwelling Focus Group 1

Indeed, many older adults discussed the role of sugar as a health and nutrition issue, with several explaining how they had chosen to reduce their consumption of sugar either for general health reasons, or due to medical advice:

"Yeah, we're more conscious of you know, the sugar contents and things like that in foods. Even with recipes and that when my wife makes a cake or something like that when she does, which is not very often now, she doesn't put as much sugar in as the recipes put in it." - Participant in Community Dwelling Focus Group 5

"You know, but it's changed because I'm a diabetic now too. You know, I'll have things with sugar in them, but not as much as I'd like to." - Participant in Community Dwelling Focus Group 2

With ongoing medical and age-related health issues, older adults are often taking multiple medications. As such, polypharmacy was found to impact on the types of food older adults can consume, but also, in some cases, polypharmacy was found to be the reason older adults were actively partaking in meal times:

"That's another aspect of it. As you get older you generally have a lot more medications that you're on really, and that has an impact what you can eat as well." - Participant in RACF Focus Group 1

"Most of the time I won't eat at home. I have to because I've got all these pills I have to take with food, but if I didn't have to, I wouldn't bother. I mostly eat when I'm out." - Participant in Community Dwelling Focus Group 1

Aside from the apparent medical related health issues, there were also age-related impairments that reduce older adults' abilities to physically consume food, such as the ability to eat, chew, and swallow:

"[His] teeth are issue so he can't eat those hard nuts. So something that he has to give up." - Translation for Mandarin-speaking Participant in Community Dwelling Focus Group 4

The older adults also observed that they are more sensitive to the after effects of food consumption, with many participants agreeing that spicy food impacts digestion. While others observed that due to age, it can be a struggle for food to travel through the body:

"If it's got too much chilli in it my digestive system lets me know, in no uncertain terms, and can be very uncomfortable."
- Participant in Community Dwelling Focus Group 5

"I think it's the ability to digest it. Because it takes a very very long time from what I eat to get to my stomach. And the last procedure I had, I mean I was only -- allowed on fluids what, four days beforehand to really let the food get down, you know, into the rest of my body. It just tends to get stuck there. And that's not so nice." - Participant in Community Dwelling Focus Group 6

A decline in manual dexterity can also impact the decision-making for food choices. If older adults are unable to prepare certain foods, they are less inclined to consume them:

"Even the kiwifruit, it's hard to peel it. Well, when your hands aren't so mobile."
- Participant in RACF Focus Group 2

Additionally, there was a concern by older adults regarding weight management with many expressing displeasure in gaining weight, especially as the weight gain could have a detrimental impact on their medications:

"Probably most of the people here as we get older ... we find it harder to keep the weight off. And especially for your medication you think, "Geez, how am I going to keep this weight off", because, you know, with the medications that I take, I have to try and keep it off, so that's another concern of portions of food and the type of food that I eat." - Participant in Community Dwelling Focus Group 1

Thus, health considerations were found to be a major factor influencing older adults' food choices. For some participants, such considerations were based primarily on a desire to maintain their health as they aged, while for others, health-based decisions regarding their diet came in response to disease states and medication demands.

11.2.2.8 Economic considerations

Unlike health considerations, which generally motivated participants to make healthy food choices, economic factors were found to influence older adults purchasing power and thus force them to make food choices based on what was affordable and attainable, rather than what is healthy. The capacity to afford food was reiterated by the older adults, with participants emphasising:

"The price of living goes up but our pension doesn't." - Participant in Community Dwelling Focus Group 3

"But -- what even an apple that I can't really enjoy an apple like I used to. But the nashi pears, they're soft enough to eat. The peaches, the plum, but like you said the price ranges are there." - Participant in Community Dwelling Focus Group 2

Given the tendency to reduce food intake and a loss of appetite due to dietary changes with age, another factor that can influence decision-making is the size of portions available for purchase and having access to appropriate quantities:

"I don't cook a roast now, being on my own ... I've got to master the oven ...but one of the problems being on your own like that is getting a roast small enough. If you buy a roast ... you've got to say, "Well I've damn well got to eat it", and then you get tired of it." - Participant in Community Dwelling Focus Group 5

"This is something I found compared with England, and the supermarkets there, they make quite small portions for people like ourselves. Whereas here in New Zealand they don't cater for [people living on their own]."
- Participant in Community Dwelling Focus Group 5

Appropriate portion size was an important aspect for the older adult participants as it corresponded with their ingrained need to minimise food wastage and to finish meals, discussed above in terms of their formative experiences. Thus, it was found to influence the choices of types of food they bought. Moreover, the socio-economic status of the older adults was found to either be a positive factor, or a barrier when making food-based decisions. Socio-economic status can influence whether older adults receive catered meals, either through the RACF or for other catering services; or if they must prepare and cook for themselves:

"Yeah, I'm totally guilty and that's where I feel for the change with me, it's faster to pull out a money than going turn the oven on." - Participant in Community Dwelling Focus Group 2

"We have meals on wheels. For five times a week. Not at the weekends. They're good healthy meals." - Participant in Community Dwelling Focus Group 6

"We're made to change our ways, but we just can't afford what's in the shop. You know, like we're fed oyster, but for a dozen you have to pay 28 bucks for them. You know. And so I think, "Nah, I could get a bread probably with that and…" you know, something else with it." - Participant in Community Dwelling Focus Group 1

Such economic factors, as those discussed above, are considered here to be non-modifiable, given that a large proportion of older adults are on fixed incomes, and the direct link between an individual's budget and their ability to afford food and meal options. However, as this last quote highlights, an individual's socio-economic status can not only impact negatively on their ability to access the foods they desire but can also exacerbate their sense of forced alienation from their cultural food practices. A sentiment conveyed through the words "*we're made to change our ways, but we just can't afford what's in the shops."* Such impacts on dietary change are discussed further in the section below.

11.2.2.9 Environmental considerations

Similar to the economic considerations, environmental factors are often impacted by socio-economic status; however, in this context, environmental considerations are focused on the built environmental change that is influencing older adults' physical accessibility to food options. Many of the participants discussed the types of food available in their current vicinity and how the landscapes had altered, restricting their capabilities to access foods, and in turn the impact this lack of self-sufficiency had on their sense of self:

> *"That's what I'm missing at the moment; I moved from a huge garden. My husband was a very keen gardener, and I've now got a tiny little garden. Just a few fruit -- vegetables in it. But I'm missing the making of the pickles and the preserving of the fruits and the jams and all those sorts of things." - Participant in Community Dwelling Focus Group 6*

Another key aspect that was reiterated throughout the findings was the disconnect some older adults have experienced with accessing traditional foods, either through availability or by accessibility:

> *"Our diets changed since we've had kids because we, you know, my brothers and them used to go and fish at the river, when we were kids. You know, we ate eels and catfish, you know, because that was part of the diet that was there on the table at the time, aye. You know. But today the only time I might try eel if I'm at somewhere special at a Marae and they put it on the table as a treat." - Participant in Community Dwelling Focus Group 3*

> *"Back home we don't use oil ... when we cook food. We put in a hangi and wrapped with coconut leaves or banana leaves." - Pacifica Participant in Community Dwelling Focus Group 2*

> *"Traditional we have rice for our main meal so we eat congee for breakfast... congee is lots of water to cook with rice ... but when we moved to New Zealand ... we eat whatever we can get."*
> *- Chinese Participant in Community Dwelling Focus Group 4*

> *"You've got to get a permit to go and get your fish today. You're only allowed to fish [at] certain times of the year. Whereas that was controlled by the seasons, by*

my grandparents, and it's just a total shift." - Maori Participant in Community Dwelling Focus Group 1

The ability to connect with cultural food practices was viewed as an important component of participants' sense of self, as their socio-cultural backgrounds were found to influence their food knowledge through norms, values, and beliefs. Consideration of the environment is therefore needed when analysing food-based perceptions, as the changes older adults experience in the physical environment, can influence their choices.

11.2.2.10 Social Considerations

The social experience of food was also one of the main reoccurring themes discussed by older adults. These social considerations differ from the social and cultural factors discussed above in that the focus shifts from the association's individuals had around food as they grew up, to the current social factors influencing their food choices. For example, the loss of a loved one was found to alter the food decisions of several participants. For some, such grief could lead to comfort eating and an inability to manage their food intake:

"I lost my wife last year and I went through probably six months of straight comfort eating and put on about 10kg. I've now lost 4 of that, you know, but I was just eating a lot of unhealthy things, and I think it was just comfort food for me." - Participant in Community Dwelling Focus Group 5

While for others, the loss of a loved one could result in individuals experiencing difficulties with planning, preparing, or eating meals alone when they had either little experience doing so, or little desire to do so:

"My wife decided what she was going to have -- what we were going to have, and that's what we would have. Did I have a role in it? Not other than working and providing the money to buy the things, not really. If there was something particular, I didn't like, I would tell her, and she wouldn't cook it."
- Participant in Community Dwelling Focus Group 5

"I think it's just … I've done it, I've cooked it, it looks nice and -- you know, colours and things, I just, sort of take one look and, "Oh, I don't know if I want that". I think it's just my attitude. I think that I'm really going to have to work through that one because at times I'll sit down and think, "Oh gosh, that was nice. I really enjoyed it". And other times it's just -- sometimes I'll push it aside and have it half an hour later if it's a salad. If it's something hot well I think, "Well, I better eat that", you know. It's just I don't really enjoy my meals at the moment. And that's a shame."
- Participant in Community Dwelling Focus Group 6

The feelings of isolation and being disconnected from others expressed in the above quote can be a barrier to making appropriate decisions about food. The social aspect of meals, such as sharing food

and catering for others, can, as the participants informed us, enhance the food experience of eating and help alleviate some of the disconnect:

> *"I lost my wife so now I -- did all my own cooking and things like that, it's just the effort to go and cook a steak, out on the barbeque etcetera. If you're doing it for a number of people, yeah, but when you do it on your own, no. So that has had an impact." - Participant in Community Dwelling Focus Group 5*

> *"Today like a roast is quite rare. There's lots of other things, and if there was to be a roast it would be a real treat, you know. And so, if it was a roast it would be with a lot of others and I think enjoying even more, sharing it with everybody." - Participant in Community Dwelling Focus Group 1*

The social factors of food decision-making were strongly emphasised by the older adults as food-related experiences (planning, preparing, and consuming meals) were commonly seen as social or shared experiences, whether with family, or friends. The impact of social isolation and feelings of social disconnection therefore were found to be a barrier to some older adults consuming sufficient nutritious food.

11.2.2.11 Connections between food preferences and food choices

As outlined above, there are certain factors that appear to shape older adults' food preferences; however, this study found a significant difference between such food preferences and individual's actual food choices. The relationship between the factors that influence food preferences, and those that interact with these preferences to shape food choices is shown in Fig. 10.

While formative experiences, socio-cultural dynamics and many of the dietary and sensory changes related to the ageing process are non-modifiable, we contend that there is potential for certain enhancements to the sensory properties of food to compensate for some of these factors influencing food preferences. Ideally, such interventions should be mindful of the modifying factors in tier 2 of Fig. 10, so as to survive these factors and be translated into actual food choices. Therefore, minimising negative nutrients to alleviate concerns over common health issues, ensuring the products are affordable, accessible and easy to use, and are formulated and marketed to be aligned with traditional values and perceived as "natural", are likely to address many of these barriers to consumption.

11.2.2.12 Meat consumption and older adults' food choices

One of the aims of the study was to determine older adults' attitudes to meat consumption and whether there is potential to use meat as a flavour-enhancement product. The findings show an overall reduction in the intake of meat; however, this was predominantly red meat. Although older adults were found to generally consume more fish and poultry, the flavour profile of red meat is still the preferred savoury taste. Most of the participants discussed their enjoyment of these flavours but

due to the health and nutritional aspects of meat consumption, as well as the economic barriers, they have made the decision to choose alternative options:

"And I'm very aware of meat and you know, the fat on it and all that sort of stuff so, yeah, I don't eat a lot of red meat. I eat a lot of chicken and try and have fish when I can. So yeah, I mean economically too. It's not always easy to afford those sorts of things. Especially when you're on your own. You know you've only got that one person to, sort of, provide for."
– Participant in Community Dwelling Focus Group 6

"I don't think I need [meat] anymore. If I eat too much it makes me sluggish. Aye. Too heavy." – Participant in Community Dwelling Focus Group 3

"I prefer chicken and pork and fish. I don't really like red meat."
– Participant in Community Dwelling Focus Group 6

"… too heavy with regards to meat and all that raw meats and so forth. But no, the chicken I prefer and the pork." – Participant in RACF Focus Group 3

Subsequently, we explored attitudes around the consumption of offal in terms of its acceptability to older adults. According to both the kitchen managers, and the focus group participants', the general sensory experience of offal was predominantly negative, with most of the critique we encountered based on offal's smell and taste:

"I think the flavour and the texture of the liver or something, is for some people just don't like it. And it can smell quite strong too." – Kitchen Manager 1

"For our sensories [sic] and that, it's very powerful in smell and taste. A kidney..."
– Participant in Community Dwelling Focus Group 2

Except offal... The look of it, the taste... I just don't like it. I don't like the taste."
– Participant in Community Dwelling Focus Group 6

"We don't have offal, you know, the tripe or anything. We tried making that one time but people didn't like that either so … or the smell" – Kitchen Manager 2

Aside from smell and taste, some older adults discussed their general dislike of offal:

"I don't like tripe. I don't wish to eat tripe"
– Participant in Community Dwelling Focus Group 5

"One thing took me back; we went to Scotland about five years ago and one thing took me back that is very big over there is black puddings. But the food was awful in Scotland, it was black pudding, square sausage, haggis, the tour we're on it was a heart attack on a plate, sort of" – Participant in Community Dwelling Focus Group 5

However, some of the older adults did enjoy the taste of offal, however they were sceptical about using offal as a flavour enhancer:

"I didn't mind [offal], but I had it as a kid, you know, yeah, dad always had black puddings and he had friends that were butchers." – Participant in Community Dwelling Focus Group 4

"Not for increasing the flavour, no. But I prefer [offal] better than the normal meat that's, you know, it's the taste of it. Yeah, the taste is really good... I can always put my flavours in, you know, the flavour that I like... When I was young, oh yeah, because my husband likes kidneys, livers and tongues, yeah. Tripes." – Participant in Community Dwelling Focus Group 2

Another dominant perception around offal was the 'yuck' factor. This was based on negative connotations surrounding offal, and the knowledge of what offal is:

"I love venison and I love things like that but when it comes -- it's just offal, it's just knowing what it is." - Participant in RACF Focus Group 2

"In the winter [menu] we have bacon and lambs fry... But ... when we had that we had to have just as much substitute because half the people won't eat the lambs fry... Don't know, probably because of what it is, people won't eat it." – Kitchen Manager 2

The acceptability of offal could arguably be increased when incorporated into meat-based meals, as one participant suggested:

"But I think if [offal] was inside something, like a meat -- a stew in that, and no one told me and I ate it [that would be okay]." – Participant in Community Dwelling Focus Group 2

However, a key part of the acceptability expressed by this participant, was a desire to be unaware of their offal consumption.

Our findings therefore suggest that, while older adults like the savoury flavour of meat they often reduce their consumption of red meat as they age. Older adults are, instead, choosing to consume more chicken and fish as alternative sources of meat-based protein. As for offal, the perceptions surrounding this meat-product were predominantly negative, with both older adults and RACF staff commenting on the strong, and unappealing, taste and smell. Additionally, the 'yuck' factor further influenced some older adults' decisions around offal, as they were put off consuming it due to the type of meat it is. Interestingly, a suggestion to use an offal-based product in a stew, or potentially a casserole, could be a potential avenue for a nutritionally-dense, and more acceptable, supplement.