Final report

Identifying interventions to increase value-added lamb products for quick service restaurants (QSR)

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Prepared by: Aarti Tobin, Carlos Batista, Adam Fitzgerald and Anita Sikes
Commonwealth Scientific and Industrial Research Organisation

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Meat & Livestock Australia Limited
PO Box 1961
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Abstract

MLA wanted to understand the barriers that quick service restaurants (QSRs) and full service restaurants (FSRs) had in featuring lamb products on their menus. The aim of the project was to identify and address these barriers, to drive the demand for Australian lamb products in this sector. Interviews were conducted with thirteen QSR/FSR companies that had 2 to 350 outlets around Australia. The main barriers that these companies identified were inconsistent product quality, reliability of supply and high costs, compared to other proteins. Recommendations for new lamb products were the inclusion of Mediterranean flavours and utilisation of existing equipment in the restaurants for cooking and reheating. The two product opportunities that were identified from the interviews, and later successfully developed were (i) a high-quality lamb burger patty and (ii) a pulled lamb product. Both these products suited the needs of most consumer demographics. These two lamb products provide the industry with a great opportunity to value add to lower value lamb cuts and address the unmet need of the QSR/FSR market. Both products maintained their sensory quality after 28 days of frozen storage. As these products could be cooked from frozen, this would reduce product wastage and a continuous supply of these products could be maintained so that they could be regularly featured on QSR/FSR menus, which would increase the demand for Australian lamb. Hence it is recommended that MLA approach the companies that had shown interest in trialling these products at their venues and CSIRO could assist with the scale up, reformulation and commercialisation of these products.

Executive summary

MLA wanted to understand the barriers that quick service restaurants (QSRs) and full service restaurants (FSRs) had in featuring lamb products on their menus on a regular basis. Currently lamb is presented as a "limited time offer" product, often aligned with promotional events, such as Australia Day. One key assumption was that the warmed over flavour (WOF) that develops in cooked and reheated lamb products was the main reason for the lack of lamb-based products on the menu, as the consumers found WOF unacceptable. Therefore, the main aim of this project was to consider which interventions could address WOF in lamb, thus allowing it to be better received by QSR menu planners and increase the demand for Australian lamb product. This was achieved through the following three activities:

1. Activity 1 – Short literature review on WOF in cooked lamb products to identify mitigation strategies that could be applied to two selected products in Activity 3.
2. Activity 2 – Interview manufacturers and users (QSR/FSR) of lamb products and understand the barriers to featuring lamb-based products in their menus.
3. Activity 3 – Develop and evaluate two value added lamb products for the QSR market.

Twenty companies in the QSR/FSR sector were invited to participate in the interviews. Thirteen companies, with 2 to 350 outlets, agreed to be interviewed using a set questionnaire. Most of the interviews were conducted with senior chefs from these companies. The main positive attribute for lamb was that the Australian population, mainly the older demographics, really liked the flavour of lamb. Some of the challenges that companies identified in featuring lamb on their menu included – inconsistent product quality, reliability of supply and high raw material costs. Cost of lamb, especially lamb racks at $40-45/meal, deemed them as a premium, special occasion meal and not a QSR product. They also indicated that Mediterranean flavours like Middle Eastern and Greek, suited lamb and that any new products should be able to be cooked/reheated using existing equipment. Surprisingly, none of the participants indicated that WOF was an issue with QSR/FSR products. Hence the focus of the project pivoted from WOF to cost reduction and value adding. Interview participants identified market opportunities for a high-quality lamb burger patty and a pulled lamb product.

A high-quality lamb burger patty was successfully developed, which included 6 mm minced lamb, Middle Eastern spice blend, herbs, and added water, citrus fibre, and gluten free breadcrumbs to reduce the ingredient cost of the patty and maintain its allergen free status. Similarly, a pulled lamb product was developed, where the lamb shoulder was covered with a rub, consisting of Middle Eastern spice blend and thickeners, vacuum packed, cooked at 75°C for 12 hours and then shredded into pulled meat texture. Both products were kept frozen at -18°C. A 28-day frozen storage trial showed that both products maintained their sensory quality after cooking and reheating. As lamb shoulder constitutes 80-95% of the product formulation, the ingredient cost of the two products was highly dependent on the raw material cost.

These two lamb products will provide the industry with a great opportunity to value add to lower value lamb cuts and trim, as well as address an unmet need of the QSR/FSR market. As these products can be cooked from frozen, this would reduce product wastage and a continuous supply of these products could be maintained so that they could be regularly featured on QSR/FSR menus, which would increase the demand for Australian lamb. Thus, it is recommended that MLA approach the participants from the interviews that had shown interest in trialling these products at their venues, regarding adoption of these products. CSIRO could assist with further expansion of these products from proof of concept to commercialisation.

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1. Background

Lamb products are not featured as often as beef and chicken in quick service restaurants (QSRs). MLA wanted to understand the underlying reasons why QSRs are reluctant to include lamb products on their menus. Some anecdotal information obtained by MLA had indicated that lamb was an expensive indulgent meat, resulting in fixed unit costs which often exceeded those for chicken, pork and beef SKU's. As lamb was a less frequent meat of choice in the QSR market, it needed a long shelf life, both in frozen storage and in warming trays to manage operating profits at QSR outlets. Also, if it was a limited time offer, it often had to align with promotional events, such as Australia Day or "new Spring lamb", Greek Festival, etc. where markdown rates were limited to an "event".

A significant problem for lamb quality specifically within the QSR sector, was related to "warmed over flavours" (WOFs). Many past studies have identified that WOF was based on oxidative rancidity, which was due to high pH meat, resulting in odour and taste issues for Individually Quick Frozen (IQF) reheat and serve meat-based products. As lamb typically has higher pH than beef and pork, it was proposed that maybe WOF was impacting on the quality and acceptability of lamb products in the QSR market. Deterioration of product quality, especially flavour in frozen storage and in warming trays, could result in high markdowns, i.e., financial losses for the customer and poor flavour for the consumer impacting on their intent to repurchase the products. Also, the protocols of cut x cooking method for MSA Lamb are significantly less developed and adopted in industry, compared to MSA beef.

Therefore, the overarching aim of the project was to consider several interventions that could address WOF issues in lamb thereby enabling provisions for the meat to be better received by QSR menu planners - ultimately driving its demand for Australian product.

This was to be achieved through three main activities:

1. Activity 1 – Short literature review on warmed over flavour (WOF) in cooked lamb products to identify mitigation strategies that could be applied to two selected products in Activity 3.
2. Activity 2 – Interview manufacturers and users (QSRs) of lamb products and understand the barriers to featuring lamb-based products in QSR menus.
3. Activity 3 – Development and evaluation of two value added lamb products that meet the needs of the QSR markets.

2. Objectives

1. Determine what the barriers are for value added lamb products in the QSR market and identify opportunities for lamb in this market.
2. Investigate possible processing and formulation interventions that could address barriers and thereby increase the likelihood of lamb products in the QSR market.
3. Develop and test two proof-of-concept lamb QSR products, i.e. one minced/comminuted product (e.g. reheated lamb kofta/sausage/burger) and one whole-muscle product (e.g. pulled lamb shoulder).

3. Methodology

3.1 Literature Review

Scientific and commercial literature was reviewed to elucidate the development of WOF in QSR type lamb products that were pre-cooked and reheated using commercial equipment such as clam shells, menu master etc. Based on the findings from the literature, various mitigation strategies were identified to reduce WOF in lamb products. The most suitable strategies were to be applied to the two proof of concept lamb QSR products.

3.2 Stakeholder Interviews

The purpose of stakeholder interviews was to (i) determine the reasons behind the lack of value-added lamb products in the QSR sector, (ii) understand the key criteria for selecting products in the QSR menu and (iii) document the typical array of QSR cooking/serving platforms used in the industry such that concept products could be prepared using existing cooking and reheating facilities.

3.2.1 Selection of the interview participants

MLA chef, Sam Burke, provided a list of 20 companies in the QSR sector and their contact person's details. These ranged from fast food companies, pubs, hotels, stadiums, restaurant chains etc. An email was sent to the contact person from each of these companies, inviting them to participate in the survey. The content of the email was as follows:

"CSIRO, with the support of Meat and Livestock Australia, are investigating why lamb products are not a frequent choice in QSR markets. To help understand this, and to develop concept lamb products for this market, we are gathering insights from the manufacturers and users of QSR lamb products. Topics to be discussed will include the potential opportunities and challenges for value-added lamb products in the QSR market, typical cooking/serving platforms for lamb products, key criteria for menu selection and input into the types of lamb products that would be successful in the QSR market.

We would like to invite you to participate in an interview, that would require 20-30 minutes of your time. If you are interested in participating, please respond with dates/times that would suit you for an interview".

3.2.2 Customer interviews

To undertake these interviews, applications were submitted to CSIRO Ethics (CSIRO Health and Medical Research: Low Risk Review Panel, CHM LRRP) and Privacy (CSIRO Privacy Team, Privacy Threshold Assessment approved) Committees. The approved ethics number for this project was 2020-112-LR-B.

Interview dates and times that suited the participants were booked and the interview questions were sent to the participants in advance, with the meeting invitation. All interviews were conducted virtually via Teams. At least one CSIRO and one MLA personnel (mainly Sam Burke) were present during the interview. The responses from the participants were recorded manually and their responses de-identified once the data was collated. The questionnaire used for the interviews can be found in Appendix 8.1.

3.3 Development of two concept products

Based on the findings from the stakeholder interviews, two lamb products were selected to be developed. The two products were:

1. Lamb burger patties
2. Pulled lamb

3.3.1 Proof of concept products from MLA chef

The initial concept development was undertaken by Sam Burke. Due to Covid 19, Sam was unable to travel to Brisbane and develop the products with CSIRO staff. Instead, he sent recipes and videos of the two products, which were then modified such that they could be produced commercially and cost effectively. However, there was a pivot in the project and the focus then was to produce the products more cost-effectively.

3.3.2 Development of the lamb burger patty

Lamb shoulders (80 CL) were minced using a 6 mm mincer plate, mixed with salt, spices and herbs and formed into 120 g burger patties with a hand operated patty former, as shown in the photos below in Fig.1. The patties were frozen immediately and were stored frozen until required for further assessment.

Figure 1: Process to manufacture lamb burger patties – lamb shoulder, mincing through 6 mm plate, mixing with spices, and forming the patties.

3.3.3 Development of the pulled lamb product

Lamb shoulders (80 CL) were coated with a spice blend at 5-10% of the weight of the shoulder, vacuum packed and cooked in a waterbath at 75°C for 12 hours. After cooking, while the shoulders were still hot, they were removed from the vacuum bag and mixed vigorously in a mixer to separate the meat into fibre-like texture of pulled meat. The residual sauce in the vacuum bag was added back to the pulled lamb, which was absorbed back into the meat. The process to manufacture pulled lamb is shown in Fig. 2. The pulled lamb was packed into 100 g portions, vacuum packed and frozen until required for further assessment.

Figure 2: Process to manufacture pulled lamb – coated lamb shoulder, cooked in waterbath, mixed to separate the fibres and 100 g serve of pulled lamb.

3.3.4 Assessment of product

Both the lamb burger patties and pulled lamb were stored frozen at -18°C for 4 weeks to determine if the storage time or temperature resulted in deterioration of product quality and taste. Informal sensory assessments were undertaken on Day 1 and Day 28 of storage for both products. The lamb patties were also objectively assessed for cook loss, shrinkage and texture.

Cook Loss

Frozen lamb patties were weighed and cooked in triplicate. The Silex hotplate was preheated to 165°C and the patties were cooked for 6 minutes on each side, then flipped and cooked for a further 2 minutes on each side (total cooking time: 16 minutes) until a core temperature of ≥75°C was reached. Samples were allowed to cool for 5 minutes at room temperature. They were then patted dry to remove excess oil and weighed. Cook loss was calculated as weight change before and after cooking.

Frozen patties were also cooked in an oven to replicate cooking processes in some commercial kitchens. Patties were cooked in a dry heat oven at 165^{o}C dry heat for 18 minutes until the core temperature was ≥75°C. Similar to Silex cooked patties, cook loss was calculated by weighing the patties before and after cooking.

Shrinkage

The diameter of the patties was measured using a ruler, in triplicate, before and after cooking. Shrinkage was calculated by the change in diameter of the patty before and after cooking.

TBARS

Lipid stability was determined by the thiobarbituric acid reactive substances (TBARS) assay as per Witte *et al* (1970), with modifications. Samples of cooked lamb were ground in an Oskar food processor and 2 (± 0.05) g was weighed into scintillation vials and capped. Samples were homogenized on ice in 6 mL of chilled TCA solution (7.5% trichloroacetic acid, 0.1% propyl gallate and 0.1% EDTA) using an Ultra Turrax for 30 s at 13 000 rpm. The homogenate was passed through filter paper and the sediment was rinsed with an additional 2 mL of TCA solution. Aliquots (2.5 mL) of the filtrate were transferred, in duplicate, to test tubes, diluted with 2.5 mL distilled water and reacted for 16 h with 5 mL of 0.02M thiobarbituric acid solution at room temperature, in a dark cupboard. An aliquot of sample (200 µL) was added to a microplate well, in duplicate, and the samples were read at 532 nm using an EnSpire Multimode Plate reader (Part number: 2300-0000, PerkinElmer Pty Ltd, Glen Waverley, Australia) and the TBARS value as mg/kg malondialdeyde (MDA) equivalents was determined against a standard curve prepared from 1,1,3,3-tetraethoxypropane. Samples collected were stored at -80°C before analysis.

Kramer Shear (cooked sample)

Kramer shear measurements were performed on a Lloyd LS 2.5 universal testing machine fitted with a 1 kN load cell and a 10 blade Kramer shear cell (Lloyd Instruments, West Sussex, United Kingdom). Half of a cooked burger patty was placed into the cell and sheared by the blades at 100 mm/min for a maximum of 50 mm. A preload of 0.3 kgf at 2 mm/s was used prior to measurement. The peak force (N) required to shear the sample was recorded. A minimum of six samples were tested per batch of product.

Informal Sensory

Informal sensory analysis was performed in house at Coopers Plains by CSIRO staff. The sensory assessment form used to evaluate the lamb patty and pulled lamb is included in Appendix 8.2. The lamb burger patty was cooked as described above (Section 3.3.4) in the cook loss method. The pulled lamb was reheated in a non-stick pan, at medium heat until the temperature was ≥75°C. To assess the products, participants were given half a cooked patty and a tablespoon of pulled lamb as shown in Fig. 3. The participants recorded their answers on printed sensory assessment sheets. The data from the participants was collated and assessed to guide the development of the two products.

Figure 3: Samples presented for sensory evaluation; half a cooked lamb patty (left) and pulled lamb (right).

4. Results

4.1 Literature Review

4.1.1 Introduction

Lipids are responsible for both desirable and undesirable flavours and aromas in meat and contribute to improving the tenderness and juiciness of meat products. Fat content and composition are important for meat quality and nutritional attributes. However, lipid oxidation can deteriorate the quality and can cause flavours and aromas that are regarded as undesirable by consumers.

Phospholipids (PLs) are found in cell membranes and are rich in polyunsaturated fatty acids (PUFAs) which are susceptible to oxidation. They are a major lipid fraction that generates volatile compounds. The distinct flavour associated with cooked sheep meat (sometimes known as 'mutton flavour') is related to the presence of volatile short, branched chain fatty acids (FAs), such as 4-methyl, 4-ethyloctanoic and 4-methylnonanoic acids (Brennand & Lindsay, 1992; Watkins et al., 2021).

Oxidative processes that occur during the conversion of muscle to meat, at processing or during storage, can lead to undesirable changes in meat including discolouration, texture changes, reduced shelf life, and the development of off-flavours and odours (Falowo, Fayemi, & Muchenje, 2014). It is proposed that the development of warmed-over flavour (WOF) in sheep meat products is the key reason why lamb products are not part of the menu plan for the quick service restaurant (QSR) sector. This short literature review highlights lipid oxidation, factors affecting oxidative rancidity and suggested strategies to inhibit or delay lipid oxidation in lamb products.

4.1.2 Lipid Oxidation

Lipid oxidation, also known as oxidative rancidity, is a complex process which includes multiple mechanisms that interact with each other (Fig. 4). To explain briefly, unsaturated fatty acids (UFAs) react with molecular oxygen via a free radical mechanism (Falowo et al., 2014; Guéraud et al., 2010). Hydroperoxides are produced, which are odourless, and are considered as the primary oxidation products. These compounds are highly unstable and decompose rapidly, forming many secondary compounds that include hydrocarbons, aldehydes, ketones, alcohols, esters and acids (Min & Ahn, 2005). Some of these secondary products, even at low concentrations, can be responsible for the appearance of off-flavours and odours. Of all lipid oxidation products, it is the aldehydes as a class of compounds that are regarded as the most important and the largest volatile contributors to the formation of the perceived aromas. The aldehydes can also react with proteins, which contribute to protein oxidation, resulting in loss of essential amino acids as well as product functionality.

Based on the levels of more susceptible UFAs in PLs and natural antioxidants present in muscle tissue, the susceptibility of species to lipid oxidation has been suggested to lie in the order as follows: poultry > pork > beef > sheep (Byrne, Bredie, Mottram, & Martens, 2002; Jayathilakan, Sharma, Radhakrishna, & Bawa, 2007).

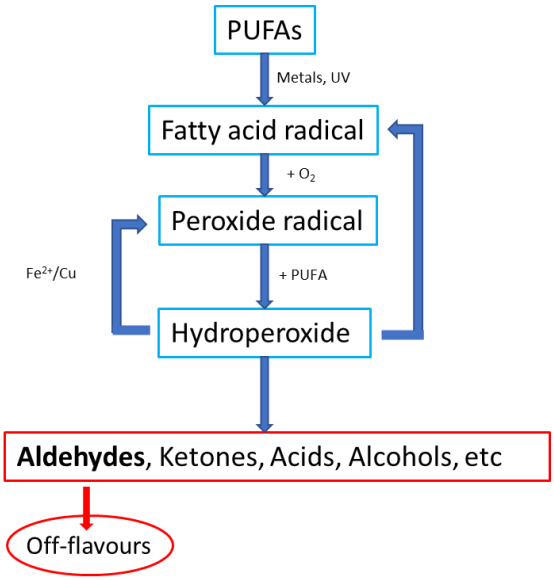

Figure 4: Representation of the lipid oxidation process. (Adapted from Castillo et al. (2013)).

4.1.3 Factors affecting lipid oxidation

Oxidative stability depends on several different intrinsic and extrinsic factors (Ladikos & Lougovois, 1990) as well as the balance between pro-oxidants and antioxidants naturally present in muscle tissue. The intrinsic factors can include species, breed, production system, diet, anatomical location, muscle type, and meat composition, such as fatty acid composition and pro-oxidant concentration (haem proteins, metals, enzymes, vitamins), while extrinsic factors can be related to processing (including method) and product storage of meat products, along with pH, temperature, light, oxygen, and ingredients.

Meat composition

Approximately 39% of the total FAs in Australian lamb cuts are saturated, with the monounsaturated fatty acids (MUFAs) making up about 47% and PUFAs about 14% (Droulez, Williams, Levy, Stobaus, & Sinclair, 2006). The higher amount of UFAs (~ 61%) favours oxidative processes (Kumar, Yadav, Ahmad, & Narsaiah, 2015). Lipid oxidation increases with increasing unsaturation of the FA moieties (PUFAs oxidise more rapidly than MUFAs) and so the differences in the lipid content and the FA composition are directly related to oxidative stability. A higher lipid content and PUFA/SFA ratio promotes lipid oxidation in meat (Kumar et al., 2015). Additionally, a high myoglobin concentration in sheep predisposes the meat to oxidation (Faustman, Sun, Mancini, & Suman, 2010).

The presence of metal ions that easily donate electrons, such as copper and iron, can lead to an increased rate of free radical production. Iron is the most abundant transition metal in biological systems and has multiple oxidation states and plays an important role in lipid oxidation (Min & Ahn, 2005).

Processing and storage

Oxygen exposure is a key factor for lipid oxidation. Any process which leads to membrane rupture, exposing PLs to oxygen and/or size reduction processes (such as cutting, grinding, and cooking) can accelerate lipid oxidation.

Meat and meat products when subjected to processing (heat) and storage undergo changes in their physical and chemical characteristics which leads to the development of oxygenated free radicals, resulting in the oxidation of PUFAS, and the destruction of natural antioxidant systems in the meat. Pre-prepared products such as cooked meats are even more susceptible to lipid oxidation than raw meat (Byrne et al., 2002). Higher temperatures lead to the release of oxygen and haem iron, thereby inducing production of free radicals.

Pre-cooked meat and meat products, which are re-heated after a short period of refrigerated storage, develop a distinctive flavour referred to as warmed-over flavour (WOF, (Tims & Watts, 1958). The development of this flavour is largely attributed to the auto-oxidation of PUFAs, mainly in the PLs, and with iron, in different forms, regarded as an important catalyst for these reactions (Gray, Gomaa, & Buckley, 1996). Cooking can also lead to myoglobin oxidation, resulting in the conversion of haem iron to non-haem iron. The susceptibility and rate of oxidation is dependent on the level of FAs and the related degree of unsaturation.

WOF is described by consumers as 'stale', 'rancid', 'painty', 'cardboard-like', and a loss of fresh meat aroma with an increase in 'cardboard-like' aroma. Within 1-3 days, this off-aroma is gradually replaced by a rancid 'painty' aroma, followed by the development of a sour taste. Consumer rejection of refrigerated cooked meat can occur after 24 to 48 hours of storage, whereas the slow onset of rancidity in raw meats is not often apparent for weeks or months of storage (Pearson, Love, & Shorland, 1977).

The secondary products of lipid oxidation have been implicated in the sensory detection of WOF in cooked and chilled-stored meats (St Angelo et al., 1987). Hexanal is regarded as a marker for WOF. There is also evidence that suggests that oxidative changes in proteins and other components, e.g., Maillard-derived aroma volatiles, are involved (Byrne et al., 2001).

4.1.4 Interventions

In general, the main strategy used by the meat industry to inhibit or delay oxidation reactions is the addition of antioxidants during the processing of meat and related products. Antioxidants inhibit lipid oxidation by chelating transition metals, breaking the oxidative chain reaction or scavenging free radicals and reactive species (Augustyniak et al., 2010). However, the majority of these ingredients are synthetic, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butyl hydroxy quinone (TBHQ) and propyl gallate (PG), and some studies have shown adverse health effects to the consumer (Cunha et al., 2018). Therefore, many studies have investigated the use of natural antioxidants.

Supplementation of animals' diets with antioxidants is also another strategy to control lipid oxidation in meat, but this is beyond the scope of this review.

Natural antioxidants

Over the last decade, many natural sources of antioxidants for use in food products have been investigated with a focus given to horticultural products, due to the high content of antioxidant compounds, including fruits, vegetables, tea, herbs, spices, nuts (Agregán et al., 2017). The main groups of phytochemicals which have antioxidant activity are polyphenolic compounds, carotenoids, and essential oils (Munekata, Franco, Trindade, & Lorenzo, 2016). For example, rich sources of polyphenols can be found in extracts from green tea, grapes, and olives. While the antioxidant efficacy of certain extracts is well established, some care is required to find the optimal amount for addition to reduce minimise any influence on the meat flavour. Additionally, as some of these

compounds can interact with iron, so the potential exists for the reduction in its bioavailability in cooked meat. Some researchers also note that, while plant extracts, herbs, spices, and essential oils have significant antioxidant activity, and have been studied extensively in meat products, there is a lack of sufficient data about their safety and efficacy (Kumar et al., 2015).

Herbs from the *Lamiaceae* family, such as oregano, rosemary, sage and thyme, have been shown to have significant antioxidant activity (Velasco & Williams, 2011), with oregano having the highest activity (Muchuweti et al., 2007). Spices such as clove, cinnamon, nutmeg and black pepper (*Lauraceae* family) also have antioxidant activity and have similar chemical composition and functions as herbs (Radha Krishnan et al., 2014).

As highlighted in the next section, cooking (method, temperature, time, endpoint temperature) influences WOF development. Maillard reaction products (MRPs, browning products) are formed between reducing sugars and amino acids when cooking meat to internal temperatures greater than 100°C, and the intermediates that are produced can be effective antioxidants (Bailey, 1988). Meat naturally contains low levels of reducing sugars such as glucose and ribose. Several authors have investigated amplifying this reaction by adding sugars which naturally occur in beef (Food Science Australia, 2003; Jayathilakan et al., 2007; Morales & Jiménez-Pérez, 2001).

Numerous studies assessing the antioxidant effects of different plant materials in meat and meat products have been reported in the literature (Amaral, da Silva, & da Silva Lannes, 2018; Cunha et al., 2018; Hygreeva, Pandey, & Radhakrishna, 2014; Karre, Lopez, & Getty, 2013; Kumar et al., 2015; Shah, Bosco, & Mir, 2014). Many of these studies involved laboratory extractions of plant-derived products, and although many of these extracts have shown antioxidant capacity, the use of such extracts is, of course, controlled by national and/or international jurisdictions (Karre et al., 2013).

Considerable research has been undertaken to understand the effects of natural antioxidants on meat quality, with particular attention given to poultry, pork, and beef, with less focus given to sheep. Table 1 shows a summary of the literature relating to sheep meat and, where appropriate, further discussion on the use of relevant plant extracts with other species is given below.

The effect of thirteen herb and spice extracts was investigated to identify the most promising replacement for sodium erythorbate in sheep meat burgers (Fernandes, Trindade, Tonin, et al., 2016). Oregano, rosemary, lemon balm and marjoram had the highest antioxidant capacities, and based on consumer sensory acceptance, there was no difference between the four extracts or sodium erythorbate. Further work focussed on the addition of oregano to raw sheep burgers that were stored chilled, and compared to BHT (50 ppm, (Fernandes, Trindade, Lorenzo, Munekata, & de Melo, 2016) as well as raw burgers that were stored frozen using sodium erythorbate as an oxidant (500 ppm) (Fernandes et al., 2017). The oregano extract slowed lipid oxidation, was comparable to synthetic antioxidants, improved the colour stability and either improved or had no adverse effects on sensory acceptance. It must be noted that the packaging conditions in these studies was not similar which could confound these results. Similarly, Ahmad, Shawnm, and Sabow (2019) showed that the addition of fenugreek leaves to raw sheep burgers, which were stored chilled, lowered TBARS values at 7 days and lowered bacterial counts. TBARS, also known as Thiobarbituric Acid Reactive Substances Assay, is used as a measure for oxidative stability (the lower TBARS value, the lower oxidation).

An extensive study by Villalobos-Delgado et al. (2015) showed that hops (as a powder and an infusion) had a significant antioxidant effect on lamb patties, with the powder being stronger than the infusion. Lipid oxidation was inhibited for patties that were raw-chilled, raw-frozen, and cooked-

chilled. The patties' colour stability was also improved with the hop treatments, but there was a slight decrease in consumer acceptance using the powder compared to the control and infusion treatments. Cooked pork patties with added commercial rosemary and lemon balm extracts (30 mg/100 g) and stored in modified atmosphere packaging under lights for 3 days, reduced TBARS values and hexanal production compared to the use of BHT (20 mg /100 g, Lara, Gutierrez, Timon, & Andres, 2011). The rosemary extract provided better inhibition of lipid oxidation without any adverse effects on overall acceptability.

The antioxidant capacity of different plant extracts has also been studied in ground sheep meat. Extracts from clove oil (Aliakbarlu & Khalili Sadaghiani, 2015), sumac and barberry (Aliakbarlu & Mohammadi, 2015) and cinnamon bark oil (Hussain et al., 2021) were added to ground meat and aerobically stored raw at 4°C. The use of these extracts reduced lipid oxidation, and in some studies, reduced bacterial counts as well as improved colour stability. Powdered cinnamon and clove extracts, as well as Maillard reaction products (glucose/lysine), were evaluated for controlling WOF in ground sheep, beef and pork meat which was cooked and stored chilled (5°C for 6 d in vacuum packaging, (Jayathilakan et al., 2007). Maillard reaction products had similar antioxidant activity to TBHQ and was higher than other treatments, resulting in lower hexanal formation and non-haem iron values, leading to the conclusion that that this antioxidant system controlled WOF during chilled storage (5°C for up to 6 d, Jayathilakan et al., 2007).

To achieve internal meat temperatures greater than 100°C, which leads to the formation of MRPs, meat products can either be autoclaved or retorted. However, Morales and Jiménez-Pérez (2001) demonstrated that effective Maillard antioxidants could be produced without excessive browning occurring, which usually is associated with Maillard reactions. This observation led to a subsequent study, conducted by the then Food Science Australia, which lead to the production of sufficient Maillard browning and antioxidant properties without adversely affecting meat flavour and texture (Food Science Australia, 2003). Glucose, fructose and ribose (0.4%) were injected into beef blade muscle prior to cooking (200°C for 25 min; internal 76°C) with storage of beef slices at 5°C in unsealed bags for 1, 2, 3 and 6 days. The development of rancidity (determined by TBARS) showed that ribose treatment lowered oxidation by 40% compared to the control at each storage time point. Additional experiments showed that it was possible to obtain oxidative stability from using ribose and cooking at non-browning temperatures (75–90°C), but internal temperatures of 80–90°C were necessary to reduce lipid oxidation. Sensory assessment indicated that ribose treatment reduced the development of WOF, increased juiciness, had no effect on tenderness and overall, was more acceptable than controls.

Oregano and sage oils (3% w/w) increased the oxidative stability of raw and cooked (85°C for 30 min) pork and beef mince during storage (4°C for 12 d, (Fasseas, Mountzouris, Tarantilis, Polissiou, & Zervas, 2008). These authors suggested that the addition of antioxidants was more important for cooked meat than raw products. Similarly, the oregano extract inhibited lipid oxidation in cooked ground beef and pork while a commercial oregano extract (Origanox, RAD Natural Technologies Ltd., USA, 0.02%) was effective at reducing lipid oxidation in vacuum-packed cooked beef held at -18°C for 4 months, based on TBARS results (Rojas & Brewer, 2008). In another study, dried plum puree reduced lipid oxidation in pre-cooked pork sausages that were vacuum packaged and stored at 4°C for 28 d, as well as stored at -20°C for 90 d (Nuñez de Gonzalez, Boleman, Miller, Keeton, & Rhee, 2008).

Recently, commercially available rosemary (Guardian 20S, Guardian G09, Danisco, USA; StabilEnhance OSR4, Naturex, USA) and green tea extracts were added to several deli-style meat products: cured deli turkey, chicken fillet and pulled pork, with the intention of replacing phosphates

(Bak & Richards, 2021). Products were stored under refrigeration for up to 13 weeks in the dark under modified atmosphere packaging. A water/oil-soluble rosemary extract (400 mg/kg) was effective as an antioxidant in the turkey product, whereas the water-soluble rosemary extract (400 mg/kg), in combination with phosphate, was most efficient in the chicken fillet. None of the extracts were as efficient as phosphate in reducing lipid oxidation in pulled pork but were moderately effective without phosphate.

Other sheep meat products and plant extracts as antioxidants have been investigated to inhibit lipid oxidation under different storage conditions (Table 1). The use of olive leaf extract for lamb meatballs (Rubel et al., 2020), grape seed extract in restructured mutton slices (Reddy et al., 2013), turmeric extract to lamb sausages (de Carvalho et al., 2020) and guava powder to sheep meat nuggets (Verma, Rajkumar, Banerjee, Biswas, & Das, 2013) has shown that lipid oxidation can be reduced and sensory attributes improved with the addition of natural antioxidants.

Cooking methods

The rate of oxidation increases with temperature and depends on the cooking method and time. Both temperature and cooking time have a large effect on the production of free radicals which leads to lipid oxidation. Roldán, Antequera, Martín, Mayoral, and Ruiz (2013) assessed the oxidative stability of lipids and proteins of *sous vide*-cooked lamb loins, with different temperature-time combinations (60–80°C and 6–24 hours) and, as expected, heating induced both lipid and protein oxidation. A subsequent study showed that higher temperature–time combinations increased conjugated dienes and decreased TBARS values and hexanal (Roldan, Antequera, Armenteros, & Ruiz, 2014). Pork cheeks cooked by the *sous vide* method had lower TBARS values in samples that were cooked at higher temperatures for longer times (Sánchez del Pulgar, Gázquez, & Ruiz-Carrascal, 2012).

When meat has been cooked to internal temperatures of 60–70°C and stored chilled, increases in WOF development have been shown to be correlated with increasing internal meat temperature (Mielche, 1995; Mielche & Bertelsen, 1993, 1995). However, at a higher internal temperature of 100°C (rather than 70°C), WOF development remained constant during chilled storage. It was proposed that heating accelerated PL oxidation through the release of protein-bound iron. However, at high internal meat temperatures greater than 100°C, these authors observed a remarkable increase in oxidative stability when stored in air for 7 days at 4°C.

Recently, *sous vide* (75°C/35 min, internal 72°C) and grilling (150°C, internal 72°C) of 25 g lamb patties were assessed for lipid stability immediately after cooking and after heated display (65°C for 4 hours) (Ortuño, Mateo, Rodríguez-Estrada, & Bañón, 2021). Sous vide prevented TBARS formation, whereas grilled patties showed a larger proportion of highly oxidisable PUFAs. The progression of Maillard reactions was indicated during heated display. These authors concluded that sous vide cooking was a 'healthier' way of cooking when lamb meat was kept warm for considerable periods before consumption.

Packaging

As oxygen is the main determinant of lipid oxidation, reducing its concentration in any packaging of meat and meat products will be a good strategy to limit oxidative reactions. The most common forms are vacuum packaging, modified atmosphere packaging and active packaging. Several reports confirm that lower lipid oxidation is found in meat packaged in low oxygen concentrations or under vacuum, than those in high oxygen atmospheres (Cayuela, Gil, Bañón, & Garrido, 2004; John et al., 2005).

Different packaging types (vacuum and modified atmospheres) of lamb meat (used for Souvlaki) demonstrated that lipid oxidation was enhanced by aerobic storage with a modified atmosphere of 30% CO_2/70% N_2, whereas vacuum packaged with a higher concentration of CO2 (70% CO_2/30% N_2) controlled lipid oxidation at 4°C for 13 days. Colour stability was not affected by vacuum or modified atmospheres (Soldatou, Nerantzaki, Kontominas, & Savvaidis, 2009).

4.1.5 WOF conclusions and recommendations for interventions

Based on the literature review, the following conclusions can be drawn regarding WOF in QSR type lamb products:

- Processing and storage conditions can accelerate lipid oxidation
- Consumers are seeking natural antioxidants in meat products
- Oregano and rosemary extracts have significant antioxidant activity
- Need to optimise the addition of antioxidants such that there is minimum influence on flavour, while maintaining food safety and efficacy against WOF
- Cooking method and conditions influence the development of WOF

Hence the following three interventions were recommended to reduce WOF in QSR lamb products:

- Sodium erythorbate
- Commercial natural antioxidant
    - Oregano extract
    - Rosemary extract

However, the findings from the stakeholder interviews (section 4.2) indicated that WOF was not an issue in the QSR/FSR sector. Hence, none of these WOF interventions were trialled during the development of the two lamb products. Instead, the focus of the product development pivoted to cost reduction.

Table 1: Plant extracts used in sheep meat products and the effects on quality attributes.

Product	Extract	State	Storage	Quality effects	Reference
Burger	Dried fenugreek leaves (0.5, 1.0,1.5%)	Raw-chilled	4°C/10 d	Lower TBARS values at 7 d Lower bacterial counts	(Ahmad et al., 2019)
Burger	Basil leaves, chamomile flower, fennel seeds, ginger, laurel leaves, lemon balm leaves, marjoram leaves, mint leaves and stalk, mustard seeds, oregano leaves, rosemary leaves, sage leaves, turmeric Replace sodium erythorbate Similar antioxidant capacities as 500 ppm sodium erythorbate	Raw-frozen	-18°C/5 d	Oregano, rosemary, lemon balm and marjoram had highest antioxidant capacities No difference in sensory acceptance between 4 extracts and sodium erythorbate	(Fernandes, Trindade, Tonin, et al., 2016)
Burger	Oregano (1000 ppm) Compared to BHT (50 ppm)	Raw-chilled	2°C/20 d MAP	Slowed lipid and protein oxidation, similar to BHT Oregano prevented loss of sensory qualities up to 15 d Similar bacterial counts to BHT	(Fernandes, Trindade, Lorenzo, et al., 2016)
Burger	Oregano (13, 18, 24 mL/kg) Based on antioxidant capacity of sodium erythorbate at 500 ppm	Raw-frozen	-18°C/120 d	Higher extract concentration reduced lipid oxidation Improved colour stability No change in sensory acceptance	(Fernandes et al., 2017)
Burger	Hop infusion (2 g/kg) Hop powder (2 g/kg)	Cooked-chilled Raw-chilled Raw-frozen	4°C/3 d 4°C/7 d -18°C/90 d	Hop powder had a stronger antioxidant effect than hop infusion	(Villalobos-Delgado et al., 2015)

				Improved colour stability with hop treatments Hop powder caused a slight decrease in consumer acceptance compared to control and hop infusion	
Meatball	Olive leaf (0.1, 0.2, 0.3%)	Raw-chilled	4°C/10 d	0.3% suitable antioxidant Lower TBARS values Improved sensory attributes (colour, odour, juiciness, acceptability)	(Rubel et al., 2020)
Slices (restructured)	Grape seed (0.1%) Compared to BHA (0.01%)		4°C/28 d Aerobic and vacuum packaged	Lower TBARS values Higher sensory scores (colour, flavour, juiciness, acceptability) Reduced bacterial counts	(Reddy et al., 2013)
Sausage (cured)	Oregano (3 concentrations) Based on antioxidant capacity of sodium erythorbate at 500 ppm	Cooked-chilled	20°C/135 d Vacuum packaged	Oregano extract improved the lipid and protein stability All treatments resulted in a redder colour than control	(Fernandes, Trindade, Lorenzo, & de Melo, 2018)
Sausage	Turmeric (250, 500, 750 mg/kg) Compared to sodium erythorbate (500 ppm)	Raw-chilled	2°C/18 d MAP (80% O_2, 20% CO_2)	Slowed lipid oxidation Affected colour (more yellow) Acceptable by consumers	(de Carvalho et al., 2020)
Ground meat	Sumac, barberry (3%, water extract)	Raw-chilled	4°C/9 d Aerobic	Reduced lipid oxidation Reduced bacterial counts	(Aliakbarlu & Mohammadi, 2015)
Ground meat	Clove- oil extract (0.25%)	Raw-chilled	4°C/9 d Aerobic	Decreased TBARS values	(Aliakbarlu & Khalili Sadaghiani, 2015)
Ground meat	Powdered spices (cinnamon, cloves) (250 mg/100 g) Compared to TBHQ, BHA, PG (0.02%); ascorbic acid (500 ppm); Maillard reaction products MRPs	Cooked-chilled	5°C/6 d Vacuum packaged	MRPs similar antioxidant activity to TBHQ; higher than other treatments MRPs – lower hexanal and non-haem iron values – control WOF during chilled storage	(Jayathilakan et al., 2007)

	(60 mM/2 h, glucose/lysine)				
Ground meat	Cinnamon bark oil (0.01, 0.025, 0.05, 0.5%)	Raw-chilled	4°C/16 d	Lower TBARS and pH values (0.025, 0.05%) Higher L*, a*	(Hussain et al., 2021)
Nuggets	Guava powder (0.5, 1%) (antioxidant dietary fibre) Compared to BHT (0.1%)	Cooked-chilled	4°C/15 d Vacuum packaged	Retarded lipid oxidation Decreased pH of emulsion and nuggets Decreased emulsion stability, cook yield and moisture content of nuggets Improved redness of product No effect on sensory attributes Guava comparable to BHT	(Verma et al., 2013)

4.2 Stakeholder Interviews

4.2.1 Interview participants

Of the 20 companies in the QSR, pubs and clubs market that were invited to participate in the interviews, 13 companies agreed to be interviewed using the questionnaire outlined in Appendix 8.1. The 13 companies that were interviewed consisted of:

- 1 – Quick service restaurant (QSR)
- 5 – Full-service restaurants (FSR)
- 3 – Hotels/pubs
- 1 – Cruise ship
- 3 - Stadiums

Most of the interviews were conducted with senior chefs from these organisations, who provided feedback on behalf of their chain of restaurants, hotels, or stadiums which ranged in total from 2 to 350 outlets. Some of the larger companies had outlets throughout Australia.

4.2.2 Lamb products on menu – successes and challenges

Lamb products had featured on menus for 12 of the 13 companies interviewed and ranged from mince-based dishes to roasts and lamb shanks, as can be seen in Table 2.

Table 2: Lamb dishes featured on menus.

Shanks	Ribs	Ragu	Salads (grilled lamb, back strap)
Racks	Croquettes	Rissoles	Braised shoulder
Koftas	Shawarma	Cutlets	Pies (minced, pulled)
Curries	Canapes	Stews	Roast (brine injected)
Wraps	Pizza		Burger (minced, pulled)
Sandwich	Grab ‘n’ Go		

From these interviews, one of the positive attributes of lamb was that it was liked by consumers, and from a restaurant’s perspective, it was a successful promotional meat, but only in winter. However, there were many challenges with featuring lamb on their menus which are listed below:

- Raw material costs
- Premium price – becomes a special occasion meal
- Too expensive compared to other proteins, especially chicken
- Consistency of quality – variability in the product quality
- Consistency of supply (ribs) – when purchasing for a chain of restaurants as a promotional item, supply can be an issue
- Seasonal issues – rib fattiness
- Source of halal lamb

- Whole of carcass is utilised with limited off-cuts i.e. lamb legs, ribs and shanks are often used for roasting or slow cooking, hence boneless shoulders tend to be the only source of manufacturing meat for value adding
- Do customers want lamb on menu – disconnect
- Lamb is not a 'go to' protein in QSR compared to chicken and beef

4.2.3 Flavours that suited lamb

The interview participants indicated that the lamb dishes that they served often featured flavour influences from three main ethnic backgrounds - Middle Eastern, Mediterranean, and Greek. This was because lamb is similar in flavour to goat and the flavours which suit goat meat, also suit lamb. The respondents also used lamb in Indian, Asian and Sri Lankan curries.

4.2.4 Holding parameters before serving lamb products

The purpose of asking this question was to determine the impact of holding time and temperature on the quality of the lamb products. Several different approaches were used depending on the product:

- Made to order – cooked from raw
- Shanks, slow cooked lamb and pulled lamb were held in warming drawers/hot boxes (65-80°C) for several hours. Some participants added a liquid base to keep the product moist to ensure that the products did not dry out and become stringy
- Pre-cooked meats were often reheated on the grill
- Regeneration in a combi-oven with subsequent holding in hot boxes

None of the participants mentioned any deterioration of the flavour of the lamb product (WOF) or any other quality issues, while the product was being held in warming drawers or hot boxes.

4.2.5 Value proposition and performance of lamb on the menu

According to the participants, lamb was considered a comfort food and consumers really liked the flavour of lamb. However, lamb needed to find its place on the menu. Most of the participants considered lamb as a special occasion meal and not a QSR product as, for example, rack of lamb meal could cost as much as $40 - $45 per portion. Therefore, compared to other meats, the cost of the portion was very high. Some participants indicated that they had started to add cheaper lamb products like sausages, rissoles, braised meat to lamb cutlet meals to increase the amount of meat on the plate and reduce the price of the meal. Finally, the consistency of lamb and its supply issues were also of concern.

4.2.6 Potential lamb products on the menu

Survey participants indicated that if they were going to offer lamb on their menu, they would feature the range of products as outlined in Table 3.

Table 3: Lamb dishes that could be featured on menus.

Shanks	Ribs	Dry aged	Salads (grilled lamb, back strap)
Pies	Burgers	Meatballs	Braised shoulder for tacos
Gyros	Burritos	Pizza	Minced lamb products on pita bread
Curries	Skewers	Cutlets	Kebabs/souvlaki
Wraps	Sausages	Stews	Burger (minced, pulled)
Gozleme	Ravioli	Dumplings	Pulled lamb – as an ingredient for pies, wraps, roll etc.

4.2.7 Equipment for cooking and reheating

The range of cooking and reheating equipment used by different organisations is listed below. It was also dependent on the product. Some products were cooked from raw (chilled/frozen) whereas other products like pulled meat and lamb shanks that were bought pre-cooked, were only reheated prior to serving.

- Microwaves – commercial (e.g. Menu Master)
- Combi-ovens (e.g. Alto-Shaam)
- Bain marie (some companies steering away from such equipment)
- Stove top
- Grill plate
- Flat top plate
- Hot box
- Chilled cabinet
- Sous-vide equipment – tanks, wands (thermo circulators)
- Vacuum sealers

The participants strongly suggested that any new lamb products or processes would need to be designed around existing cooking and reheating equipment i.e., the need to buy new equipment could be a deterrent in featuring the product on their menu.

4.2.8 Product cost, price and portion sizes

For all the participants, the cost of goods ranged from 29-40%. The portion sizes and prices for typical lamb products are summarised in Table 4.

Table 4: Typical lamb products, portion sizes and price per meal.

Product	**Weight (g)**	**Price per meal ($)**
Burger patties	120 - 180	15-20
Whole muscle	180 - 220	
Lamb Shanks	350 - 500	>20
Single Racks	350 - 400	40-45
Wraps/rolls/sandwiches	120 - 140	15-20
Protein bowls	120 - 130	
Lamb chops	200 - 250	

The survey participants indicated that the general pricing rule for various meats were as follows:

- $12-13 - "tradie" market
- $15-17 - lunch meal
- $24-30 - dinner meal
- $40-45 - *á la carte* meals

4.2.9 Markets for lamb products – current and new

According to the survey participants, the current consumers of lamb are families, females over the age of 45 years, for a lighter meal option e.g., lamb salad, and seniors who have grown up with eating lamb. Seniors preferred lamb shanks.

Some of the new market opportunities for lamb products that were identified from the survey were:

- Products for 50+ year old demographics who liked lamb
- 20 to 40 year old's, upwardly mobile, tech savvy generation e.g. a hot pastry item and grab 'n' go type products
- Homemade sandwiches

4.2.10 Lamb cuts of interest

Survey participants indicated that lamb shoulder was a very versatile cut as it can be used in a variety of products:

- Diced meat for curries and stews
- Mince for burgers
- Pulled meat for pies, sandwich etc.

There was also interest in shanks, rumps, and ribs.

4.2.11 New products of interest

- Burgers – 7 of the 13 participants suggested that a good quality lamb burger, which had a point of difference could be successful. Burgers were popular with most age groups and could be sold at a reasonable price point.
- Pulled meats - 7 of the 13 participants indicated that the versatility of pulled meat makes it a product of interest. It could be used in wraps, rolls, pie fillings etc. It can also be bought pre-cooked and only needs to be reheated.
- Braised products – e.g. curries, stews, roasts and pies were becoming popular as there was a trend towards more homestyle type dishes.
- Wraps/shawarma/salads – using lamb backstrap in salads instead of kofta's gives a perception of higher value
- Lamb cutlet (like KFC chicken)
- Semi-*sous vide* products
- Pressed lamb shoulder was becoming popular
- Regional influences – coast *vs* country

4.2.12 Product opportunities in different QSR/FSR sectors

As the participants were from different QSR and FSR sectors, the following product opportunities were identified:

- FSR - Hotels/Pubs
  - Pulled lamb – that can be used in a variety of products – pies/rolls/wraps
  - Good quality burger patty (18-20% fat)
- QSR - Fast Food Restaurants
  - Pulled lamb
  - Burger
  - Slow cooked shoulder – pressed into a regular shape
  - Cold-set bound shoulder – thinly sliced for steak burger
- Stadiums
  - Limited opportunity for lamb products with the general public food outlets, as beef and chicken are too popular
  - Opportunity exists for lamb racks and shanks in the corporate side of stadiums with sit down meals

4.2.13 Other issues/opportunities for lamb

During the interviews, the following issues and potential opportunities for research were highlighted for lamb:

- Branding and provenance of lamb was limited compared to beef
- MSA for lamb – cut/cook methods would be beneficial for value adding
- Further insights are needed on the regional influences for lamb-based meals and products.

4.2.14 Willingness to participate in lamb promotion campaign

Majority of the organisations interviewed (11 out of 13), were willing to participate in the lamb promotion campaign with MLA. They were interested in trialling the lamb products developed in this project, in their venues.

4.2.15 Lamb products selected for development

Based on the survey findings, it was concluded that there were market opportunities for the following two products:

1. High quality lamb burger patty
2. High quality pulled lamb product

Both these products would be suited to QSR's and FSR's and would meet the needs of most consumer demographics. For example, burgers were popular with most age groups and pulled lamb could be used in a variety of meals – wraps, rolls, pies, pizzas etc.

4.2.16 Conclusions from the interviews

- Lamb is traditionally eaten as part of a meal e.g., as roasts and chops, hence it is not considered as a fast food.
- Lamb is preferred by the older demographics, as they grew up with eating lamb and like its flavour.
- There are several challenges with featuring lamb on the menus:
    1. Cost of raw meat – too expensive compared to other meats, especially chicken
    2. Consistency of quality
    3. Reliability of supply
    4. Whole of carcass is utilised hence limited amount of meat is available for further processing; often relying on lamb shoulder
- Middle Eastern, Greek and Mediterranean flavours go well with lamb
- Warmed over flavour is not an issue with QSR and FSR products
- New lamb products must be able to use existing equipment for cooking and reheating
- There are market opportunities for high quality lamb burger patties and pulled lamb product and hence the two lamb products that were selected to be developed were:
    1. Lamb burger patties
    2. Pulled lamb product

4.3 Development of lamb patties

During the stakeholder interviews, WOF was not identified as an issue in QSR and FSR products, hence the focus for the development of the two lamb products pivoted from WOF to cost reduction and value adding.

4.3.1 Formulation from MLA chef

The initial formulation for the lamb patties, provided by Sam Burke, can be seen in Table 5. This formulation consisted of fresh ingredients.

Table 5: Sam Burke's formulation.

Ingredient	Percentage (%)	Amount (g)
Lamb shoulder	74.7	89.64
Brown onion	9.0	10.80
Parsley	3.7	4.44
Capsicum	10.5	12.60
Salt	1.2	1.44
Black pepper ground	0.2	0.24
Baharat spice mix	0.7	0.84
Total	**100**	**120.00**

The patties were made using the method outlined in section 3.3.4. The meat was minced using an 8 mm mincer plate and the vegetables were diced using a knife (hand cut). The patties were cooked from fresh not frozen, on a 165°C Silex flat grill for 5 minutes on each side to reach an internal temperature ≥75°C.

Based on the informal sensory assessment of the patties by CSIRO staff at Coopers Plains, the following conclusions were made:

- Good appearance, nice aroma, juicy, good meaty bite, slightly salty
- 8 mm mince size gave a good texture but resulted in some large fat and connective tissue particles in the mouth, which made the patties unpleasant to consume

4.3.2 Development of lamb patties

Based on the evaluation of the lamb patties, the following development work was undertaken to reformulate the product to make it more suitable for commercial production:

- Evaluated different particle size of mince – 8, 6 and 4 mm, to improve the texture and reduce large pieces of gristle and connective tissue.
- Developed a dry blend of a Middle Eastern spice mix called Baharat spice mix (Table 6).
- Replaced fresh ingredients with dried ingredients, to suit commercial production.
- Reformulated the patties (Table 7) to match the flavour and texture of the formulation from the MLA chef.

Table 6: Baharat spice mix.

Ingredient	Percentage (%)	Amount (g)
Ground black pepper	19.0	10.50
Ground paprika	19.0	10.50
Ground cumin	19.0	10.50
Ground coriander	9.5	5.20
Ground cloves	9.5	5.20
Ground nutmeg	9.5	5.20
Ground cinnamon	9.5	5.20
Ground cardamon	5.0	2.75
Total	100	55.05

Table 7: Reformulated lamb patty with dry ingredients.

Ingredient	Percentage (%)	Amount (g)
Lamb shoulder	95.0	114.00
Onion kibbled (dry)	0.7	0.84
Rosemary (dry)	0.5	0.60
Chives dry	0.1	0.12
Capsicum (dry)	2.0	2.40
Salt	0.9	1.08
Baharat spice mix	0.8	0.96
Total	100	120.00

Note: the meat content has increased by about 20% (compared to Table 5) because the fresh ingredients like onion, parsley and capsicum were replaced with dry ingredients which have much lower water content and hence needed to be used in significantly lower quantity.

After evaluation of the reformulated product, the following conclusions were made to progress the project, keeping in mind that the market opportunity was for a high-quality lamb burger patty.

- 6 mm mince was the most suitable particle size for the lamb patties, as it resulted in a meaty texture and reduced the amount of gristle and connective tissue pieces.
- Baharat spice blend, adapted from an existing recipe, gave a nice Middle Eastern flavour to the patties, and was to be used in future trials (Table 6).
- Dry ingredient levels were acceptable and to be used in future trials (Table 7).
- The unit cost for the ingredients for a 120 g lamb patty, based on the formulation in Table 7 was $2.06 or **$17.21/kg**. The details of the costs can be seen in Appendix 8.3, Table A1.

4.3.3 Reformulation of the lamb patty for cost reduction

The aim of the cost reduction stage was to maintain the product quality, while reducing the ingredient cost. The following cost reduction steps were undertaken:

- 10% water was added to the formulation, directly replacing 10% meat.

- Citrus fibre was added to increase the water holding capacity and improve fat binding. After several trials, 0.3% citrus fibre was selected as it reduced cook loss and shrinkage and improved the texture of the cooked patty.
- Gluten free breadcrumbs were added as a cost-effective filler, and to maintain the allergen free status of the patties. Breadcrumbs also improved the texture and retained moisture in the cooked patty.
- Addition of dry ingredients instead of fresh, improved commercial processing of the product and reduced chilled/frozen storage costs as dry ingredients can be held at room temperature.
- The revised formulation with cost reduction strategies can be seen in Table 8.
- The unit cost for the ingredients for a 120 g lamb patty, based on the revised formulation was $1.87 or **$15.62/kg**. The details of the costs can be seen in Appendix 8.3, Table A2.

Table 8: Reformulated lamb patty with added ingredients for cost reduction.

Ingredient	**Percentage (%)**	**Amount (g)**
Lamb shoulder	80.0	96.00
Onion kibbled (dry)	0.7	0.84
Rosemary (dry)	0.4	0.48
Chives dry	0.1	0.12
Capsicum (dry)	2.0	2.40
Salt	0.9	1.08
Baharat spice mix	1.0	1.20
Citrus fibre	0.3	0.36
Breadcrumbs (gluten free)	4.6	5.52
Water	10.0	12.00
Total	100.0	120.00

4.4 Development of pulled lamb

4.4.1 Formulation from MLA chef

The initial formulation for the pulled lamb was provided by Sam Burke and can be seen in Table 9. This formulation consisted of lamb shoulder and a commercially available meat rub.

Table 9: Sam Burke's formulation.

Ingredient	Percentage (%)	Amount (g)
Lamb shoulder	89.7	2242.50
Lemon pepper rub (Corona)	10.3	257.50
Total	100.0	2500.00

The pulled lamb product was made using the method outlined in section 3.3.3. The lamb shoulder was sourced from a Woolworths supermarket and the meat rub was provided by MLA.

Based on the informal sensory performed by CSIRO staff at Coopers Plains, the following was concluded on the cooked pulled lamb product:

- 10% rub resulted in an overpowering flavour and the purge/cook loss within the bag was too thick and slightly slimy.
- The rub had a very strong citric acid flavour which was considered unacceptable by the team.
- The meat was tender but still had a meaty bite. However, the consistency of texture from bite to bite varied as some connective tissue had not fully broken down. Also, as a whole shoulder was used, the meat had to be cut up into pieces after cooking to shred the meat into the pulled meat texture.

4.4.2 Reformulation of pulled lamb to improve quality and reduce cost

In a pulled lamb type product, where the product is cooked in a vacuum bag, all the purge/cook loss remains in the bag. To minimise any loss of this flavoursome liquid once the bag is opened, it is vital that the rub can thicken the cook loss into a sauce/gravy. So based on the sensory evaluation of the pulled lamb made using the rub and MLA formulation, the following development work was undertaken to reformulate the product and reduce cost:

- From the survey, it was indicated that Greek and Middle Eastern flavours went well with lamb, hence two different rubs were initially trialled. One was a commercial blend sourced from a premix supplier and the other was developed in-house.
- Different levels of rubs were trialled to optimise the application level in the final product.
- The rub was formulated to add flavour and thicken the captured purge/cook loss to create a sauce/gravy.
- All the sauce was captured and added back into the pulled meat, resulting in minimal weight loss.
- The raw shoulder was cut into pieces and mixed with the rub prior to vacuum packing and cooking. This would avoid having to open the bag after cooking to shred the meat i.e., the meat could be shredded within the bag without opening it, which would reduce packaging and processing costs.

- Reduced cooking times (~8 hours), which would reduce processing cost and provide a more practical processing timeline, were explored. However, reducing the cooking time to 8 hours resulted in a product with inconsistent texture.

Based on the reformulation trials, a new rub was developed which had a Middle Eastern flavour, like the lamb patties, and thickeners like Xanthan gum and modified starches were added to thicken the purge/cook loss, into a sauce/gravy type texture. The new formulation for the rub and the final formulation of the pulled lamb product, can be seen in Tables 10 and 11, respectively.

The lamb shoulder was butterflied to a consistent thickness, mixed with the rub and cooked for 12 hours at 75°C. Using this cooking procedure, lamb shoulder was easy to shred/pull in a mixer. All the sauce was added back and absorbed into the pulled meat, minimising any loss of product.

Table 10: Baharat rub formulation.

Ingredient	Percentage (%)	Amount (g)
Baharat spice mix	55.0	2.37
Rosemary (dry)	4.0	0.17
Capsicum (dry)	15.0	0.65
Xanthan gum	4.0	0.17
Sugar	5.0	0.22
Citric acid	1.0	0.04
Modified Starch	16.0	0.69
Total	100.0	4.30

Table 11: Reformulated pulled lamb formulation.

Ingredient	Percentage (%)	Amount (g)
Lamb shoulder	95.0	950.00
Salt	0.7	7.00
Baharat rub	4.3	43.00
Total	100.0	1000.00

The cost reductions for the pulled lamb product, were based on improving the processing methods, which in turn would result in cost savings. For example, optimising the cooking times, butterflying the shoulder, and shredding/pulling the meat in the bag, would result in long chilled shelf-life of the product and reduce packaging and handling costs. The cost of ingredients per kilogram of pulled lamb based on the formulation in Table 11 is **$17.03**. The details of the costs can be seen in Appendix 8.3, Table A4. During the survey, various portion sizes for pulled meat were suggested. The ingredient cost for various portions of pulled lamb, based on the formulation in Table 11 are as follows:

- 60 g – $1.02
- 70 g – $1.19
- 80 g – $1.36
- 100 g – $1.70

Like the patties, lamb shoulder is 95% of the formulation, hence changes in the lamb shoulder price will have a significant impact on the price per portion.

4.5 Storage trial

Based on the survey results, a single time point storage trial, 28 days (4 weeks), was undertaken to assess impact of frozen storage on sensory and product attributes as outlined in Section 3.3.4. i.e., cook loss, shrinkage, TBAR's, objective texture and informal sensory for lamb patties; and informal sensory for pulled lamb. Samples were assessed on Day 1 and Day 28.

4.5.1 Storage trial results for lamb burger patties

Analysis of lamb patties

The lamb patties were manufactured using the reduced cost formulation in Table 6 and method described in Section 3.3.2. The patties were cooked from frozen on a Silex hot plate and analysed for various attributes on Day 1 and Day 28. The data from the analysis is summarised in Table 12.

Table 12: Product attributes for cooked lamb patties on Day 1 and 28.

Analysis	Unit	Day 1	Day 28
Cook Loss (n=6)	%	24.4 ± 1.4	22.6 ± 4.7
Shrinkage (n=6)	%	21.2 ± 0.9	19.7 ± 1.5
Kramer shear texture (n=6)	N	698.2 ± 61.2	591.2 ± 24.1
TBARS (n=3)	mg/kg	0.237 ± 0.025	0.230 ± 0.016

Informal sensory on lamb patties

As outlined in section 3.3.4, informal sensory was undertaken by CSIRO staff, using the questionnaire in Appendix 8.2.1. The twelve participants' responses to each of the sensory attributes for Days 1 and 28 are summarised in Fig. 5. The results show that the sensory attributes of the lamb burger patties did not change over 28 days frozen storage. There was a slight decline in overall flavour intensity, however all other attributes remained the same. Hence it can be concluded that the frozen storage did not negatively affect the sensory attributes of the lamb patties.

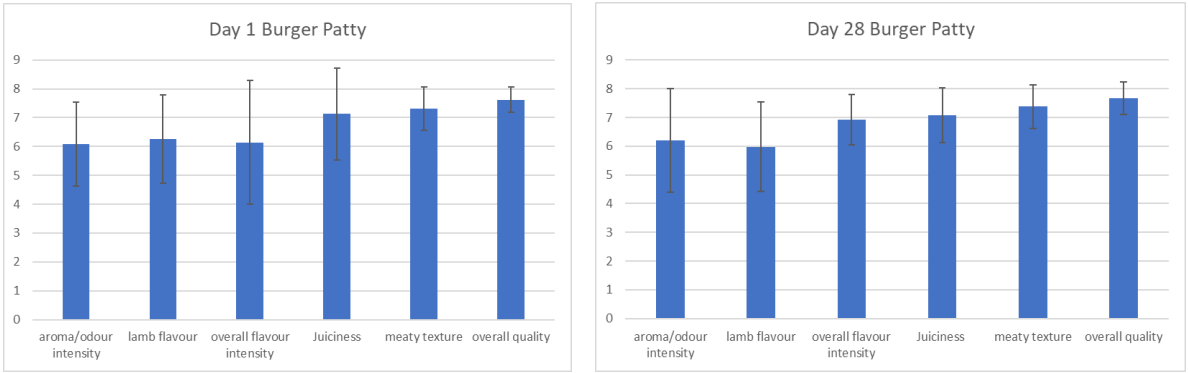

Figure 5: Sensory attributes of lamb patties cooked on a Silex hot plate on Day 1 (left) and Day 28 (right).

During the survey, some participants had indicated that they cooked burger patties in the oven as well. Hence for Day 28 assessments, lamb patties were cooked using two different cooking methods i.e., grilled on a Silex hot plate and dry baked in the oven and evaluated by the informal sensory panel. The effect of the cooking method on sensory perception is summarised in Fig. 6. The appearance of the grilled patty was preferred by most participants, and the grilled version was rated

slightly higher for all attributes except juiciness, which may be due to the lower cook loss in the baked patty (data not shown).

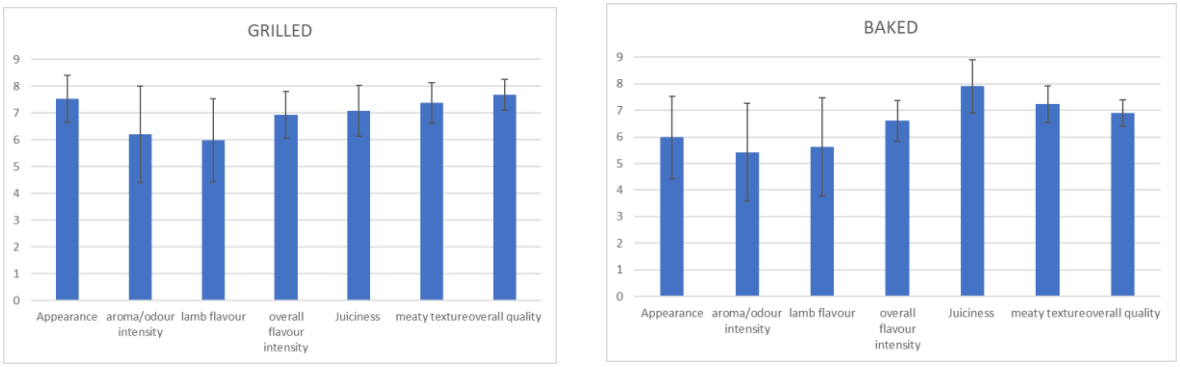

Figure 6: Sensory attributes of lamb patties cooked on a Silex hot plate (left) and baked in an oven (right) after Day 28 of storage.

4.5.2 Storage trial results for pulled lamb

The pulled lamb product was manufactured using the formulation in Table 11 and the method described in Section 3.3.3. The vacuum packed, pulled lamb product (100 g) was defrosted in a 2°C chiller overnight and reheated in a non-stick fry pan to an internal temperature of ≥75°C. A portion of the product (approximately a tablespoon) was given to the participants for sensory assessment on Days 1 and 28. The participants used the questionnaire in Appendix 8.2.2 to assess the pulled lamb. The results from the sensory assessment are summarised in Fig. 7. As can be seen, there were minimal changes in any sensory attributes over the 28-day storage period. Hence it can be concluded that frozen storage did not negatively impact on the sensory attributes of pulled lamb.

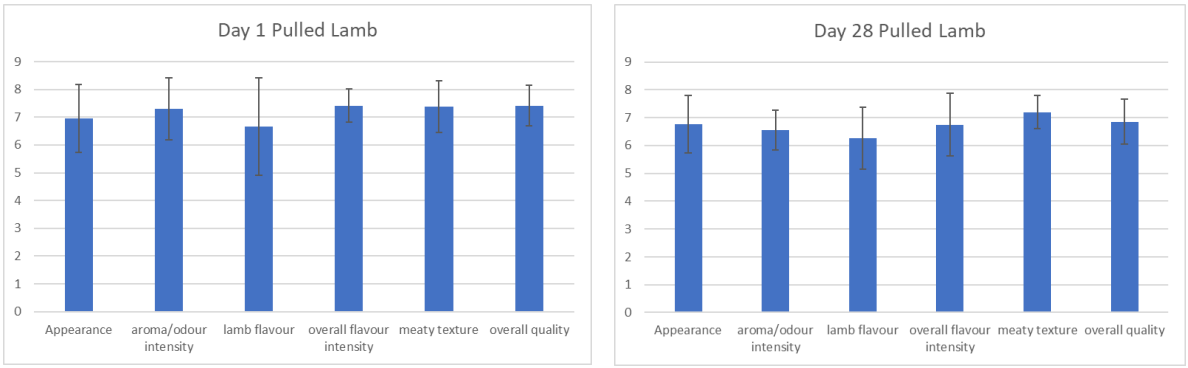

Figure 7: Sensory attributes of reheated pulled lamb on Day 1 (left) and Day 28 (right) of storage.

4.6 Nutritional profile of two lamb products

The nutritional profile of the raw lamb patty and pulled lamb was calculated using the FSANZ Nutrition calculator Manage Recipes (foodstandards.gov.au), based on the formulations in Table 6 and Table 9, respectively.

Raw lamb patty

NUTRITION INFORMATION				
Servings per package:	1			
Serving size:	120	g		
	Average Quantity per Serving		Average Quantity per 100 g	
Energy	982	kJ	818	kJ
Protein	16.6	g	13.8	g
Fat, total	16.4	g	13.7	g
- saturated	6.6	g	5.5	g
Carbohydrate	5.2	g	4.3	g
- sugars	0.9	g	0.8	g
Sodium	484	mg	403	mg

Pulled lamb

NUTRITION INFORMATION				
Servings per package:	1			
Serving size:	100	g		
	Average Quantity per Serving		Average Quantity per 100 g	
Energy	902	kJ	902	kJ
Protein	16	g	16	g
Fat, total	16.2	g	16.2	g
- saturated	6.5	g	6.5	g
Carbohydrate	1.5	g	1.5	g
- sugars	0.3	g	0.3	g
Sodium	313	mg	313	mg

4.7 Conclusions from the product development trials

In line with the findings from the stakeholder interviews, two high quality lamb products for QSR/FSR applications were successfully developed.

- Cost of raw material was addressed by replacing meat with water and added ingredients.
- Product quality and consistency was improved through mincing and mixing of the product for the lamb patties.
- Cook or reheat from frozen product resulted in increased shelf-life and reduced wastage.
- 28 days of frozen storage did not impact on the objective and sensory quality of both products.
- No specialized equipment was required to cook or reheat the two products.
- Product cost is highly dependent on the cost of the lamb shoulder.
- Unit cost can be further reduced, but this could impact on product quality.

5. Conclusion

The stakeholder interviews provided great insights into the positive aspects, and the challenges that the QSR and FSR industry face with featuring lamb on their menus. They identified market opportunities for two products: (i) high quality lamb burger patties and (ii) pulled lamb product, which were developed in this project.

Warmed over flavour was not identified as an issue in QSR and FSR products, hence the focus for the development of the two lamb products pivoted from WOF to cost reduction and value adding. As lamb shoulder constitutes 80-95% of the product formulation, the ingredient cost of the two products was highly dependent on the raw material cost – lamb shoulder.

5.1 Key findings

Stakeholder interviews

- Lamb is traditionally eaten as part of a meal e.g., as roasts and chops, therefore lamb is not considered a 'go to' protein in QSR compared to chicken and beef.
- Lamb is preferred by the older demographics, as they grew up with eating lamb and like its flavour.
- There are several challenges with featuring lamb on the menus:
  - Cost of raw meat – it was too expensive compared to other meats. The premium price leans it towards a special occasion meal rather than QSR.
  - Consistency of quality – variability in the product quality e.g., seasonal issues with rib fattiness.
  - Reliability of supply (ribs) – when purchasing for a chain of restaurants as a promotional item, supply can be an issue.
  - Whole of carcass is utilised with limited off-cuts i.e. lamb legs, ribs and shanks are often used for roasting or slow cooking, hence limited amount of meat is available for further processing; often relying on lamb shoulder to be the only source of manufacturing meat for value adding.
- Mediterranean flavours (Middle Eastern, Greek) are suited to lamb.
- Warmed over flavour is not an issue with QSR and FSR products.
- New lamb products must be able to use existing equipment for cooking and reheating.

Development of two lamb products

- High quality lamb burger patties and pulled lamb products were developed and were rated highly by an informal sensory panel.
- Cost reduction strategies for lamb patties included replacing meat with water, citrus fibre and breadcrumbs, which led to ingredients costs of $15.62/kg.
- Cost reduction strategies for pulled lamb included formulation and processing changes such that there was minimal wastage when the cooked lamb was shredded in pulled lamb texture, which led to ingredient costs of $17.03/kg.
- Frozen storage for 28 days did not impact on the sensory quality of either product.
- The products could be cooked and reheated using existing equipment in QSR/FSR i.e., no specialised equipment was required.

5.2 Benefits to industry

- The industry should consider the findings from the stakeholder interviews and address the challenges that have been identified around product quality, consistency, reliability of supply, and costs, such that lamb can be featured on the QSR/FSR menu all year round, rather than as a special occasion meat.
- The two products developed in this project – lamb burger patty and pulled lamb – both utilise lower value cuts. This creates a great opportunity for the industry to value add to the lower value lamb cuts and trim, as well as address the unmet needs of the QSR/FSR market and consumers.
- Both products can be stored and cooked from frozen without impacting on sensory quality. This would negate the need to thaw the product in advance which would reduce product wastage; and the industry could maintain a continuous supply of these products such that lamb products could be regularly featured on QSR/FSR menus, which would increase the demand for Australian lamb.

6. Future research and recommendations

It is recommended that MLA approach the various stakeholders that were interviewed and had indicated their interest in participating in the lamb promotion campaign and gauge their interest in further developing these products and testing/featuring these products at their venues.

CSIRO can collaborate with the stakeholders on product development, product expansion and technology transfer strategies, based on their needs.

The ingredient costs used in this project were based on purchasing these items at small scale i.e., retail prices. These ingredient costs could be reduced if they were purchased in bulk. Alternatively, an ingredient supplier can be contracted to prepare the pre-mix for the lamb patties and pulled lamb. These approaches would ease production costs of these items at commercial scale.

The outcomes from the product development stage of this project could be deployed to other red meats such as beef and goat.

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8. Appendix

8.1 Customer Interview Questionnaire

Introduction

As mentioned in our email, in a joint project between CSIRO and MLA, we are trying to find out why lamb-based products are not served in QSR restaurants as frequently as beef and chicken-based products. We would like your opinion on your previous experience with serving lamb, including a description of things you would need to take into consideration in order to add lamb products onto your menu. Also, what type of products we should try to develop for the QSR market.

1. Have you previously made available a range of lamb products on your menu?

   Yes/No

   If Yes, what was your offer and was it successful?

   If No, what prevented you from using any lamb-based products on your menu?

2. You indicated previously that you had ranged a lamb-based alternative on your menu. Were there any issues that you had identified in maintaining and ranging the product?

3. How long were they maintained at a safe serving temperature, prior to purchase and consumption?

4. Was lamb product quality maintained during this holding period or was it compromised, and if so, what were the challenges identified?

5. Were there any particular regional influences on your menu selection? For example, Greek, Australian, Asian and Middle Eastern cuisine styles.

6. What do you think were the compelling value/quality propositions for customers who purchased this lamb product?

7. When lamb is on the menu how does it perform relative to other menu items? That is, what percentage of customers purchase lamb?

8. Why do you believe that this is/was the case?

9. If you were to offer lamb products on your menu what would they look like, and how would it be prepared and offered relative to other proteins on your menu?

10. Would you utilise existing kit and equipment or would you require additional kit?

11. How would you maintain temperature and quality of this product in your prep/service area?

12. What would be your target volumes and cost per unit if you were to offer a lamb product on your menu?

13. And based upon your response to the previous question, what would be your target weight/portion size for your lamb product? For example, what would be the targeted weight for a lamb patty for a lamb burger.

14. Who do you believe are the target market for the consumption of lamb products on your menu?

15. Do you believe there are any target markets that could be identified in the development of a lamb new product development range?

16. What cuts/products would be of particular interest if you could range them? burgers/rissoles/kofta, lamb shanks/shank meat, pulled lamb shoulder, diced lamb, lamb ribs, roasting portions such as leg and shoulder

17. Would an opportunity to work with MLA/CSIRO to develop new and unique lamb products be of interest to you? This could include participation with our award-winning lamb campaign activation and integration. For example, MLA Australian lamb and summer lamb campaigns.

8.2 Informal Sensory Questionnaire

8.2.1 Grilled Lamb Patties

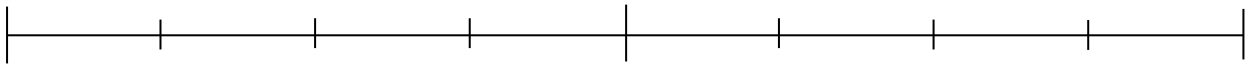
Name: ***Date:***

Grilled Lamb Patties

please place a mark on the line provided

Appearance

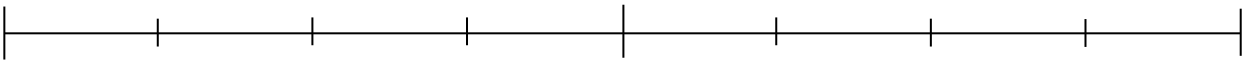
1 2 3 4 5 6 7 8 9

Low  High

Comments on appearance:

Odour/aroma intensity

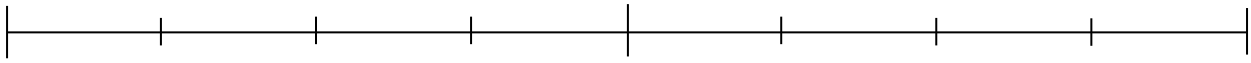
1 2 3 4 5 6 7 8 9

Low  High

Comments on aroma intensity:

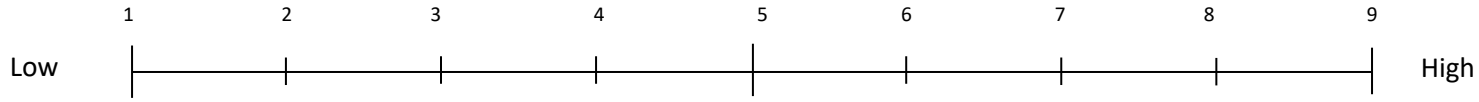
Lamb flavour intensity

1 2 3 4 5 6 7 8 9

Low  High

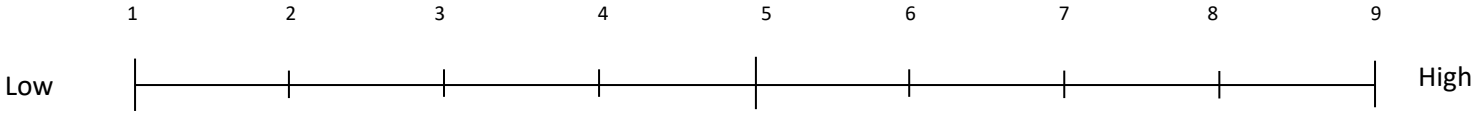
Comments on meat flavour intensity:

Overall flavour intensity



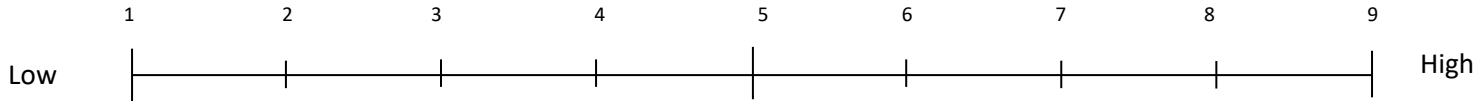
Comments on flavour intensity:

Juiciness



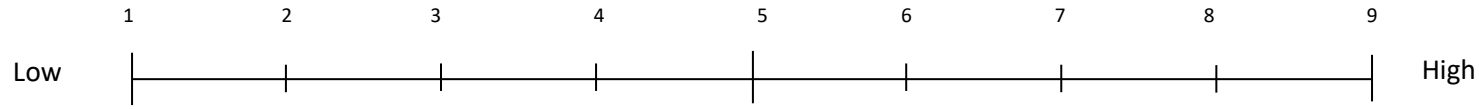
Comments on juiciness:

Meaty texture



Comments on meaty texture:

Overall quality



Comments on overall quality:

8.2.2 Pulled Lamb

Name: ***Date:***

Pulled Lamb

please place a mark on the line provided

Appearance

1 2 3 4 5 6 7 8 9

Low High

Comments on appearance:

Odour/aroma intensity

1 2 3 4 5 6 7 8 9

Low High

Comments on aroma intensity:

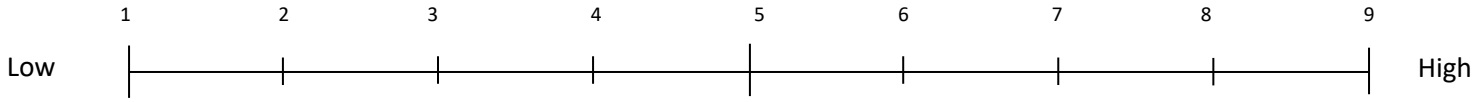
Lamb flavour

1 2 3 4 5 6 7 8 9

Low High

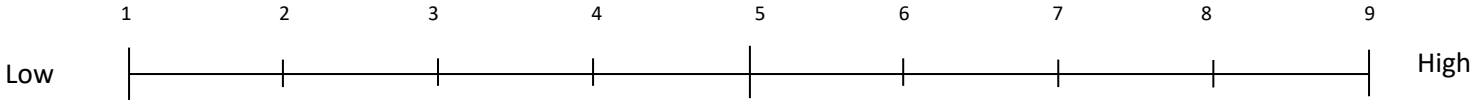
Comments on lamb flavour:

Overall flavour



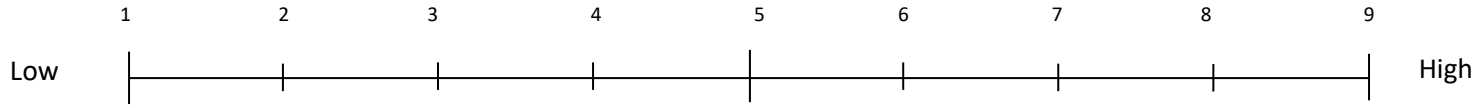
Comments on overall flavour:

Meaty texture



Comments on meaty texture:

Overall quality



Comments on overall quality:

8.3 Product costings

Table A1: Ingredient cost for lamb burger patty with dry ingredients.

Lamb burger (original)					
Ingredient	**Percentage (%)**	**Amount (g)**	**Price/kg**	**Cost per unit**	**Cost per kg**
Lamb shoulder	95.0	114	16.00	1.82	15.20
Onion kibbled (dry)	0.7	0.84	38.00	0.03	0.27
Rosemary (dry)	0.5	0.6	50.00	0.03	0.25
Chives (dry)	0.1	0.12	133.00	0.02	0.13
Capsicum (dry)	2.0	2.40	45.00	0.11	0.95
Salt	0.9	1.08	0.90	0.00	0.01
Baharat spice mix	0.8	0.96	55.00	0.05	0.44
Total	100	120.00		**2.06**	**17.21**

Table A2: Ingredient cost for cost reduced lamb burger patty - with dry ingredients, citrus fibre, breadcrumbs and water added.

Lamb burger (cost reduced)					
Ingredient	**Percentage (%)**	**Amount (g)**	**Price/kg**	**Cost per unit**	**Cost per kg**
Lamb shoulder	80.0	96	16.00	1.54	12.80
Onion kibbled (dry)	0.7	0.84	38.00	0.03	0.27
Rosemary (dry)	0.4	0.48	50.00	0.02	0.20
Chives dry	0.1	0.12	133.00	0.02	0.13
Capsicum (dry)	2.0	2.4	45.00	0.11	0.90
Salt	0.9	1.08	0.90	0.00	0.01
Baharat spice mix	1.0	1.2	55.00	0.07	0.55
Citrus fibre	0.3	0.36	80.00	0.03	0.24
Breadcrumbs (gluten free)	4.6	5.52	11.40	0.06	0.52
Water	10.0	12	0.00	0.00	0.00
Total	100.0	120		**1.87**	**15.62**

Table A3: Ingredient cost for Baharat rub.

Baharat rub			
Ingredient	**Percentage (%)**	**Price/kg**	**Cost per kg**
Baharat spice mix	55	55.00	30.25
Rosemary	4	50.00	2.00
red bell peppers (dry)	15	45.00	6.75
Xanthan gum	4	55.00	2.20
Sugar	5	1.10	0.06
Citric acid	1	30.00	0.30
Modified starch	16	5.00	0.80
Total	100		**42.36**

Table A4: Ingredient cost per kilo for pulled lamb.

Pulled lamb shoulder				
Ingredient	**Percentage (%)**	**Amount g**	**Price/kg**	**Cost per kg**
Lamb shoulder	95	950	16.00	15.20
Salt	0.7	7	0.90	0.01
Baharat rub	4.3	43	42.36	1.82
Total	100	1000		**17.03**