Final report

Baseline consumer sensory testing of alternate protein burgers

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Abstract

In 2019 there was a large increase in the range of plant protein burgers available on the Australian market. This trial was designed to gauge consumer response to alternative burger products ranging from entirely plant-based, beef blends through to pure beef patties. All patties were reformed to a standard size (60mm x 20mm) and weight (60g) and cooked for 4.25 minutes to a minimum internal temperature of 70 ˚C. The burgers were tasted by 120 consumers in both a “rural” and “city” location. Primary results revealed different weightings of the sensory variables (BQ = 0.1*tn + 0.1*ju + 0.5*fl +0.3*ov) for calculating a burger patty eating quality score compared to the standard MQ4 calculation. There was no difference found in eating quality scores between the two locations. The blended patties were most liked by consumers and, the plant-based alternatives liked the least. Overall, the range of consumer scores from burger products, were less variable than typical across different beef cuts. These results provide an important insight into what variables are valued by consumers in their burger products and related attitudinal responses affecting purchasing habits. Of note was the strong adverse reaction to the ingredient lists of alternative protein products.

Executive summary

The project was commissioned by MLA to gauge untrained consumer sensory and attitudinal response to a range of burger products including meat-free and beef blend products which have been recently introduced to the Australian market with considerable marketing and public relations support.

These market changes, and in particular aggressive promotion of an anti-meat agenda linked to claims relating to climate change, human health and animal welfare, represent a well-funded challenge to the industry with the project designed to establish some baseline knowledge as to both product performance, and consumer attitude to burger products ranging from pure beef to blends to non-meat. The new market dynamics are instructive in that, where butcher tradition may have been to add some vegetables and fillers to a burger or sausage to reduce cost and offer a lower retail price, the new paradigm has the non-meat products priced at a factor of 2 to 6 times a traditional low end beef burger, the premium being asked for a claimed beef-like taste and the absence of actual meat.

Six products were tested with two non-meat offers, 2 beef blends, 1 high beef content and a benchmark 100% beef patty with no additives. A 95% lean 100% beef unseasoned patty was used as a standard "link" product, served first to all consumers prior to the 6 test products which were rotated in a balanced presentational order. The test patties were standardised for size (60mm diameter by 20mm depth) and to a 60gm weight and cooked for standard time to ensure a 70 to 75˚C internal temperature. Initial cooking tests were conducted with each product in their standard form to measure changes in dimension and cook loss. A standard cooking chart was then developed for the consumer tests. Label ingredient and marketing claims were recorded for each retail product.

Consumer testing was conducted in two locations, Deepwater NSW representing a country demographic and Helensburgh NSW representing an outer urban Sydney demographic, with 60 consumers participating in each. Each consumer was served the link and 6 test products which they scored on 100mm line scales for tenderness, juiciness, flavour and overall satisfaction and then selected a category box with options of unsatisfactory, good everyday, better than everyday or premium quality. Basic demographic data was recorded and, after tasting all products, further data relating to willingness to pay and attitudes to purchasing alternative protein products and to alternate ingredient lists collected.

While further improvement may occur in the non-meat products this trial found that associated value claims would need to heavily relate to perceived benefits unrelated to the eating experience. Both non-meat products rated lowest, with one exceptionally low, allied with price points of 6 and 2 times the lower end traditional beef burger with fillers. In contrast the blended products scored best, differentiated by very high tenderness and juiciness scores whereas the high and pure beef products had lower tenderness and juiciness, correlated with higher cook loss and possibly reflecting their lower fat content and high cooking temperature.

Flavour was the dominant (50%) influence on consumer eating satisfaction and above the standard MSA beef weighting of 30%. A burger specific "BQ" descriptor was established from the data with weightings of 10% for tenderness and juiciness, 50% flavour and 30% overall satisfaction.

Consumer attitudes to trialling alternative proteins differed by income, higher income groups being more open to trial, but all groups expressed concern as the ingredient list expanded and included many unnatural or uncommon ingredients.

Given the low to moderate sensory results for non-meat products it is likely that premium priced marketing of these products will be based on unsubstantiated claimed benefits relating to human health and diet, animal welfare and climate impact. It is vital that industry continues to improve in these aspects and, critically, to successfully communicate from a solid science base resulting in a balanced factual appreciation at farm and consumer level.

This project only represents a small number of samples and consumers, so some more work in this space would lead to more conclusive results and increased reliability. It is recommended that further work be conducted to better define relationships to fat level in high beef content burgers and to both minor ingredient additions and cooking regimes that may reduce cook loss which was correlated strongly with reduced tenderness and juiciness in this study.

It is also strongly recommended that detailed chemical analysis of the trial products be considered to establish the human dietary implications and relative quantity and bioavailability of key dietary components. The profiles of fatty acids, proteins and amino acids, micronutrient levels and bioavailability of each in alternative protein products relative to the beef and beef blends are currently not known.

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1. Background

The MLA project brief defined the project as follows:

In 2019 there has been an increase in the range of plant protein burgers in the Australian market. This has also included some meat and plant protein blended products such as reduced meat content sausages, often targeting the flexitarian consumer.

MLA has several blended prototypes such as meatballs, burgers, dumplings and dried meat snack "twiggy-style" sticks being developed with a leading US ingredient supplier (V.RMH.0003) with key learnings in ingredient functionality as well as insights into shopper behaviours and category drivers being derived for flexitarian and meat-less markets.

MLA is also currently completing a large systems dynamic modelling project (V.RMH.0081) comparing the sustainability impacts of 100g mince of alternate proteins along with a watching brief on consumer insights and sentiment globally for this category.

This project will apply the MSA protocols for juiciness, tenderness, flavour and overall meat quality (MQ4) score for 6 types of burgers currently available in the retail to enable provisions for a baseline of "eating-profiles" to be developed.

2. Objectives

The project objectives were agreed as:

- Design and deliver a MSA protocol sampling plan for 6 different burger patties as agreed to by MLA (Achieved)
- Procure burgers, recruit panellists and complete sensory tests. (Achieved)
- Record shrinkage yields from cooking from the sample size in terms of weight loss and diameter of the patties from pre- and post-cooking across the burger types (Achieved)
- Complete statistical analysis on the results (Achieved)
- Final report – collate key findings into standard MLA final report template and include an overview of the methodology used. Include pictures of the sampled product and related labels or information from vendors such as ingredient listing and nutritional information panel and serving suggestions and retail sell pricing. Include pictures of the pre- and post-cooked burgers. Include commentary of MSA MQ4 score for burgers. (Achieved)

3. Methodology

A small project was designed to achieve a baseline for consumer testing of alternative protein burgers. It was decided that products be representative of the current protein burgers available to consumers from the large food retailers such as Coles and Woolworths.

Existing MSA consumer testing methodology was adapted to suit testing of burgers. The adaption related to creating burgers of standard dimension and weight to enable a common cooking protocol and the post tasting collection of additional attitudinal data related to alternative protein products. Existing MSA protocols were utilised to control product cooking, serving and data recording routines providing excellent reference points to over 180,000 consumer tests of beef cuts and cooking methods, conducted in 11 countries over a 25-year period.

The MSA standard protocols specify the serving of a standard presumed mid-range product as the first sample to all consumers, termed a "Link", followed by six products of anticipated different quality. Each of the 6 test products are served in a 6x6 Latin square order resulting in each being served equally before and after each other product, and equally in serving orders 2 to 7. Testing is arranged in "Picks" being a group of 60 consumers who evaluate the 42 samples, 6 being Links and 6 within each test product. Each consumer evaluates 7 samples, with each sample being assessed by 10 consumers. The "Link" results are handled separately to the core 6 test products.

The products selected were:

I. The Beyond Burger – (Plant-based protein), Coles
II. The NextGen2 Burger – (Plant-based protein), Woolworths
III. Type A Mince Prototype – (Blended beef and vegetable)
IV. Beef BBQ Burgers – (fillers), Coles
V. 85VL Mince – (no additives), similar to Coles or Woolworths mince
VI. Cleaver's Chuck and Brisket Burger – (seasoning and sautéed onions), Coles
VII. LINK – 95VL Mince, similar to Coles or Woolworths lean mince

3.1 Sourcing product

On the 11th of March 2020 the retail burger products were purchased at different stores along the NSW Coast as listed below with further detail in Table 1. Shop location was written on each of the packets for traceability purposes.

- Helensburgh, 2508 (Coles)
- Engadine, 2233 (Coles & Woolworths)
- Menai, 2234 (Woolworths)
- Carlingford, 2118 (Coles)
- Gosford, 2250 (Coles)
- Lisarow, 2250 (Coles)
- Wyoming, 2250 (Coles)
- Erina, 2250 (Coles)

A total of 6Kg of each product was obtained to ensure that there was sufficient to fabricate the consumer sensory samples (n = 420), test the packaged product and obtain 2 large samples (approximately 500gm) of each product for chemical analysis.

The Type A mince blend prototype was supplied directly from the processing factory and was therefore not packaged or labelled like a retail product. The 85 and 95VL mince was supplied and mixed at The University of New England Meat Laboratory, and therefore also not packaged or labelled.

Table 1: Distribution of retail burger packs purchased from different store locations (counts).

Shop location	Burger id			
	Beyond burger (BYB99)	NextGen2 burger (NXG99)	Beef BBQ burgers (BBQ99)	Cleaver's chuck and brisket burger (CBB99)
Carlingford (Coles)	3			7
Engadine (Coles)			4	
Engadine (Woolworths)		5		
Erina (Coles)	9			
Gosford (Coles)				4
Helensburgh (Coles)	6		1	3
Lisarow (Coles)	5			
Menai (Woolworths)		9		
Wyoming (Coles)	1		1	
Total	**24 packs**	**14 packs**	**6 packs**	**14 packs**

These products were kept chilled for transport to UNE, Armidale and held in the UNE Meat laboratory chiller at 2°C prior to commencing further activity.

3.2 Product measurements

On the 12th of March each retail pack was placed in a shop location group as shown in Figure 1, then labelled with a code and number that was related to shop location (e.g. Beyond Burger Packet 1 was BYB P1, as shown in Table 2). Once all packets were labelled, photographs were taken of the packaging and labels on each of the products to identify ingredient lists, nutritional information, cooking instructions and label claims (See Appendix 8.1).

Table 2: Burger products and their respective codes.

Burger	Burger ID
Beyond Burger	BYB999
NextGen2 Burger	NXG999
Type A Blended mince prototype	ARB999
Beef BBQ Burger	BBQ999
95VL Mince	BBN095
85VL Mince	BBN085
Cleaver's Chuck and Brisket Burger	CBB999

Each packet was then opened, and the following information was recorded on a spreadsheet; Burger/Packet ID, Store location, best before date, Patty weights (gms), diameter (mm) and thickness (mm) and a description of the product such as texture, smell or quality. Each patty from all packets was weighed and measured to determine the range and consistency across batches (Fig. 2 & 3). Several patties dispersed across the different shop locations and best before dates were kept aside for cooking trials (Fig. 4).

Figure 3: Measuring the diameter and thickness of the pre-packaged patties.

Figure 4: Selected patties were put aside for cooking evaluation in retail packaged form.

3.3 Pooled samples

All remaining patties from each individual product was mixed vigorously together to create uniform pooled samples to eliminate any batch effect (Fig. 5). This was done for all 7 products. The 85VL and 95VL was made up at UNE using a meat mixer / grinder (Appendix 8.1.6). The 85VL was made by combining 10% of fat to the 95VL mince and processing through the grinder several times to ensure that the fat was well dispersed throughout the batch.

Figure 5: Patties mixed together to create a uniform mix of all samples within each product.

3.4 Cooking trial – standard retail form

The selected patties were cooked as packaged following the on pack cooking instructions. A SILEX S-TRONIC 161 grill was used at a temperature of 250°C, cooking on the bottom plate only with the upper plate left in the raised (no contact) position (Fig. 6). Three burgers of the same product were placed on the grill at three designated positions each time and flipped at the 2-3-minute mark cooking until an internal temperature of 75°C was reached as measured by a probe thermometer (Fig.7). A finish time was recorded on a spreadsheet and each cooked patty weighed and measured to determine cook loss and physical shrinkage. The degree of browning, cooked odour and spread of liquid and fat was also noted on the spreadsheet for each product. Photographs were taken of each product after cooking (Appendix 8.1). This was repeated for all products. While each retail product was cooked in standard form the Type A mince prototype blend and 85/95VL products supplied as bulk mixes were cooked in the 60gm sample patty form adopted for the formal consumer testing.

Figure 6: Grill trial setup for alternative protein burgers.

Figure 7: Packaged samples cooked on the SILEX S-TRONIC 161 at 250C as per cooking instruction on the label with common plate position used for all products and temperature recorded.

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3.5 Consumer sensory samples

Consumer sample patties were made up from the large pooled batch of each product, previously mixed to eliminate any batch effect and ensure a uniform composition. These patties were made using a 60mm wide and 20mm high metal scone cutter to ensure samples were uniform across the trial (Fig. 8). The scales were tared for the weight of the scone cutter and each sample patty was formed to 60 grams. Sample patties were then placed into vacuum bags (300mm x 250mm), 5 samples per bag with product labels, then frozen (Fig. 9). The product labels were created using the MSA CUD Software adapted from the GRL protocols and contain two unique identifiers:

- Sequence number, a sequential number used to store, and retrieve cut up samples
- EQS reference, a four-character alpha numeric code used as the primary sample identifier throughout the sensory system.

For this trial 2 consumer picks were designated with one to be served to a rural population and the other to a progressive urban population in Sydney or Melbourne. The pooled sample procedure was adopted to minimise variability within the 7 products served to every consumer across both demographics. For two picks 84 samples were required, 42 per pick and 6 within each product in each pick. The 5 patties within each sample were designated for serving to 10 consumers, being halved after cooking. Consequently 12 samples, each with a unique Sequence and EQSRef code and containing 5 patties, were required.

Hence for each product a total of 60 patties was required to serve the 120 consumers in the 2 picks (5 patties x 6 unique EQS positions for each product) x 2 picks) resulting in a total of 420 patties being fabricated.

Figure 8 and 9: 60gm sample patties (60mm diameter by 20mm height) being made and shaped by the scone cutter (left) and samples placed into labelled vacuum bags (right).

3.6 Cooking timing chart trial

3.6.1 Previous timing protocol

Initial cook testing utilised an earlier MSA burger trial with the timing chart shown in Figure 10. The prior work had been conducted using a SILEX S143 clam shell grill with the lid closed and both plates set at 250°C. Additional patty samples were made to test the previous timing chart for burgers using the SILEX S-Tronic 161 also with the lid closed. To determine sample positioning on the grill (Fig. 11), round sheets were adapted from the current MSA GRL Protocols designed to ensure randomised product positioning across the grill and to control serving order within each pick (Appendix 8.2). The Round sheet allocation ensures that cooking results are not confounded by positioning on the grill. Internal temperatures were taken after samples were removed from the grill after each round and recorded on a spreadsheet. Again, these burgers were weighed and measured to calculate cook loss. Results revealed that the cooking time was slightly too long with burger internal temperatures averaging 83.2°C. It was also noted that the Cut up & Serve time was quite long with burgers resting for over 2 minutes resulting in the internal temperature being significantly lower at the chart denoted serving times in Figure 10.

It was also noted that the cooking time was considerably reduced with the top plate closed and significantly lower than those observed for retail product on the bottom plate only.

Figure 10: The initial timing sheet for 60gm burgers with a cook time of 4 minutes and 30 seconds.

COOKING CHART FOR 60 gm Beef Burgers (60mm dia x 20mm thick) ON SILEX S143

Top Plate 250°C **Bottom Plate 250°C**

Note: Cooked with central Wt/Ht setting

Round No.	*Unload Steaks*	Load Next	*Close Lid*	Cut Up & Serve
		START	*00:30*	
Starters	*4:30*	6:00	*6:30*	
1	*10:30*	12:00	*12:30*	12:30
2	*16:30*	18:00	*18:30*	*18:30*
3	*22:30*	24:00	*24:30*	*24:30*
4	*28:30*	30:00	*30:30*	*30:30*
5	*34:30*	36:00	*36:30*	*36:30*
6	*40:30*	42:00	*42:30*	*42:30*
7	*46:30*			*48:30*

Figure 11: The round sheet layout (left) and grilled patties (right) testing the previous timing chart for 60gm patties.

3.6.2 New amended timing protocol

Additional sample patties were made for the following day, 13th of March to allow for another cooking trial using a revised cooking sheet with cooking time reduced by 15 seconds to 4 minutes 15 seconds per round (Fig. 12 & 13) and an earlier cut up and serve time. An additional person was required for this protocol as burgers needed to be temperature checked and cut up in a shorter time frame to avoid cooling. Three rounds were completed using the amended timing chart and internal temperatures were recorded after samples came off the grill in each round. These temperatures were much less variable and closer to the desired 75°C internal temperature with an average burger temperature of 75.9°C. It was noted that the 7 products cooked at a very similar rate despite radically differing composition, possibly reflecting common mass, density and moisture content.

Therefore, for this trial the changes in protocol to previous cooking trials were;

1. Cooking time was reduced by 15 seconds to avoid over cooking of the samples
2. Cut up & Serve time was brought forward by 45 seconds
3. An additional person was required at the grill to temp all the samples in time for the earlier cut up & serve timings

Figure 12: Revised cooking timing chart of shortened cook time to 4 minutes and 15 seconds.

COOKING CHART FOR 60 gm Beef Burgers (60mm dia x 20mm thick) ON SILEX S-Tronic 161

Top Plate 250°C Bottom Plate 250°C

Note: Cooked with central Wt/Ht setting

Round No.	*Unload Steaks*	Load Next	*Close Lid*	Cut Up & Serve
		START	*00:30*	
Starters	*4:15*	6:00	*6:30*	
1	*10:15*	12:00	*12:30*	11:30
2	*16:15*	18:00	*18:30*	*17:30*
3	*22:15*	24:00	*24:30*	*23:30*
4	*28:15*	30:00	*30:30*	*29:30*
5	*34:15*	36:00	*36:30*	*35:30*
6	*40:15*	42:00	*42:30*	*41:30*
7	*46:15*			*47:30*

Figure 13: Test rounds 1 and 2 of prepared 60gram burger samples ready to be loaded onto the Silex.

3.7 Picking and posting sensory samples

The frozen samples allocated to the 2 picks were managed utilising standard MSA GRL Procedures (Fig. 14). MSA software was utilised to allocate samples to sensory products 1 (link) to 7 with each burger type being a product and 6 samples within each product for each pick. The software allocated each patty to a round sheet and position which controlled cooking and serving order and ensured precise 6 x 6 Latin square presentation.

Each pick box was checked to confirm the correct EQSRef samples were present, then "posted". The posting procedure, illustrated in Figure 14, was conducted by laying out the 42 samples in alphanumeric order adjacent to the vacuum packer. One person then placed a Round sheet in a water protective sleeve in turn within a large 250 x 350mm vacuum bag placed on a metal clipboard. The 10 EQSREF codes printed on the Round sheet were then in turn called, a second person located the matching bag and called back the Sequence number. When the cross check was confirmed one patty from the sample was passed to the first person and placed over the relevant EQSRef and Sequence code. When the 10 patties were in place the Round sheet was transferred to the vacuum packer, vacuumed and sealed to retain the patties in position.

The 21 Round sheets for each pick were then packed in Styrofoam boxes together with 3 bags of beef starter steaks used to condition the grill prior to the sensory sample rounds and returned to frozen storage ready for sensory testing.

Figure 14: Posting of burger samples to Round sheets as per MSA grill procedures.

3.8 MSA consumer sensory sessions

MSA sensory evaluation by untrained consumers was conducted on 7 burger products to evaluate differences between the wide range of burger products available on the market ranging from beef through to plant-based alternatives. The product was tested by 2 groups of 60 NSW consumers (each group of 60 comprising a pick). Two different populations were chosen for the different sensory sessions;

- A remote ("country town") group – Deepwater (D), NSW
- A city ("trendy big city") group – Helensburgh (H), NSW

These two groups were chosen to obtain some additional information regarding whether there was a difference in acceptance/liking for alternative protein sources dependent on location.

While the original plan was to recruit the "city" population from Newtown NSW, a suburb known to represent a young and "trendy" population including anti-beef type consumers COVID restrictions prevented recruitment of the required 3 groups of 20 consumers in this and similar postcodes within the trial timeframe. A population from Helensburgh was utilised due to this postcode being immediately adjacent to the greater Sydney region but under COVID requirements that allowed testing.

All consumer testing was conducted by Polkinghornes Pty Ltd.

3.8.1 Pick design

The individual "picks" each allocated 42 samples across 60 consumers, tested in three groups of 20 per session. All consumers received a "link" sample as the first of 7 samples with this product made up to 95VL and predicted to be of mid-range eating quality. The allocation of samples followed MSA protocols (Watson *et al.*, 2008b) which in brief allocate six test samples, each from a separate product, according to a 6x6 Latin square that ensures each product is served an equal number of times in each serving order and equally before and after the other 5 products to balance potential halo or serving order effects. The samples were allocated to product groupings by the type of burger patty to ensure each consumer received all products.

3.8.2 Consumer recruiting

Consumer recruitment for sensory appraisal of cooked product was managed by the University of New England and Polkinghorne Pty Ltd who utilised community groups for recruitment with the community organisation/group paid for participation rather than individual consumers.

Consumers were screened and selected on the following criteria:

- Aged between 18 and 70
- Regular consumers of red meat, at least once per fortnight
- Prefer beef cooked to medium doneness

3.8.3 Cooking, serving and data protocols

Standard MSA grill cooking and serving protocols as described by Watson *et.al*, 2008a were utilised for sensory testing other than the modified cook timing chart described in section 3.6.2. In brief a 3 phase Silex (S-Tronic 161) double sided grill was utilised with all cooking procedures regulated by count up timers. A first round of scrap (starter) meat was cooked to stabilise plate temperature recovery with the link and six sample rounds following at designated intervals. The round sheets were aligned beside the grill and burger patties transferred onto the grill and after cooking to a cutting board for serving in a strict 3-4-3 left to right, top to bottom sequence to ensure ID was maintained.

10 burger patties, 60mm x 10mm and 60g were cooked within each of the seven rounds as per the cooking sheet in Figure 12. After each round was unloaded, every patty was weighed and a temperature taken and recorded on the round sheets. After these measurements were taken patties were then halved with each served to 2 consumers. The ID on the consumer plates was further checked against the empty round sheet codes during cutting and serving. Allocation of patties to rounds and to consumer ID was controlled by software in accordance with the design criteria described previously.

After an initial briefing each consumer completed a number of demographic questions followed by an individual scoring sheet for each of the 7 samples. Each sample was identified only by the 4-digit alphanumeric EQSref code. The sample score sheets included four 100mm line scales for each of tenderness, juiciness, flavour and overall satisfaction followed by four category boxes labelled as unsatisfactory, good everyday quality, better than everyday quality and premium quality.

The tenderness scale was anchored with the words not tender and very tender, the juiciness scale with not juicy and very juicy and the flavour and overall scales with dislike extremely and like extremely. Consumers were instructed to make a vertical line across each scale at a point that reflected their judgement for each sample. They were also asked to mark one of the four category boxes.

The MSA sensory survey consumer demographic and sample scoring sheets are shown in Appendix 8.3.

Following serving and sensory evaluation of the 7 samples each consumer was asked to mark a further line scale, graduated in $10 increments from $0 to $40, representing the value they ascribed to a 500gm pack of 4 burgers from each of the category boxes.

Another 2 sheets were added to the standard sensory survey for the purpose of this trial. Several attitudinal questions were asked. Three of these questions simply required the consumer to check a box, where the other page asked consumers to consider the importance of specific variables when purchasing protein products utilising 100mm line scales.

Each sheet was checked after completion by serving staff. The mm to the consumer mark from the left end of the line scale was recorded as a score between 0 and 100. Each sheet required manual double entry and a cross check prior to acceptance and finalisation of the sensory data file. The completed file for each pick was then emailed to the research manager who utilised further software to calculate both 10 consumer averages for each line scale and category score and a clipped score that removed the two highest and two lowest scores and averaged the remaining central six creating a 10-6 clipped mean as designated by MSA protocol.

In addition, a raw and clipped MQ4 score was calculated by multiplying the tenderness, flavour and overall scores by 0.3 and the juiciness scores by 0.1, these weightings being the current MSA standard, before summing the results. The output was visually checked and raw product means calculated prior to uploading the sensory summary for each sample (a single row with the 10 consumer averages and clipped scores) to the AUSBlue database where the sensory data was matched to the burger product detail.

Examples of the demographic, scoring sample, WTP (willingness to pay) and attitudinal sheets are presented in Appendices.

The raw and collated AUSBlue data was forwarded to Dr Garth Tarr, Dr Ray Watson and for independent statistical analysis.

3.9 Statistical analysis

Statistical analysis was applied to all trial data to examine a number of separate and interrelated factors. Primary issues investigated the cut-off points across the star categories and weightings of the sensory variables for burger patties and how these differed from the standard MQ4 calculation; a difference in consumer scores and demographic responses between a “city” and “rural” population when testing alternative proteins; cook loss effects on consumer scores; willingness to pay for burger products; relationships between attitudinal, demographic, purchasing and sensory responses.

Dr Watson utilised Minitab for primary analysis including linear discriminative analysis with star (2* = unsatisfactory, 3* = good everyday, 4* = better than everyday and 5* = premium quality) as the category to be predicted by tenderness, juiciness, flavour and overall (Watson et al. 2008a & 2008b). This analysis determines the weightings for each of the sensory variables that is optimal for predicting the overall eating quality of samples within the project data. Weightings and cut-offs could not be assigned to individual products as each consumer tested all product and there were not enough samples to go to a product level. Dr Watson also conducted analysis using several different linear models which examined the effects of product, location and consumer response means on the different sensory variables (tenderness (tn), juiciness (ju), flavour (fl), overall satisfaction (ov), MQ (a meat quality 4 variable composite score) and BQ (a 4 variable composite score constructed to more precisely match burger response utilising these project data). Complementary analysis included a comparison of a 3-scale statistic (with ov removed) relative to the 4 scale, a technique that evaluates tn, ju and fl weightings at the individual quality boundaries (2*/3*, 3*/4* and 4*/5*).

Dr Tarr and Dr Cuthbertson conducted independent and complementary analysis utilising the R Team software package and associated graphical tools.

Bar charts, dot, scatter and box plots were used for summarising and visualising the data. Correlations were performed among attitudinal, demographic and purchasing variables.

4. Results

4.1 Product information

4.1.1 Packaging and product details

Details of the product purchased are displayed in Table 3. The products varied widely in units per pack, weight and purchase price per Kg which ranged from $9.00 for the BBQ999 product to $53.10 for the BYB99. Photographs of the retail packaging are shown in the Appendix.

Table 3: Product information of the products used in the workshop.

Product	Servings per package	Price $/Pack	$/Kg	Location	Description
Beyond Burger (BYB99)	2 pack (226g)	$12.00	$53.10	Coles	Strong Odour
NextGen2 Burger (NXG99)	4 pack (450g)	$8.00	$17.80	Woolworths	Very hard, playdough consistency
Type A Prototype (ARB99)	Mince	Prototype	NA	Arcadian Meat Co	Visible vegetables
Beef BBQ Burgers (BBQ99)	10 pack (1kg)	$9.00	$9.00	Coles	Very sticky hard to pull apart
85/95 VL (BBN95/95)	Mince	NA	NA	UNE	85 more oxidised
Cleaver's Chuck and Brisket Burgers (CBB99)	4 pack (450g)	$8.50	$18.90	Coles	Held shape well (oval), Some oxidation in the middle

4.1.2 Nutritional information

Nutritional information displayed on the packaging is shown in Table 4. There are significant differences between products for all measures other than the common Nil for gluten. The label ingredients and claims also differed widely as displayed in Table 5. Interestingly, the plant-based alternatives actually contained higher percentages of total fat than all beef burgers excluding the Coles Beef Burgers which contained fillers. The Beyond burger claims several beef-like properties on the products packaging such as marbling, juiciness and tenderness. This product actually claims to be "meatier" than ever, implying to the consumer that they can get all the benefits of a beef burger through this guilt free plant-based alternative.

[i]Table 4: Nutritional information obtained from packaged labels per 100gm.

Product	Energy	Protein	Fat		Carbohydrates		Dietary Fibre	Sodium	Gluten
			Total	Saturated	Total	Sugars			
Beyond Burger (BYB99)	925kJ	17.7g	15.9g	5.3g	2.6g	0	1.7g	345mg	Nil
NextGen2 Burger (NXG99)	1060kJ	12.6g	17.4g	10.9g	10.6g	<1.0g	NA	330mg	Nil
Type A Mince Prototype (ARB99)	890kJ	13.7g	14.4g	6.0g	7.4g	2.2g	NA	506mg	Nil
Beef BBQ Burgers (BBQ99)	1360kJ	14.6g	28.1g	13.3g	3.8g	1.6g	1.2g	712mg	Nil
Cleaver's Chuck and Brisket Burgers (CBB99)	712kJ	20.6g	9.7g	3.6g	0.3g	0.1g	NA	412mg	Nil

Table 5: Ingredients list and claims on product labels for retail burger products.

Burger	Ingredient List	Claims
Beyond Burger (BYB99)	Water Pea Protein Isolate (17-18%) Expeller – Pressed Canola Oil Refined Coconut Oil Rice Protein Natural Flavours Cocoa Butter Mung Bean Protein Methylcellulose Potato Starch Apple Extract Salt Potassium Chloride Vinegar Lemon Juice Sunflower Lecithin Pomegranate Fruit Powder Beet Juice Extract (for colour)	The Future of Protein Complete Protein Marbled Juiciness Marbling that Melts and Tenderizes Now Even Meatier Non GMO Project No soy No gluten Vegan
NextGen2 Burger (NXG99)	Rehydrated Pea Textured Protein Water Coconut oil Vegetable oil Potato Starch Thickeners 461, 407 Maltodextrin Plant Fibre Pea Protein Natural flavours Yeast Extract Dehydrated beetroot Burnt Sugar Salt Sunflower oil	100% vegetarian Gluten free Soy free Vegan Australia certified

Table 5 Continued: Ingredients list and claims on product labels for retail burger products.

Burger	Ingredient List	Claims
Type A Mince Prototype (ARB99)	Organic Beef (57%) Organic Vegetables (30%: Peas, Carrot, Corn) Organic flours Salt Organic Dehydrated Vegetables (Onion, Garlic) Organic Carrot Fibre Natural Seaweed Extract Organic Herbs Organic Sugar Organic Spices	Flexitarian
Beef BBQ Burgers (BBQ99)	Australian No Added Hormone Beef (78%) Water Soy flour Breadcrumbs Soy Protein Salt Mineral Salt Maize Starch Spices Vegetable Powders Preservative 223 Yeast Extract Fermented Red Rice Natural colour Coriander Extract Antioxidant 301	No added hormones Made with Australian Beef Gluten free Made from 92% Australian ingredients
Cleaver's Chuck and Brisket Burger (CBB99)	Organic Beef (96%) Organic Sautéed Onion Rendered Organic Grass Fed Beef Fat Australian Sea salt Organic Black Pepper	ACO Certified Organic Made from 97% Australian Ingredients Free Range Grass Fed Gluten free Preservative free Allergen free No added hormones No antibiotics

4.2 Workshop results

4.2.1 Batch measurements effects

As shown in Table 6 variation within each of the product retail packs was small, with little variation between the packaged patties from the different shop locations.

Burger ID	Patty weight			Patty diameter			Patty thickness		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Beyond Burger (BYB99)	115	116.7	118	90	90.7	91	18	19.3	20
NextGen2 Burger (NXG99)	113	114.7	117	90	91.3	92	15	15.3	16
Beef BBQ Burgers (BBQ99)	99	99.7	101	115	116.7	120	10	10	10
Cleaver's Chuck and Brisket Burgers (CBB99)	115	117.3	120	85	86.7	90	20	20	20

Table 6: The variation across packaged burger products.

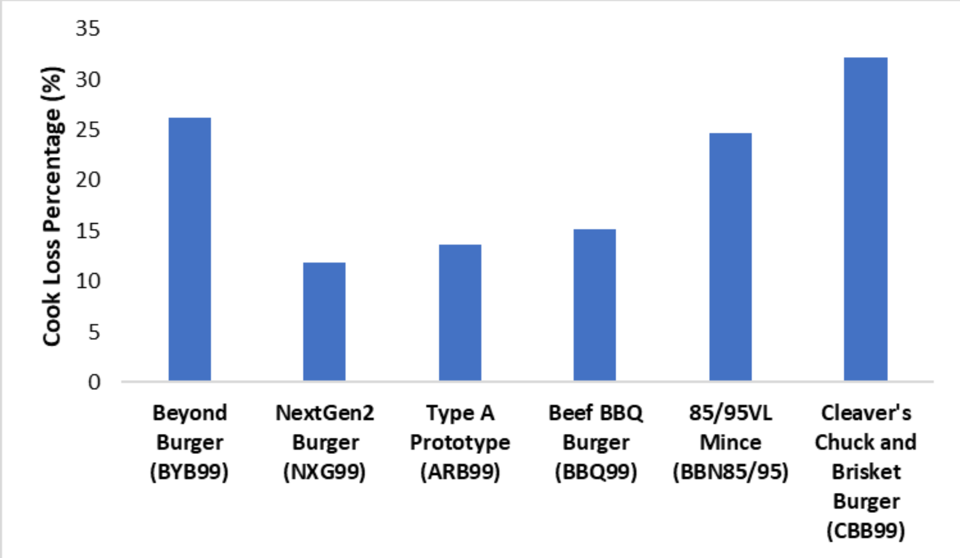
4.2.2 Cook loss percentage

Raw and cooked weights and measurements are displayed in Table 7. The Cleaver's brisket burger (CBB99) and the Beyond burger (BYB99) had the highest cook loss % and both had a noticeable excess liquid across the grill. All burgers shrunk in terms of diameter, most shrunk in terms of thickness, apart from the Type A blended burger prototype and the 85/95VL burger that increased in thickness upon cooking. Average cook loss % is displayed in Figure 15.

Table 7: Average raw and cooked patty measurements with calculated cook loss% for each product.

Product	Raw Patty Weight	Cooked Patty Weight	Raw Patty Diameter	Cooked Diameter	Raw Thickness	Cooked Thickness	Cook Loss %
Beyond Burger (BYB99)	116.67	86.11	90.67	87	19.33	16.33	26.2
NextGen2 Burger (NXG99)	114.67	100.96	91.33	89.67	15.33	15.67	11.92
Type A Mince Prototype (ARB99)	60	51.82	60	55.33	20	24.33	13.64
Beef BBQ Burgers (BBQ99)	99.67	84.62	116.67	99.33	10	10	15.12
85/95 VL Mince (BBN85/95)	60	45.17	60	48.67	20	25.33	24.72
Cleaver's Chuck and Brisket Burgers (CBB99)	117.33	79.54	86.67	77.33	20	16.67	32.17

Figure 15: The average cook loss for each brand of burger product throughout the cooking trials.



4.3 Sensory results

4.3.1 Weightings and cut-offs

Firstly, an explanation of all the abbreviations used throughout the results is provided in Appendix 8.4.1.

Figure 16 shows the weightings of the sensory variables and accurate cut off points between 2/3, 3/4 and 4/5 star resulting from alternative analyses. As with standard MSA sensory analysis of non-burger products alternative sensory scale weightings were calculated on both a 4 and 3 scale (Overall removed) basis. The SQ4 statistic relates to the calculated optimum weightings and star cut-offs for these data utilising the 4 sensory scales whereas the SQ3 represents optimal weightings and cut-offs when only the three primary scales are included. The Overall scale has been shown to act as a "smoother" in prior work, often largely representing tenderness at the 2/3* boundary and largely flavour at the 4/5* boundary. In this instance a comparison between the SQ4 and SQ3 weightings indicates that overall is largely a proxy for flavour and juiciness with these scale weightings increasing far more than tenderness in the SQ3 across the full eating quality range for both test locations. The MQ as adopted in other MSA studies is a midpoint between the SQ4 and SQ3.

The numbers in the shaded box represents the proportion of consumer category choices that are correctly allocated using the SQ3, SQ4 and MQ weightings and cut-offs, a measure of consumer consistency. It is seen that the SQ4 provides superior categorisation to the SQ3, both of which are optimal for these data. The MQ statistic reflects use of standard weightings and performs moderately well despite these products differing characteristics.

The overall weightings are markedly different from the standard MQ4 weighting of 3133, where tenderness = 0.3, juiciness = 0.1, flavour = 0.3 and overall = 0.3. A burger specific "BQ" statistic was developed from the sensory data and applied with rounded weightings of 1153 (0.1 tn + 0.1 ju + 0.5 fl + 0.3 ov) and as shown produced more accurate categorisation (0.692) than MQ (0.653) for these products. While finer BQ weightings of tenderness = 0.05, juiciness = 0.15, flavour = 0.45 and overall = 0.35 could be used there would be very little additional benefit. In saying that, the cut-offs are similar to the usual, though are a bit wider; lower at 2/3 star and higher at a 4/5 star. This is however, somewhat affected by the distribution of star categories (Fig. 17 & 18), where there are more samples categorised as unsatisfactory (2-star) than usual and relatively few samples categorised as Premium (5-star). Although MQ is less accurate than BQ at classifying the data, it still does a good job of separating the star ratings (Fig. 17 & 18).

There is no effective difference in weightings between the 2 locations, the "city" population Helensburgh only slightly placing a stronger emphasis on tenderness in comparison to the "rural" population, Deepwater. The cut-offs are also not dissimilar between the 2, results suggesting that perhaps Deepwater is slightly harsher at the bottom end, with a fail score of less than 43.6 as opposed to Helensburgh letting more product into 3 star with a score greater than 41.8. However, Helensburgh was slightly harsher at the top end with a 5-star score of greater than 82.4 vs. Deepwater's 80.0.

Figure 16: Discriminative analysis using both MQ and BQ scores from burger data to establish the weightings of sensory variables and determine cut-off points for 2/3, 3/4, and 4/5 star ratings.

Deepwater

SQ4				
0.694	37.7	66.2	79.7	
tn	-0.02	0.05	0.02	0.01
ju	0.05	0.09	0.11	0.08
fl	0.16	-0.14	0.48	0.17
ov	0.82	1.00	0.39	0.74
MQ				
0.641	43.6	66.5	80.0	

SQ3					
0.636	39.1	65.1	78.2		
tn	0.01	0.11	0.04	0.05	0.03
ju	0.14	0.23	0.16	0.18	0.13
fl	0.85	0.67	0.80	0.77	0.47
					0.37

Helensburgh

SQ4				
0.695	38.6	65.0	83.7	
tn	0.03	0.11	0.03	0.06
ju	0.06	0.18	0.03	0.09
fl	0.22	0.19	0.20	0.20
ov	0.69	0.52	0.74	0.65
MQ				
0.662	41.8	65.2	82.4	

SQ3					
0.679	39.9	64.9	82.9		
tn	0.07	0.14	0.07	0.09	0.08
ju	0.17	0.26	0.14	0.19	0.14
fl	0.76	0.59	0.79	0.72	0.46
					0.32

Both

SQ4				
0.700	38.2	65.5	82.1	
tn	0.00	0.08	0.02	0.03
ju	0.06	0.14	0.05	0.08
fl	0.18	0.04	0.29	0.17
ov	0.76	0.75	0.63	0.71
MQ				
0.653	42.7	65.9	81.3	

SQ3					
0.650	39.7	65.1	80.9		
tn	0.04	0.12	0.05	0.07	0.05
ju	0.16	0.25	0.14	0.18	0.13
fl	0.80	0.63	0.81	0.75	0.46
					0.36
BQ					
0.692	39.7	64.9	81.5		

In terms of setting cut-offs for burger products, there is less "risk" in setting the 4/5 cut-off high; and the 2/3 cut-off low, as it will ensure that no unacceptable product can slip into a category above. To go to extremes; if there were no 5-star, then we could set the 4/5 cut-off at 100, or at least above the highest 4-star. However, it is important to note that as the number of 5-star burger samples increases, we are likely to get more and more wrong unless we reduce the 4/5 cut off. A similar argument applies at the lower end also. Additional testing of burger products would provide us with more conclusive cut off points.

It is recommended that pending further data the 1153 BQ4 statistic with cut-off scores of 45 (allowing a safety margin above unsatisfactory), 65 and 78 be adopted for MSA standard analysis of burger products sourced from beef, blended and non-meat composition.

Weightings and cut-offs could not be assigned to individual products, as each consumer tested all products.

Figure 17: Dot plot showing the distribution of MQ scores of burger samples and their relative cut-off points.

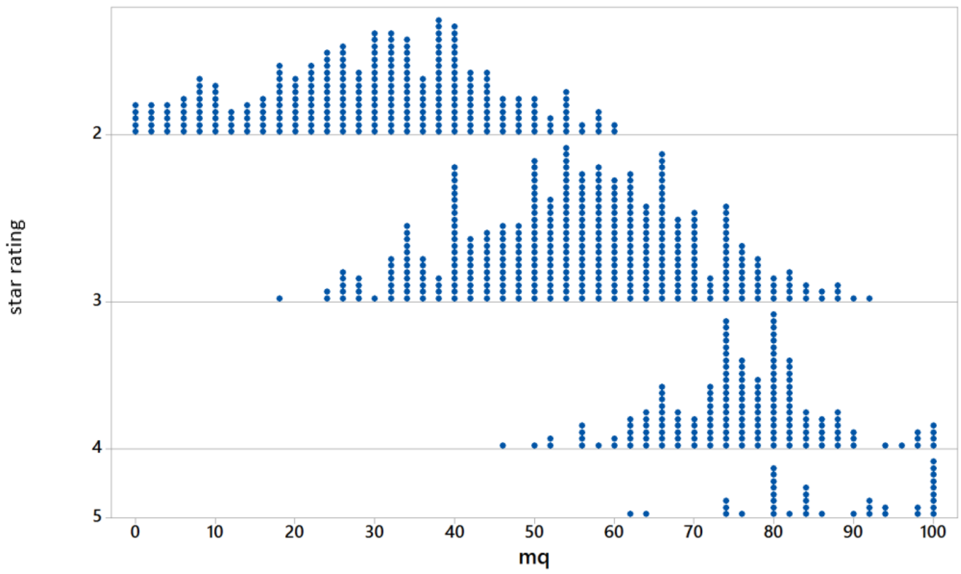
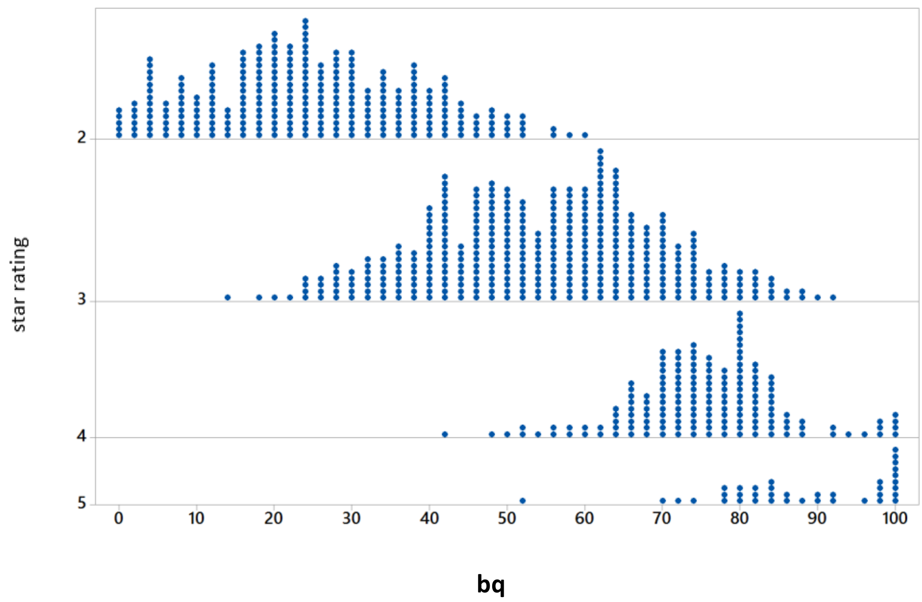


Figure 18: Dot plot showing the distribution of BQ scores of burger samples and their relative cut-off points.



4.3.2 Descriptive statistics of sensory variables

Table 8 shows the overall summary statistics for the 4 sensory variables: tenderness (tn), juiciness (ju), flavour (fl) and overall (ov), along with the MQ and BQ scores, measured across all burger samples from the trial. The spread of each primary variable is very noticeable (Fig. 19), with the standard deviations around 25-26. This result is perhaps not surprising for some (flavour and overall) as there are a wide range of flavours, including different basic ingredients and a large range of enhancements used across the 6 burger products but perhaps unexpected for tenderness with much being done to ensure a standardised preparation and cooking protocol. Tenderness does however, have the smallest spread, but only slightly.

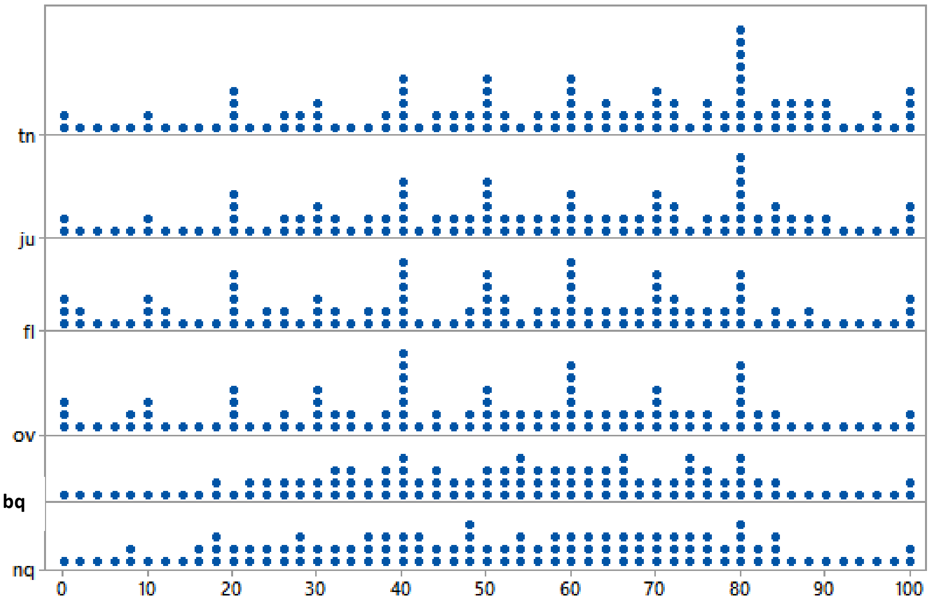
The location measures (mean and median) are roughly $\boldsymbol{ov} \approx \boldsymbol{fl} < ju < tn$. This suggests that consumers found the products relatively 'tender' and 'juicy', but did not like the 'flavour' so much.

Table 8: Summary statistics for sensory variables measured overall across all burger samples.

	n	n*	mean	sd	min	Q1	med	Q3	max
tn	838	2	59.0	25.4	0	40	62	80	100
ju	838	2	54.4	25.9	0	35	57	77	100
fl	838	2	49.1	26.5	0	28	50	70	100
ov	838	2	49.5	26.1	0	30	50	70	100
MQ	838	2	52.7	22.7	0	36	54	71	100
BQ	838	2	50.8	24.1	0	32	52	70	100

† n* is the number of missing observations.

Figure 19: Dot plot of each sensory variable to indicate the consumer giving a value from 0 through to 100 for burger samples



4.3.2.1 Sensory variables by location

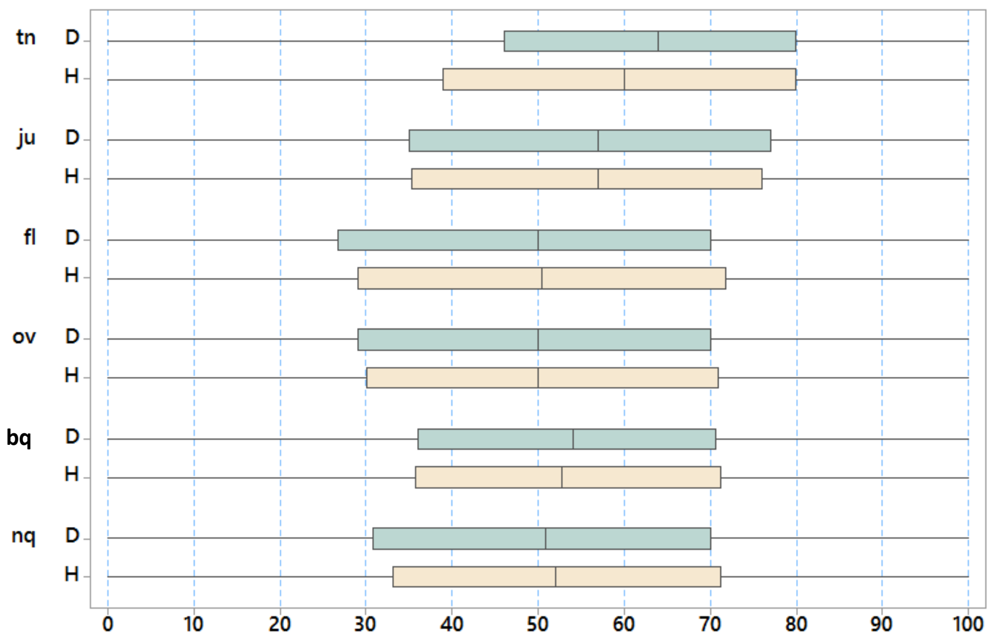
There is little difference between the two locations, except for tenderness. Deepwater appears to rate burger samples slightly greater in tenderness than Helensburgh, but all other variables are remarkably similar (Table 9, Fig. 20).

Table 9: Summary statistics for sensory variables measured across all burger samples at two different testing locations.

	location	N	N*	mean	sd	min	Q1	med	Q3	max
tn	D	418	2	61.0	24.7	0	46	64	80	100
	H	420	0	57.1	25.9	0	39	60	80	100
Ju	D	418	2	54.7	25.6	0	35	57	77	100
	H	420	0	54.2	26.2	0	35	57	76	100
Fl	D	418	2	47.9	25.9	0	27	50	70	100
	H	420	0	50.4	27.1	0	29	51	72	100
Ov	D	418	2	48.8	25.9	0	29	50	70	100
	H	420	0	50.2	26.4	0	30	50	71	100
BQ	D	418	2	50.2	23.6	0	31	51	70	100
	H	420	0	51.4	24.5	0	33	52	71	100
MQ	D	418	2	52.8	22.2	0	36	54	71	100
	H	420	0	52.7	23.1	0	36	53	71	100

† N* is the number of missing observations

Figure 20: Boxplot of the sensory variables measured across all burger samples at two different testing locations.



The model's (sensory variable = location + product) estimated differences for each of the sensory results is displayed in Table 10. The interaction between location and sensory variable was found to be non-significant. There was a significant location effect for tenderness, but not for others. There could be a sensible explanation why the "city" populations are harsher on meat tenderness, perhaps due to being in such close proximity to a large number of fine-dining restaurants, they simply have higher expectations. However, you would expect to see a similar effect across the other variables, if the "city" population was in general, harsher critics. Additionally, the "rural" Deepwater population marked down the flavour of all the burger products by more than 2 points in comparison to the city population. Hence, there is no consistency in the direction of the location effects (i.e. D > H or D < H). This makes the significance of the tenderness difference between the two locations somewhat uncertain.

Table 10: Model estimate differences between the 2 testing locations for each of the sensory variables from the burger products.

location	**(tn)**	**(ju)**	**(fl)**	**(ov)**	**(bq)**	**(nq)**
D-H	3.76	0.48	-2.43	-1.42	0.02	-1.22
P	*0.013*	*0.752*	*0.142*	*0.380*	*0.988*	*0.413*

4.3.2.2 Sensory variables by product

Complete summary statistics were produced for each of the products across the different sensory variables (Table 11). The flavour of the non-beef products were liked the least by consumers, with product 2 (NextGen2) extremely disliked (average of 25.6, Fig. 21), and the mixed beef products liked the best (average fl = 64.6 and 61.1). This pattern was repeated for all scales other than tenderness where product 2 scored relatively well, and for the combined measures. The mean score range between products was greatest for flavour (39.0) followed by juiciness (38.5), overall (37.0) and less for tenderness (32.6) (Figs.21, 22 & 23) with the beef products (pn = 5, 6 and 0) noticeably lower. Variables ov, BQ and MQ tell a similar story, plant-based product 2, NextGen2 is worst, with beef products slightly better then followed by the mixed beef products (Figs. 24, 25 & 26).

It is proposed that the tenderness and juiciness range may in part reflect the lower fat content of the beef products and the relatively high cooked temperature leading to excessive cook loss.

Table 11: Summary statistics for sensory variables measured for each of the burger products.

	pn	prod	n	mean	sd	min	Q1	med	Q3	Max
tn	0	beeftrim95	120	43.6	21.0	3	27	42	60	93
	1	beyond	120	60.1	23.9	0	42	67	80	100
	2	nextgen	120	66.0	26.6	0	50	76	86	100
	3	type A protoype	120	74.2	16.9	28	64	80	86	100
	4	coles	120	76.2	16.8	9	68	80	86	100
	5	cleavers	120	47.9	25.5	0	30	50	69	100
	6	beeftrim85	118	45.1	21.5	0	29	47	60	100
ju	0	beeftrim95	120	37.6	22.2	0	20	37	50	95
	1	beyond	120	48.1	23.5	0	30	50	66	100
	2	nextgen	120	40.8	23.8	0	21	40	55	99
	3	type A protoype	120	69.8	17.1	18	57	71	80	100
	4	coles	120	76.1	16.4	9	69	80	86	100
	5	cleavers	120	62.9	23.8	1	48	67	80	100

	6	beeftrim85	118	45.8	24.7	0	27	49	61	100
fl	0	beeftrim95	120	48.2	21.2	0	31	50	62	100
	1	beyond	120	45.5	26.4	0	27	42	70	100
	2	nextgen	120	25.6	22.1	0	6	20	40	85
	3	type A protoype	120	64.6	22.2	10	50	70	80	100
	4	coles	120	61.1	23.6	1	48	65	80	100
	5	cleavers	120	50.3	28.6	0	23	55	73	100
	6	beeftrim85	118	48.7	22.2	0	30	51	66	99
ov	0	beeftrim95	120	44.0	20.2	0	29	45	60	90
	1	beyond	120	45.5	26.4	0	23	42	69	100
	2	nextgen	120	28.8	23.3	0	8	26	40	90
	3	type A protoype	120	65.8	21.5	10	53	70	80	100
	4	coles	120	64.1	23.3	0	49	70	80	100
	5	cleavers	120	51.3	27.4	0	29	57	72	100
	6	beeftrim85	118	46.8	20.8	0	31	49	60	97
MQ	0	beeftrim95	120	44.5	18.4	2	33	44	58	91
	1	beyond	120	50.2	22.9	3	33	49	70	100
	2	nextgen	120	40.2	19.4	0	27	40	53	85
	3	type A protoype	120	68.4	17.9	19	57	72	81	100
	4	coles	120	68.0	18.1	20	56	69	81	100
	5	cleavers	120	51.1	24.5	2	34	53	71	100
	6	beeftrim85	118	46.7	19.5	0	33	48	62	91
BQ	0	beeftrim95	120	44.9	19.1	1	33	46	59	91
	1	beyond	120	46.6	24.1	1	29	45	68	100
	2	nextgen	120	31.0	20.0	0	16	28	43	80
	3	type A protoype	120	66.3	19.6	16	55	70	80	100
	4	coles	120	65.1	20.4	12	51	68	80	100
	5	cleavers	120	52.4	25.8	2	33	56	73	100
	6	beeftrim85	118	47.4	20.3	0	32	48	62	95

Figure 21: Boxplot of the sensory variable flavour as ranked by consumer from 0-100 across all burger samples.

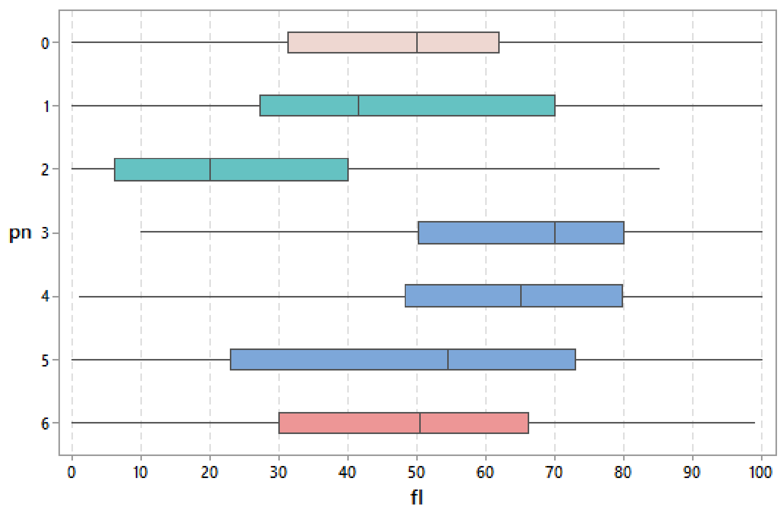


Figure 22: Boxplot of the sensory variable tenderness as ranked by consumer from 0-100 across all burger samples.

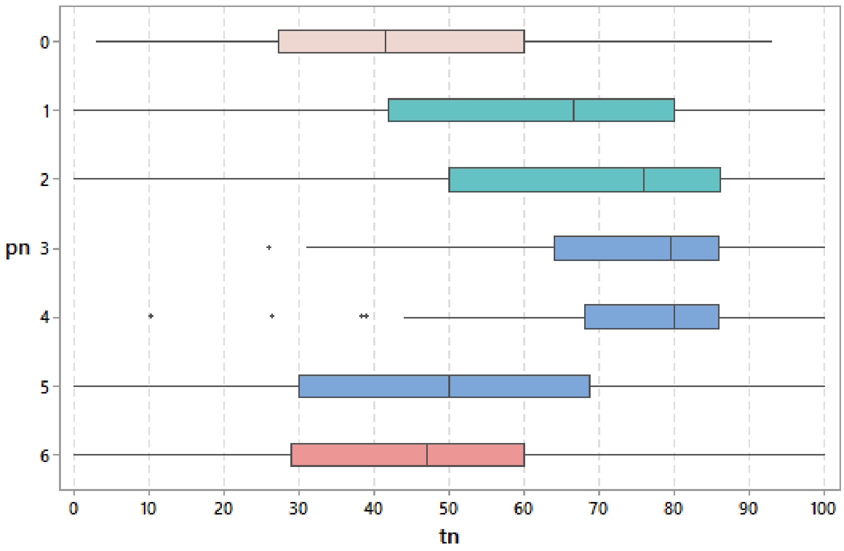


Figure 23: Boxplot of the sensory variable juiciness as ranked by consumer from 0-100 across all burger samples.

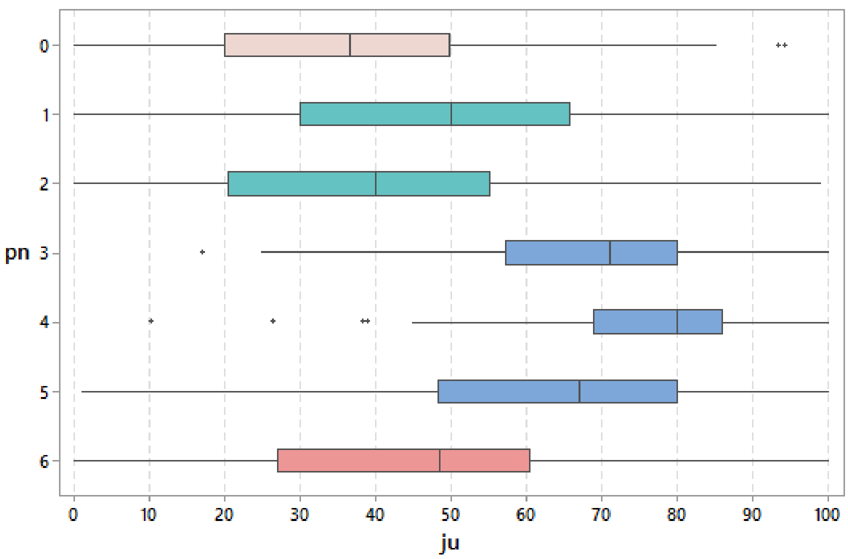


Figure 24: Boxplot of the sensory variable overall as ranked by consumer from 0-100 across all burger samples.

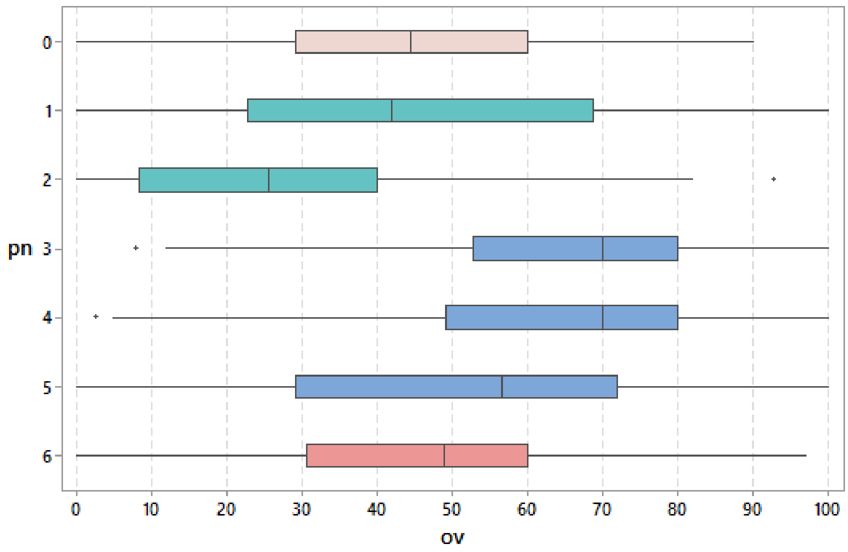


Figure 25: Boxplot of the sensory variable NQ as ranked by consumer from 0-100 across all burger samples.

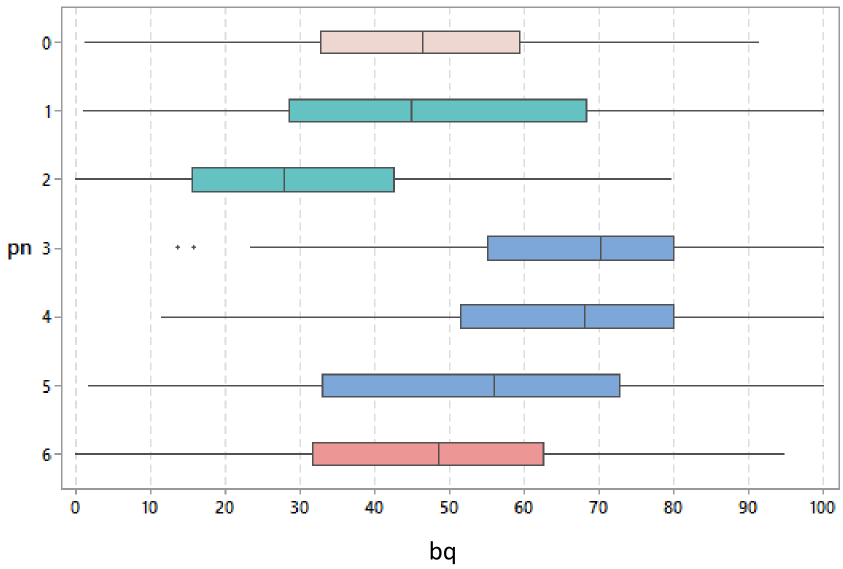


Figure 26: Boxplot of the sensory variable MQ as ranked by consumer from 0-100 across all burger samples.

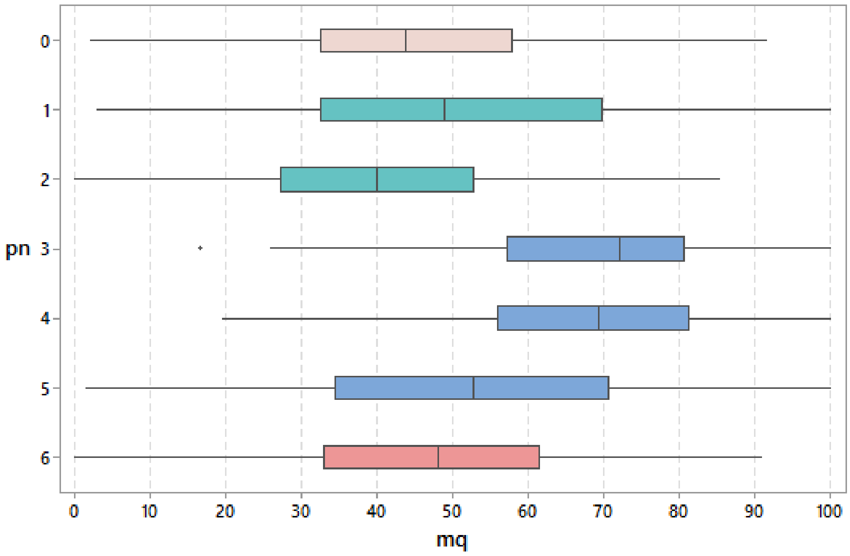


Table 12 shows the distribution of star-ratings for each of the burger products. As previously mentioned, there is a large percentage of product that has been classified as unsatisfactory (2-star), particularly for the plant-based products (n = 122), and specifically product 2 (n = 75). The mixed beef products had the least number of unsatisfactory ratings (n = 34) and the highest mean star ratings (3.37 & 3.47).

Table 12: The distribution of star ratings by burger product

pn	2	3	4	5	All	mean	sd
0	41	71	8	0	120	2.73	0.58
	34.2	*59.2*	*6.7*	*0.0*	*100.0*		
1	47	47	24	2	120	2.84	0.80
	39.2	*39.2*	*20.0*	*1.7*	*100.0*		
2	75	37	6	2	120	2.46	0.67
	62.5	*30.8*	*5.0*	*1.7*	*100.0*		
3	15	55	41	9	120	3.37	0.80
	12.5	*45.8*	*34.2*	*7.5*	*100.0*		
4	19	40	47	14	120	3.47	0.90
	15.8	*33.3*	*39.2*	*11.7*	*100.0*		
5	37	52	22	9	120	3.03	0.89
	30.8	*43.3*	*18.3*	*7.5*	*100.0*		
6	34	68	14	2	118	2.86	0.68
	28.8	*57.6*	*11.9*	*1.7*	*100.0*		
All	268	370	162	38	838	2.96	0.83
	32.0	*44.2*	*19.3*	*4.5*	*100.0*		

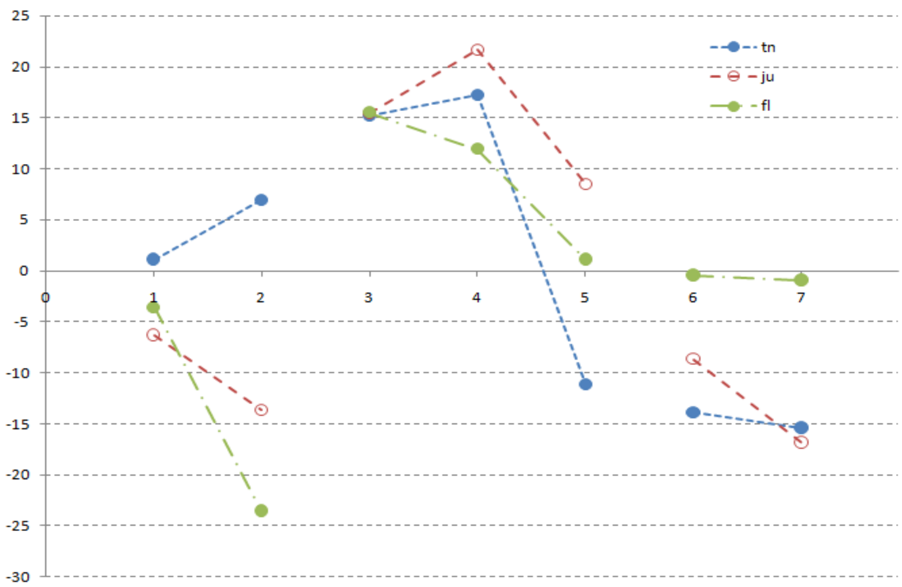
Also reported is the estimated product effects (Table 13 & Fig. 27), which demonstrate how the products rate for each of the sensory variables relative to a starting point of zero. The blended beef products (pn = 3 & 4) are consistently good across all sensory variables (+14 to +21). The plant-based products (pn = 1 & 2) are rated as bad for juiciness (-6.32 & -13.65), flavour (-3.61 & -23.53) and overall (-3.94 & -20.65), particularly product 2 (NextGen2) but rated as moderately good for tenderness. These results are somewhat similar to findings described in a study published earlier this year (Taylor *et al*. 2020) investigating the effect of adding increasing amounts of tempeh in burger patties. Tempeh is derived from soybeans and commonly used as a meat substitute. Findings from the study showed that increasing amounts of tempeh in patties significantly improved tenderness ($p < 0.05$), where the control (89VL beef) had a tenderness score overall of 1 point lower than those products that contained tempeh. The beef products (pn = 5, 6 & 0) are rated as moderate for flavour (+1.12, -0.43 & -0.94) and overall (+1.82, -2.71 and -5.47). But, are worst for tenderness (-11.14, -13.89, -15.38) and next worse for juiciness in products 6 and 0 (-8.68, -16.84).

Product 0 is the link product which is often associated with odd results as it is the first sample served to each consumer and is generally excluded from the analysis due to being only served first rather than rotated. Product 5 (Cleaver's) however, was good for all other variables. It is likely that the higher-than-normal cooking temperatures of these burgers to reach the recommended 70°C internal temperature as specified for the plant-based patties over-cooked the beef and increased cooking losses making the beef products less juicy and tougher, accentuated by their lower fat levels. This is particularly true of the Link product with a 5% fat content.

Table 13: Estimated product effects for each of the sensory variables for the 7 burger products.

pn	(tn)	(ju)	(fl)	(ov)	(MQ)	(BQ)	Name
1	1.12	-6.32	-3.61	-3.94	-2.56	-3.51	Beyond
2	6.95	-13.65	-23.53	-20.65	-12.54	-18.63	Nextgen
3	15.17	15.39	15.49	16.30	15.63	15.69	Type A prototype
4	17.18	21.65	11.91	14.65	15.29	14.23	Coles
5	-11.14	8.45	1.12	1.82	-1.62	0.84	Cleavers
6	-13.89	-8.68	-0.43	-2.71	-5.98	-3.29	beeftrim85
0	-15.38	-16.84	-0.94	-5.47	-8.22	-5.33	beeftrim95

Figure 27: Diagrammatic representation of the estimated product effects for tenderness, juiciness and flavour for each of burger products*.



*where product number 0 is plotted as 7

4.3.3 Temperature and cooking loss

Internal temperature and cooked individual patty weights were measured for all consumer tested burger patties. Cook loss was calculated as a % loss from the standard initial 60 gm of raw weight. Whereas this measurement was accurate there are accuracy concerns in regard to the recorded internal temperatures which, while reported for information, should be viewed with extreme caution due to the practical difficulties of achieving accurate temperature probe placement in the burger centre within the time available and the extreme variation inherent with non-central placement and/or seconds after removal from the grill.

There were clear differences between products in terms of their internal temperatures and overall cooking losses (Table 14, Fig. 28 & 29). Specifically, the beef and mixed beef products tended to have lower temperatures than the plant-based alternatives. While this observation is believed valid given the structured balance of patty position on the grill and replication, the observed maximum temperatures appear unlikely, and possibly reflect probe placement closer to the surface or within internal fat pools, given the accurately measured range of 70 to 75˚C recorded during the cooking protocol development across all products. Cooking loss was relatively small for products 2, 3 and 4 (around 12%) and relatively large for products 0, 5 & 6 (around 28%). Interestingly products 2, 3 and 4 contained fillers which can help the product to retain juices during the cooking process (FAO, 2007) and may explain their lower cook losses. At the other end product number 1 had a high cook loss of 24.5 and contained many vegetable related ingredients.

Table 14: Summary statistics for temperature and cooking loss by burger product.

	Pn	n	n*	mean	sd	min	q1	med	q3	max	pc<70
Temp	1	120	0	86.1	6.6	74	80	88	92	96	0
	2	120	0	82.5	7.8	59	79	82	89	101	10
	3	120	0	83.9	7.4	64	79	84	88	96	3
	4	120	0	79.8	8.5	65	73	78	87	99	12
	5	120	0	74.0	7.0	60	68	74	78	90	28
	6	118	2	76.0	7.7	62	69	76	83	90	29
	0	120	0	78.9	5.7	66	75	79	83	91	5
ckloss	1	120	0	24.5	4.1	17	21	24	27	36	
	2	120	0	12.2	3.2	4	10	12	15	20	
	3	120	0	10.0	2.3	5	8	10	12	15	
	4	120	0	11.6	3.9	2	10	12	14	24	
	5	120	0	29.1	5.0	3	28	30	31	36	
	6	118	2	28.8	2.7	21	28	28	30	35	
	0	120	0	26.8	2.7	20	25	27	29	33	

Figure 28: Box plot of the internal temperature for each burger product after removing from the grill.

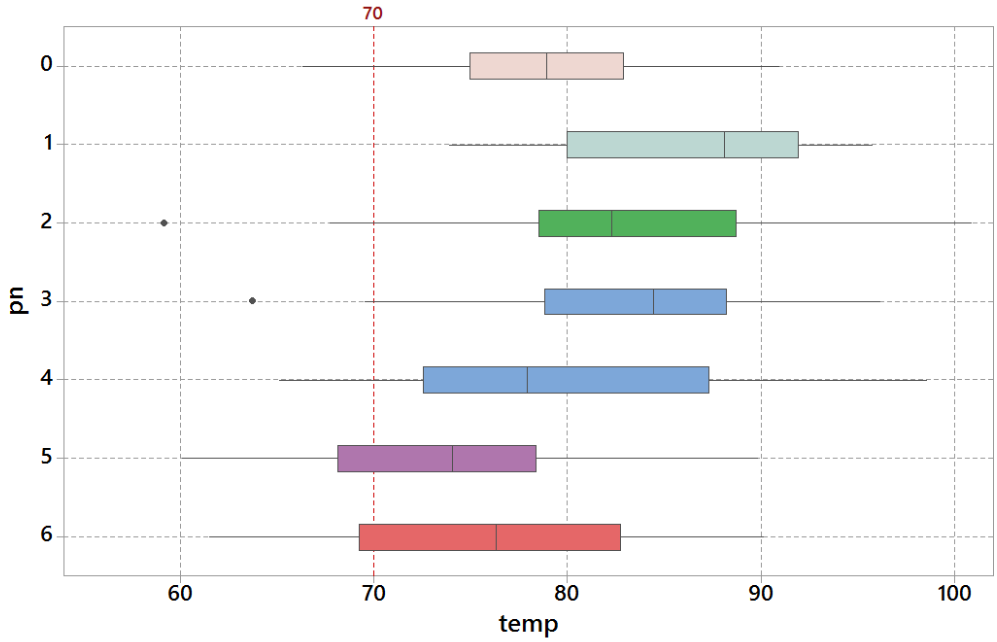
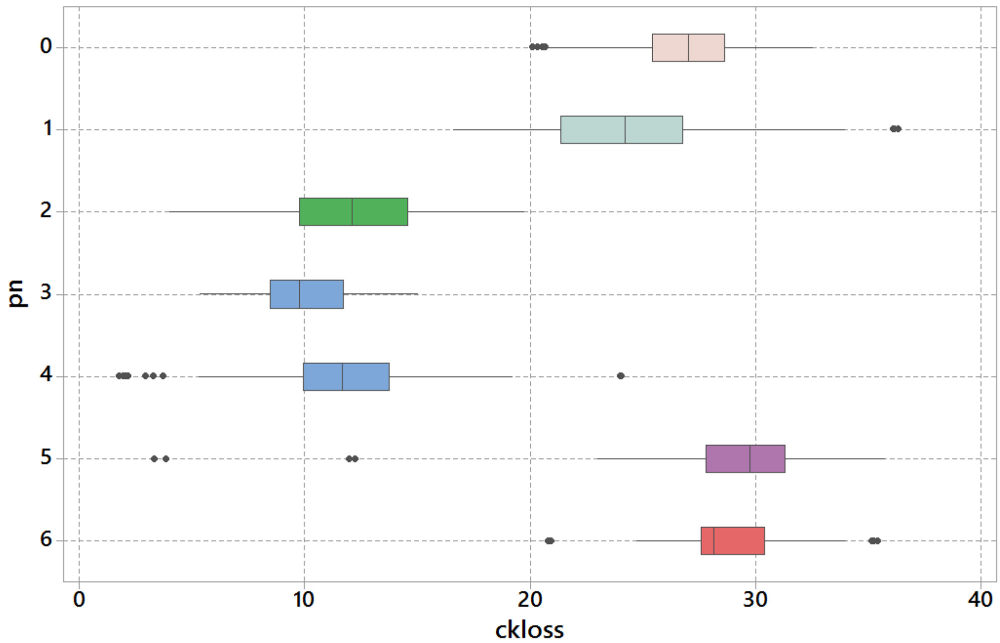
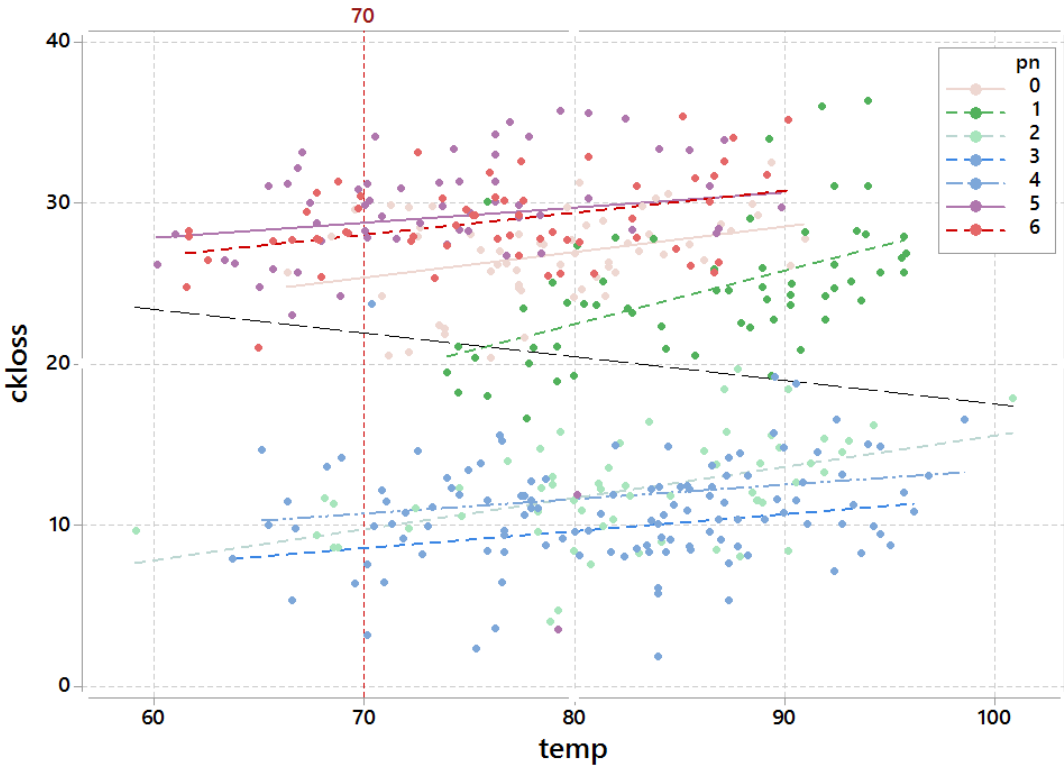


Figure 29: Box plot of the cook loss% for each burger product.



For each of the products, cook loss increased with temperature (Fig. 30). Interestingly, the overall trend (black line, Fig. 30) shows cook loss vs temperature is decreasing. This is driven by products 2, 3 and 4 having higher cooking temperatures and lower cook loss, whilst products 0, 5 and 6 have lower cooking temps and higher cook loss.

Figure 30: Scatter plot of the internal temperature and cook loss for each of the burger products*.



*70°C is marked on the graph to indicate the desired internal temperature.

Relationships between MQ and temperature (Fig. 31) and cook loss (Fig 32) by product illustrate that MQ tends to decrease slightly with temperature, with model results suggesting a decrease of around 2 points for an increase of 10°C, and a greater MQ decrease related to cooking loss with a 7-point MQ decrease for every 10% increase in cooking loss. A different trend between products is apparent from Figure 32 in which the high beef products are clearly to the right. While the decrease appears more severe for the beef products the interaction was not significant. even though the diagrams suggest a difference between the products (Fig. 31, 32 & Table 15).

Figure 31: Scatter plot showing the relationship between MQ score and internal temperature for each of the burger products.

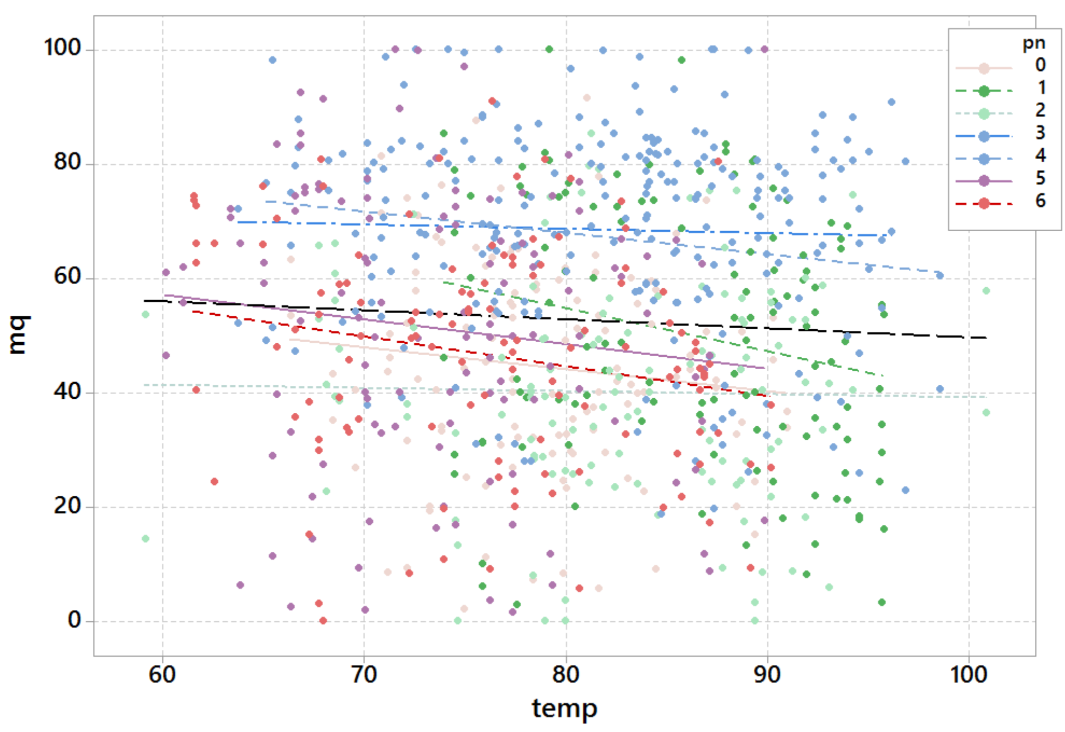
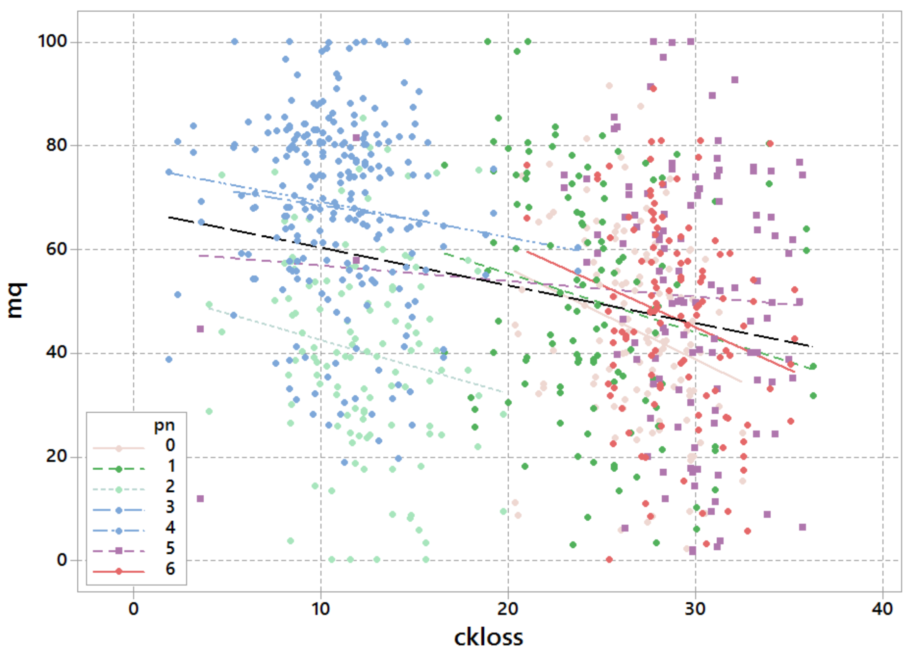


Figure 32: Scatter plot showing the relationship between MQ score and cook loss for each of the burger products.



Correlations of temperature and cook loss and their effect on the sensory variables of each product are described in Table 15. Temperature affected juiciness and to a lesser extent flavour and overall but did not affect tenderness. Cooking loss had a very large effect on tenderness and also on juiciness and overall, but not so much on flavour. For most of the beef products, MQ was negatively affected by temperature and cook loss. In the plant-based and mixed beef this effect was less with the exception of product 1, which behaved very similar to the beef products. Interestingly, this product is designed to mimic beef in every way, texture, look, taste and perhaps it's cooking habits also mimic that of beef.

Table 15: Correlations of temperature and cook loss with the sensory variable of each of the burger products.

pn=1	temp	ckloss	**pn=3**	temp	ckloss	**pn=6**	temp	ckloss
tn	-0.225	-0.247	tn	0.012	-0.111	tn	-0.300	-0.176
ju	-0.223	-0.309	ju	-0.080	-0.078	Ju	-0.202	-0.276
fl	-0.165	-0.127	fl	-0.054	-0.064	Fl	-0.143	-0.183
ov	-0.195	-0.142	ov	-0.020	-0.034	Ov	-0.212	-0.215
NQ	-0.198	-0.171	BQ	-0.043	-0.064	BQ	-0.201	-0.219
MQ	-0.218	-0.202	MQ	-0.032	-0.075	MQ	-0.242	-0.224

pn=2	temp	ckloss	**pn=4**	temp	ckloss	**pn=0**	temp	ckloss
tn	-0.074	-0.237	tn	-0.223	-0.023	tn	-0.119	-0.227
ju	-0.035	-0.210	ju	-0.260	-0.120	Ju	-0.298	-0.284
fl	0.023	-0.066	fl	-0.114	-0.104	Fl	0.000	-0.180
ov	0.015	-0.062	ov	-0.114	-0.082	Ov	-0.124	-0.254
BQ	0.004	-0.115	BQ	-0.144	-0.100	BQ	-0.088	-0.238
MQ	-0.021	-0.169	MQ	-0.174	-0.090	MQ	-0.117	-0.257

pn=5	temp	ckloss
tn	-0.109	-0.092
ju	-0.004	-0.053
fl	-0.109	-0.011
ov	-0.150	-0.069
BQ	-0.119	-0.042
MQ	-0.123	-0.061

4.3.4 Summarised "AUSBlue" data (combined from 10 consumers)

Results are also reported as an average of the ten consumers that tasted each sample. These averaged results show less spread as would be expected in comparison to the individual consumer data, but do show similar location for the sensory variables (Appendix 8.4.8 & 8.4.9) and confirm the product differences. For MSA modelling and cut or treatment (equivalent to product in this burger project) evaluation, the average and clipped scores (10-4 consumer scores with the 2 highest and 2 lowest removed) are utilised to reduce the impact of individual consumer variance. The variation in the burger products is relatively small in comparison to typical beef cut differences, specifically for products 2, 3 & 4. However, it should be noted that these spreads are not conclusive due to these spread estimates being based on very few observations (n = 12 for each product).

4.3.5 Willingness to pay

Willingness to pay (WTP) data were collected utilising line scales displaying $/pack ranging from $0 to $40 for a theoretical standard 500 gm pack of 4 burgers (see Appendix 8.3 for data sheet example). Descriptive statistics for the observed WTP for each of the 4 eating quality categories (star-ratings) and the differences between the main purchaser and non-purchaser of the household are shown in (Table 16). Overall, consumers were willing to pay on average $4.54 for 500g of unsatisfactory burger product, $11.23 for good every day, $16.05 for better than every day and $21.69 for premium. The non-purchasers indicated WTP values about 20% more than the main household purchasers as commonly seen in other consumer data.

Table 16: Descriptive statistics for willingness to pay ($/500 gm pack of 4) of the different star ratings, for all consumers and for purchaser or non-purchaser of the household.

Variable	n	mean	sd	min	q1	med	q3	max	rs3
wtp2	119	4.54	3.92	0	2	4	7	25	0.40
wtp3	120	11.23	5.25	0	8	10	15	31	1.00
wtp4	119	16.05	6.91	0	11	15	20	34	1.43
wtp5	119	21.69	8.94	0	15	20	30	40	1.93

Purchaser (1) and non-purchaser (2)

Variable	p	n	mean	sd	min	q1	med	q3	max	p21	rs3
wtp2	1	80	4.44	4.13	0	1	4	7	25		0.42
	2	39	4.74	3.45	0	3	5	7	15	1.07	0.38
wtp3	1	81	10.62	5.31	0	8	10	13	31		1.00
	2	39	12.50	4.89	5	9	12	16	25	1.18	1.00
wtp4	1	80	14.92	6.37	0	10	15	20	29		1.40
	2	39	18.39	7.39	5	12	18	25	34	1.23	1.47
wtp5	1	80	20.38	8.80	0	15	19	29	39		1.92
	2	39	24.38	8.63	5	19	25	31	40	1.20	1.95

Table 17 presents the ratios between the different star ratings compared to 3-star (good everyday product). This approach is adopted in MSA consumer studies to allow comparisons across time periods and countries. For each consumer, the ratio r23 = wtp2/wtp3, i.e. the price the consumer is prepared to pay for unsatisfactory 2 star relative to 3 star product; and similarly, for the observed values of r43 and r53. The mean of the ratio is larger than that ratio of the means, for 4/3, where av.43= 1.54, whereas av4/av3 = 1.43; and for r53, where av.53 = 2.11, whereas av5/av3 = 1.93. The means of the ratios are possible unduly influenced by outliers (Fig. 33). Again, purchaser had only a minor effect on the ratios.

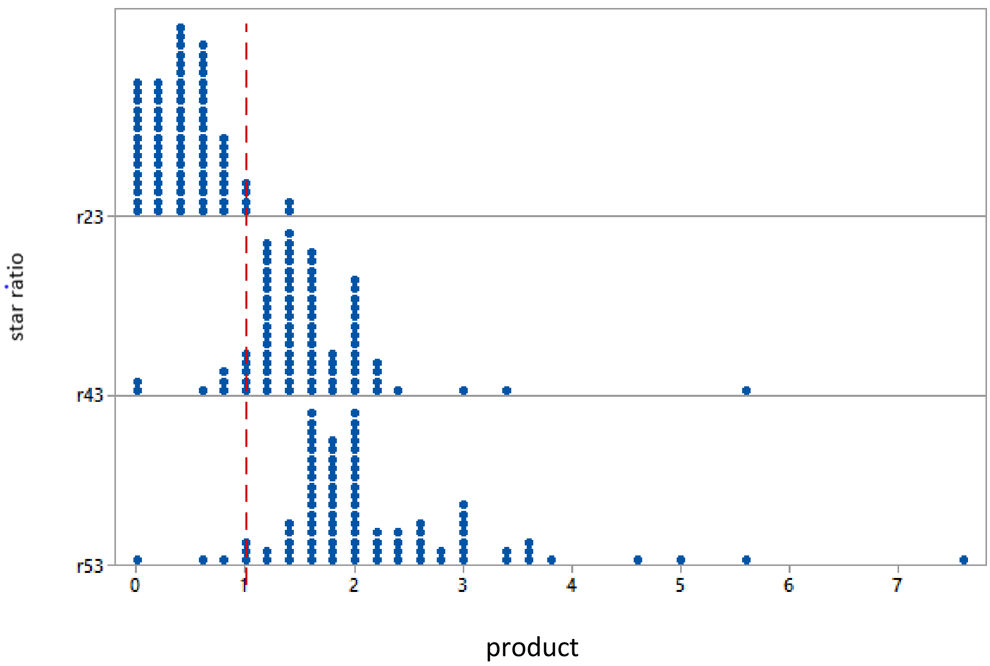
Overall, the willingness to pay ratios described relative to 3-star product (ratio 1.0) in the burger products are not dissimilar to typical beef WTP ratios of 0.5 (2 star), 1.5 (4 star) and 2.0 (5 star) and indicate that consumers accept that higher eating experiences represent value at significantly higher prices.

Table 17: Descriptive statistics for willingness to pay of the different star ratings when compared with 3-star everyday product.

Variable	n	nm	mean	sd	min	q1	med	q3	max
r23	118	2	0.41	0.30	0.00	0.21	0.39	0.54	1.41
r43	118	2	1.54	0.59	0.04	1.25	1.44	1.77	5.56
r53	118	2	2.11	0.95	0.06	1.62	1.92	2.36	7.67

Variable	p	n	nm	mean	sd	min	q1	Med	q3	max
r23	1	79	2	0.43	0.32	0.00	0.20	0.40	0.62	1.41
	2	39	0	0.37	0.22	0.00	0.21	0.37	0.51	0.85
r43	1	79	2	1.55	0.65	0.04	1.25	1.45	1.77	5.56
	2	39	0	1.53	0.46	0.53	1.25	1.43	1.79	3.33
r53	1	79	2	2.12	1.00	0.06	1.60	1.94	2.50	7.67
	2	39	0	2.08	0.82	0.55	1.65	1.89	2.30	5.56

Figure 33: Dot plot of WTP ratios compared to 3-star, good everyday.



4.3.6 Demographic data

Both location specific and overall descriptive summary statistics are reported for the demographic variables of this trial (Table 18 and 19).

The demographics in the locations were similar, but there are also some differences:

- Age: Deepwater consumers tended to be older (D60+ = 47%, H60+ = 8%)
- Gender: Slightly more females in Deepwater (Df =55%, Hf = 45%)
- Occupation: More professional/technicians in Helensburgh (Dpt = 23%, Hpt = 50%), also a lot of “other” (unemployed/retired) in both, but slightly more in Helensburgh (Ho = 47%, Do = 23%)
- Adults: There were mostly 1 or 2 adults in the households at Deepwater (D1 & 2 = 87%), whereas there were often 3+ in Helensburgh (H3+ = 51%)
- Children: Both locations had mostly no children living at home (D0 = 68%, H0 = 72%)
- Beef Statement: Both locations favoured consuming beef but Deepwater were more at the “enjoy” end of the scale (De = 52%, He = 40%)
- Doneness: The two locations were quite similar for doneness of the meat. However, there were more med/wd in Deepwater (Dmwd = 25%, Hwd = 8%).
- Income: Helensburgh had a higher proportion of high-income earners (D>150k = 15% and Helensburgh Hmwd =48%), and more low-income earners in Deepwater (D<100K = 64%, H<100K = 20%).
- Purchaser: Both locations had similar main purchaser consumers (Dp = 72%, Hp = 63%)
- Education: Helensburgh tended to be more educated (Dps = 45%, Hcg = 79%)
- Heritage: Mostly Australian in both locations (Da = 83%, Ha = 72%)

Overall, the two locations demographic data did not significantly differ from one another, The “city” Helensburgh population tended to be more educated and had higher income earners.

Table 18: Demographic variables by location descriptive statistics (%).

Deepwater

age	pc	gdr	pc	occ	pc	oft	Pc	Ad	pc	ch	pc
18-19	3%	male	43%	manager	22%	daily	8%	1	15%	0	72%
20-25	2%	female	55%	prof	13%	4-5pw	15%	2	72%	1	7%
26-30	5%	n=	98%	tech	10%	2-3pw	50%	3	3%	2	12%
31-39	10%	n.miss=	2%	community	2%	weekly	17%	4	8%	3	5%
40-60	33%			clerical	3%	fortntly	5%	5	2%	4+	0%
61-70	27%			sales	0%	monthly	3%	6	0%	n=	95%
71+	20%			machine	3%	n=	98%	7	0%	n.miss=	5%
n=	100%			labourer	7%	n.miss=	2%	8+	0%		
				home	12%			n=	100%		
				student	2%						
				other	23%						
				n=	97%						
				n.miss=	3%						

stt	pc	done	pc	inc	pc	pch	Pc	Ed	pc	htg	pc
enjoy	52%	rare	7%	0-25K	17%	yes	72%	Primary	12%	aust	83%
like	38%	m/rare	50%	25-50K	17%	no	28%	Secondary	33%	british	5%
some	8%	med	17%	50-75K	12%	n=	100%	College	37%	european	0%
rarely	2%	med/wd	25%	75-100K	18%			Graduate	18%	asian	8%
n=	100%	welldone	2%	100-125K	7%			n=	100%	other/na	2%
		n=	100%	125-150K	2%					n=	98%
				150+	15%					n.miss=	2%
				prefer na	13%						
				n=	100%						

Helensburgh

age	pc
18-19	5%
20-25	17%
26-30	22%
31-39	7%
40-60	42%
61-70	3%
71+	5%
n=	100%

gdr	pc
male	55%
female	45%
n=	100%
n.miss=	0%

occ	pc
manager	23%
prof	20%
tech	30%
community	2%
clerical	5%
sales	7%
machine	2%
labourer	0%
home	3%
student	2%
other	47%
n=	100%

oft	Pc
daily	3%
4-5pw	17%
2-3pw	53%
weekly	20%
fortntly	5%
monthly	2%
n=	100%
n.miss=	

Ad	pc
1	3%
2	45%
3	18%
4	23%
5	5%
6	0%
7	5%
8+	0%
n=	100%

ch	pc
0	68%
1	7%
2	17%
3	8%
4+	0%
n=	100%
n.miss=	0%

stt	pc
enjoy	40%
like	50%
some	10%
rarely	0%
n=	100%

done	pc
rare	12%
m/rare	55%
med	20%
med/wd	8%
welldone	5%
n=	100%

inc	pc
0-25K	2%
25-50K	3%
50-75K	5%
75-100K	10%
100-125K	10%
125-150K	7%
150+	48%
prefer na	15%
n=	100%

pch	Pc
yes	63%
no	37%
n=	100%

Ed	pc
Primary	3%
Secondary	18%
College	47%
Graduate	32%
n=	100%

htg	pc
aust	72%
british	15%
european	12%
asian	0%
other/na	0%
n=	100%

Table 19: Combined population demographics descriptive statistics (counts).

Age	count
18-19	5
20-25	11
26-30	16
31-39	10
40-60	45
61-70	18
71+	15
n=	120

gdr	count
male	59
female	60
n=	119
n.miss=	1

occ	count
manager	27
prof	20
tech	24
community	2
clerical	5
sales	4
machine	3
labourer	4
home	9
student	2
other	18
n=	118
n.miss=	2

oft	count
daily	7
4-5pw	19
2-3pw	62
weekly	22
fortntly	5
monthly	1
n=	119
n.miss=	1

ad	count
1	11
2	70
3	13
4	19
5	4
6	
7	3
8+	
n=	120

ch	count
0	84
1	8
2	17
3	8
4+	
n=	117
n.miss=	3

stt	count
enjoy	55
like	53
some	11
rarely	1
n=	120

done	count
rare	11
m/rare	63
med	22
med/wd	20
welldone	4
n=	120

inc	count
0-25K	11
25-50K	12
50-75K	10
75-100K	17
100-125K	10
125-150K	5
150+	38
prefer na	17
n=	120

pch	count
yes	81
no	39
n=	120

ed	count
primary	9
secondary	31
college	50
graduate	30
n=	120

htg	count
aust	93
british	12
european	7
asian	5
other/na	2
n=	119
n.miss=	1

age	pc
18-19	4%
20-25	9%
26-30	13%
31-39	8%
40-60	38%
61-70	15%
71+	13%
n=	100%

gdr	pc
male	49%
female	50%
n=	99%
n.miss=	1%

occ	pc
manager	23%
prof	17%
tech	20%
community	2%
clerical	4%
sales	3%
machine	3%
labourer	3%
home	8%
student	2%
other	15%
n=	98%
n.miss=	2%

oft	pc
daily	6%
4-5pw	16%
2-3pw	52%
weekly	18%
fortntly	4%
monthly	1%
n=	99%
n.miss=	1%

ad	pc
1	9%
2	58%
3	11%
4	16%
5	3%
6	0%
7	3%
8+	0%
n=	100%

ch	pc
0	70%
1	7%
2	14%
3	7%
4+	0%
n=	98%
n.miss=	3%

stt	pc
enjoy	46%
like	44%
some	9%
rarely	1%
n=	100%

done	pc
rare	9%
m/rare	53%
med	18%
med/wd	17%
welldone	3%
n=	100%

inc	pc
0-25K	9%
25-50K	10%
50-75K	8%
75-100K	14%
100-125K	8%
125-150K	4%
150+	32%
prefer na	14%
n=	100%

pch	pc
yes	68%
no	33%
n=	100%

ed	pc
primary	8%
secondary	26%
college	42%
graduate	25%
n=	100%

htg	pc
aust	78%
british	10%
european	6%
asian	4%
other/na	2%
n=	99%
n.miss=	1%

Two statistical models were run to determine whether any demographic responses were correlated to the sensory MQ. The first model results (Table 20) indicated that product and consumer were significant factors in predicting MQ, which is to be expected.

Table 20: Model results for burger products; MQ = product + id.

Analysis of Variance

source	df	SS	MS	F	P
pn	6	89510	14918.3	47.88	0.000
idz	119	118530	996.1	3.20	0.000
Error	712	221840	311.6		
Total	837	430004			

Model Summary

S	R-sq	R-sq(adj)
17.65	48.4%	39.4%

Coefficients

term	est	se
constant	52.735	0.61
pn		
0	-8.23	1.49
1	-2.57	1.49
2	-12.55	1.49
3	15.61	1.49
4	15.28	1.49
5	-1.63	1.49
6	-5.91	1.49

idz		
1	15.36	6.64
2	15.92	6.64

The second model looked to explain these differences amongst consumers (Table 21). It is observed that the product estimates remain similar with the R^2adjusted for model 2 (31.8%) not greatly behind the first model (39.4%).

Results from the second model show age, occupation, beef statement, income and heritage to be significant (P<0.001). MQ score tends to increase with age (70+ = + 2.14 points), occupation is difficult to explain as there many categories with few entries. The beef statement is as aligned with the consumers' views, those who eat meat less tend to give smaller MQ scores (rarely = -28 points). The higher-income earners tended to relate to higher MQ scores (>150K = + 5.79 points). Heritage is problematic because of a coding issue, but indicates that those of European and Asian heritage tend to give lower MQ scores (Euro = -4.03, Asian = -6.37 points).

The model coefficients are included to provide detail within each category.

Table 21: Model results for burger products and consumer demographic answers MQ = (consumer-covariates) + product.

Analysis of Variance

source	df	SS	MS	F	P
pn	6	86918	14486.3	41.37	0.000
locn	1	61	60.9	0.17	0.677
age	6	8743	1457.1	4.16	0.000
gdr	1	515	515.4	1.47	0.225
occ	10	11674	1167.4	3.33	0.000
oft	5	2589	517.9	1.48	0.194
ad	5	1139	227.8	0.65	0.661
ch	3	423	140.9	0.40	0.751
stt	3	6633	2210.9	6.31	0.000
pref	4	783	195.8	0.56	0.692
inc	7	9966	1423.7	4.07	0.000
pch	1	1	0.9	0.00	0.959
ed	3	881	293.5	0.84	0.473
htg	4	4699	1174.6	3.35	0.010
Error	729	255256	350.1		
Total	788	404476			

Model Summary

S	R-sq	R-sq(adj)
18.71	36.9%	31.8%

Coefficients

term		est	se
constant		38.62	4.56
pn			
	0	-9.09	1.63
	1	-2.68	1.63
	2	-13.07	1.63

3	15.61	1.63
4	15.27	1.63
5	-0.39	1.63
6	-5.64	1.64

Table 21 Continued: Model results for burger products and consumer demographic answers MQ = (consumer-covariates) + product.

Coefficients

	est	se	n		Est	se	n
location				Ch			
D	-0.52	1.25	60	0	1.34	1.95	84
H	0.52	1.25	60	1	0.96	2.94	8
age				2	-1.98	2.21	17
18-19	13.74	3.93	5	3	-0.32	2.78	8
20-25	-7.67	3.05	11	Stt			
26-30	-3.32	2.47	16	enjoy	15.56	3.95	55
31-39	-4.32	2.98	10	like	9.46	3.78	53
40-60	1.16	1.88	45	some	3.03	4.77	11
					-		
61-70	-1.73	2.33	18	rarely	28.00	11.00	1
70+	2.14	3.05	15	Pref			
gdr				rare	0.27	2.58	11
male	-1.46	1.20	59	m/rare	0.22	1.74	63
female	1.46	1.20	60	Med	0.74	2.09	22
occ				med/wd	3.14	2.33	20
manager	-1.99	2.50	27	welldone	-4.37	4.21	4
prof	-6.01	2.69	20	Inc			
tech	-3.89	2.71	24	0-25K	-3.12	3.63	11
community	24.15	6.25	2	25-50K	-5.53	3.23	12
clerical	5.85	6.40	5	50-75K	11.03	3.24	10
sales	-5.84	5.09	4	75-100K	-0.33	2.14	17
machine	6.86	5.76	3	100-125K	5.67	2.98	10
					-		
labourer	-7.25	4.54	4	125-150K	10.73	4.25	5
home	-9.19	4.35	9	150+	5.79	1.83	38
student	-1.49	8.33	2	prefer na	-2.78	2.34	17
other	-1.20	2.56	18	Pch			
Oft				P	0.05	1.00	81
daily	-8.50	3.71		Np	-0.05	1.00	39
4-5pw	-1.06	2.91		Ed			
2-3pw	-1.36	2.28		primary	3.90	2.47	9
weekly	2.19	2.80		secondary	-0.76	1.51	31
fortntly	3.70	4.41		college	-0.96	1.69	50
monthly	5.03	8.86		graduate	-2.17	2.16	30
Ad				Htg			
1	2.10	3.45	11	aust	6.00	2.51	93
2	1.67	2.44	70	british	1.86	3.10	12
3	-3.28	2.83	13	european	-4.03	4.17	7
4	0.68	2.39	19	asian	-6.37	4.10	5
5	3.23	4.87	4	other/na	2.54	7.35	2
7	-4.40	7.08	3				

4.3.7 Attitudinal data

The attitudinal question forms completed by each consumer after consuming and rating all sensory samples are presented in Appendix 8.3 with summary statistics of the non-standard attitudinal questions at the end of the survey shown in Table 22.

Meat was the most preferred protein (78%) with plant-based (3%) least preferred. Consumers indicated they were largely unlikely to purchase plant-based protein products with never (37%) and unlikely (34%) the top answers. Only 2% of consumers said they would definitely purchase plant-based alternative proteins.

On the basis of the ingredient list product 5, Cleaver's burger (44%) and product 6 the 85VL mince burger (33%) were the highest ranked. The least chosen products were product 1, the beyond burger and Next Gen (each 3%) followed by product 4, the Coles beef burger (5%). Clearly consumers preferred products that had the least number of ingredients listed and ones that appeared natural and could be easily understood. Consumers tended to avoid the products with long and confusing ingredient lists which is commonly the case with plant-based products or products with a lot of fillers.

Table 22: Descriptive statistics for attitudinal responses to non-standard questions on the burger products survey.

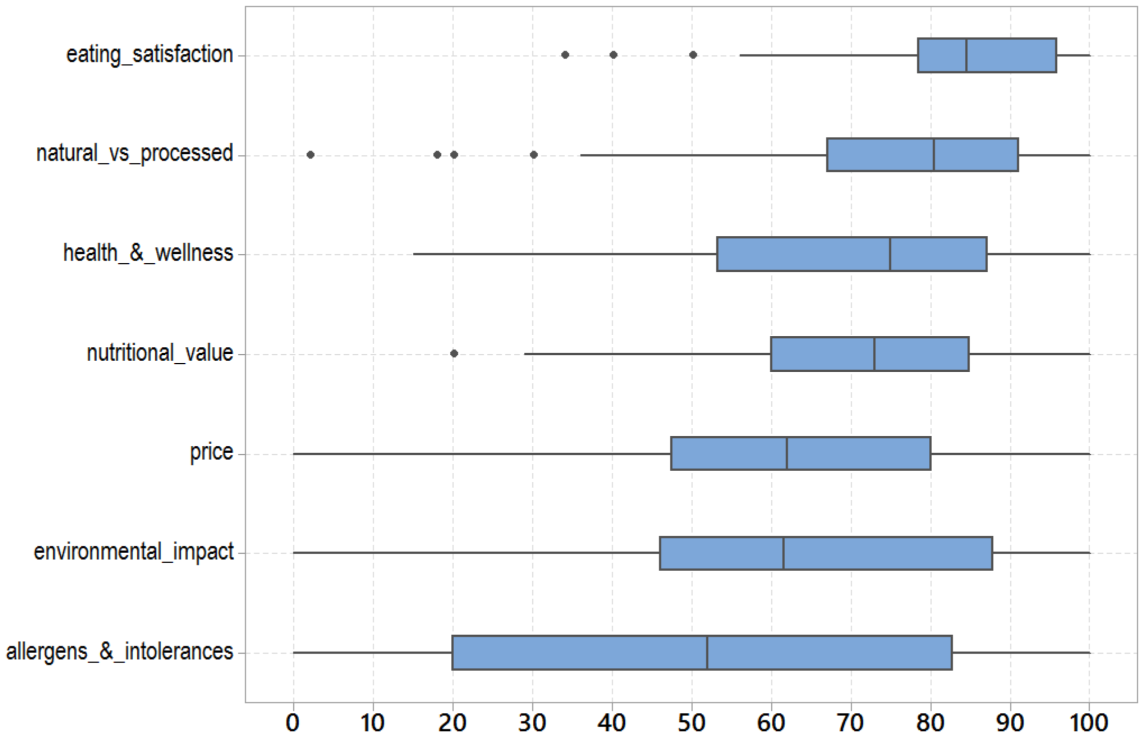
Protx	count	plant	count	ingredx	count
meat	78%	never	37%	beyond	3%
blended	8%	unlikely	34%	nextgen	3%
plant	3%	somewhat	14%	type A	12%
all=	88%	likely	13%	coles	5%
*=	12%	definitely	2%	cleavers	44%
		all=	100%	beef	33%
				all=	99%
				*=	1%

The other attitudinal responses are displayed in Table 23 and Figure 34. These summary statistics reflect the importance to consumers of each characteristic when purchasing protein products. Eating satisfaction rated highest (average 84.1), followed closely by valuing a more natural over a highly processed product (average 77.6). Nutritional value and health and wellness rank next (71.3 & 70.4) with environmental impact lower (63.5) but still of importance. Allergens and food intolerances were regarded as important by the fewest number of people. However, this characteristic is very important to some and not at all important to others, reflected by its' larger response range.

Table 23: Descriptive statistics for attitudinal responses reflecting the importance to consumers of specific characteristics when purchasing burger products.

	N	mean	sd	Min	q1	med	q3	max
eating satisfaction	120	84.1	13.6	34	79	85	96	100
natural vs highly processed	120	77.6	19.7	2	67	81	91	100
nutritional value	120	71.3	17.8	20	60	73	85	100
health and wellness	120	70.4	20.7	15	53	75	87	100
environmental impact	120	63.5	25.7	0	46	62	88	100
Price	120	61.2	24.3	0	48	62	80	100
allergens and food intolerance	120	50.7	33.6	0	20	52	83	100

Figure 34: Box plot of the attitudinal responses from consumers to reflect which characteristics they perceived of importance when purchasing protein products.



4.3.8 Correlations among demographic and attitudinal variables

Correlations between demographic and attitudinal variables are presented in Figure 35. Correct interpretation requires care to identify the direction of each variable as some are negatively correlated to beef, e.g. Oft, which is how often do you eat beef, the question starts with 1 = daily and 6 = never. Importantly, the protein type, plant-based and ingredient questions have been rearranged so that they all point the same way towards “anti-beef”.

Ingredient preference is not related to purchasing important variables except for allergens. As consumers considered allergens more important, they tended to choose the ingredients that were closest to beef. This could be due to the fact that the plant-based products have many ingredients, some quite unusual and could influence those that are concerned about allergens and intolerances towards a more natural beef product.

Protein-type preference and plant-based preference were related to the attitudes of health & wellbeing, nutrition and the environment with those who highly valued price, health, nutritional value and the environment more inclined to prefer and purchase plant-based alternatives. Interestingly this group also valued a less processed product, which in many cases is inconsistent with actual plant-based burger production. While the plant-based alternatives were considered more natural than an animal product this is contrary to the extreme processing required to make the complex plant-based alternatives. Consumer awareness of the production processes and extensive ingredient manipulation may be important factors in influencing future consumer attitudes.

The 3 protein, plant and ingredient questions are all quite positively related to Oft and Stt, confirming those that were anti-beef did not eat beef regularly. They were negatively correlated to income, with those with higher income and education level more likely to try plant-based protein, although they don't at present. They were somewhat positively correlated with gender, indicating that females were more likely to favour plant-based proteins than males.

There is generally positive correlation among the purchasing importance variables (with the exception of allergens and eating satisfaction). Most are positively correlated with age, with older people rating health and wellbeing, nutrition and non-processed as more important. All purchasing variables are positively correlated with gender, meaning females rate these characteristics more important than males. They are negatively correlated with income and education, those with a higher education and higher paying job placed less of an importance on the purchasing variables. Most of the purchasing variables (except price and allergens) are positively correlated with Stt meaning those who rarely ate beef placed a higher importance on all of these variables.

More correlations between demographic and attitudinal responses against the sensory variables (mq, tn, ju, fl) split by product are shown in Appendix 8.4.9.

Figure 35: Correlation matrix of attitudinal and demographic variables. Pink = corr > 0.2, cream = 0.1<corr<0.2, green = corr<-0.2, light green = -0.2<corr<-0.1.

	Protx	plant	ingz	eats	Price	hwell	nutrn	allg	proc	env	age	gdr	oft	stt	inc	ed
protx		0.26	0.44	0.08	0.11	0.11	0.23	-0.03	0.07	0.26	0.01	0.16	0.26	0.36	-0.16	-0.14
plant	0.26		0.31	0.04	0.03	0.24	0.23	-0.01	0.18	0.32	-0.09	0.13	0.27	0.44	-0.03	0.26
ingz	0.44	0.31		0.04	0.02	0.06	0.08	-0.13	0.09	0.14	-0.08	0.15	0.25	0.32	-0.12	0.08
eats	0.08	0.04	0.04		0.10	0.29	0.24	-0.04	0.13	0.11	0.04	0.15	0.07	0.12	0.03	0.15
price	0.11	0.03	0.02	0.10		0.09	0.08	0.33	0.09	0.19	-0.08	0.19	-0.11	0.01	-0.27	-0.23
hwell	0.11	0.24	0.06	0.29	0.09		0.79	0.32	0.45	0.50	0.27	0.18	0.01	0.22	-0.08	-0.01
nutrn	0.23	0.23	0.08	0.24	0.08	0.79		0.28	0.51	0.53	0.29	0.28	-0.01	0.27	-0.11	-0.02
allg	-0.03	-0.01	-0.13	-0.04	0.33	0.32	0.28		0.23	0.33	0.05	0.01	-0.05	0.04	-0.19	-0.31
proc	0.07	0.18	0.09	0.13	0.09	0.45	0.51	0.23		0.43	0.31	0.12	0.07	0.21	-0.10	0.07
env	0.26	0.32	0.14	0.11	0.19	0.50	0.53	0.33	0.43		0.19	0.27	0.06	0.30	-0.24	-0.07
age	0.01	-0.09	-0.08	0.04	-0.08	0.27	0.29	0.05	0.31	0.19		-0.03	-0.18	-0.07	-0.10	-0.04
gdr	0.16	0.13	0.15	0.15	0.19	0.18	0.28	0.01	0.12	0.27	-0.03		0.04	0.34	-0.23	0.14
oft	0.26	0.27	0.25	0.07	-0.11	0.01	-0.01	-0.05	0.07	0.06	-0.18	0.04		0.50	0.06	0.08
stt	0.36	0.44	0.32	0.12	0.01	0.22	0.27	0.04	0.21	0.30	-0.07	0.34	0.50		-0.07	0.02
inc	-0.16	-0.03	-0.12	0.03	-0.27	-0.08	-0.11	-0.19	-0.10	-0.24	-0.10	-0.23	0.06	-0.07		0.18
ed	-0.14	0.26	0.08	0.15	-0.23	-0.01	-0.02	-0.31	0.07	-0.07	-0.04	0.14	0.08	0.02	0.18	

5. Conclusion

Alternative protein products are being manufactured to look, taste and mimic beef, whilst making claims of being a healthier, more sustainable option. It is critical that the beef industry produce products that will be enjoyed and valued by the end-consumer. These do not need to all be at premium level but critically should offer very consistent eating experiences to provide clearly understood value points. This project provides an important insight into what is valued by consumers in terms of sensory weights, attitudes and their purchasing values, specifically towards burger patties. Interestingly, this differs to the current eating quality calculation of standard beef cuts and cooks, with consumers placing a higher emphasis on flavour in comparison to all other traits. The attitudinal data shows that all consumers want good eating quality from their products, desire those that are less processed, contain fewer obscure ingredients and are better for the environment. These are important findings and can potentially help inform future product development from the red-meat industry to compete with alternative proteins.

The study demonstrates that beef is currently in a favourable position being preferred by 78% of the project consumers and consistent across the country and city regions. Despite the hype, the alternative protein burgers tested rated below beef for sensory satisfaction, with one product extremely low and the other slightly less. In contrast, the blended products performed well, and slightly above the high beef products, with one (57% beef) blended with largely natural vegetable ingredients and the other (78% beef) containing more fillers typical of a lower price burger formulation. The relative performance of the pure (100%) and high-end beef (96% beef) options was strongly related to increased cook loss. While this may reflect higher than ideal cooked temperatures, required to ensure food safety and comply with the alternative protein specifications, fat levels below those of the blended and alternative products could also have contributed. The pure beef link product (5% fat) and pure beef product 6 (15% fat) had no additives of any sort to provide a pure beef benchmark not confounded by additions that could impact flavour or mechanical properties. In further studies and product development work it is suggested that a range of fat levels and limited use of ingredients that may reduce moisture loss and possibly further enhance flavour be examined.

A significant beef marketing benefit relates to the complex and extensive ingredient listings for the alternative protein products coupled with their highly processed nature. It appears that consumers currently relate vegetable-based product with natural, minimally processed and environmentally friendly claims. These are not substantiated by fact and consumer education could be useful in establishing a more balanced understanding.

The nutritional value of the alternative protein products is not known in sufficient detail to relate to bioavailability and their potential contribution to human diet across age groups and life stages. It is suggested that samples from this study or others be evaluated fully to rectify this situation.

While the alternative protein products are likely to further improve given heavy development expenditure beef is currently very well placed as a preferred and trusted protein. There are also indications that well designed beef blend products may add further market diversification while retaining a strong beef component. On current market dynamics these may also reverse past practice in being sold at a premium rather than blending being used to lower cost and price. From project outcomes alternative protein products offer lower sensory satisfaction, with beef flavour being the major determining component favouring beef products, with marketing likely to promote the plant-based product on the basis of environmental, health or animal welfare claims. These claims can be refuted from existing and developing science and it is vital that the beef industry continues to pursue improvement in these areas and to raise community awareness through a more balanced understanding of relevant facts.

Key findings

- Blended beef patties were rated the highest by everyday Australian consumers.
- Plant-based burgers performed the worse with many (51%) rated as unsatisfactory.
- 100% beef patties were rated above plant-based products but below the beef blends. This correlates with increased cook loss and may reflect overcooking due to the standardised cooking times needed to achieve an internal temperature of 70°C, required for plant-based burgers. Other factors affecting resilience to high temperature cooking could include lower fat content and, for the pure beef items, the lack of any ingredients that might reduce cook loss or enhance flavour.
- There was no significant difference in the eating quality scores between the “city” and “rural” populations.
- Standard MQ4 calculations were not as accurate at predicting burger eating quality.
- A new BQ statistic with greater accuracy for burgers was created from these data with BQ calculated as 0.1*tenderness + 0.1*juiciness + 0.5*flavour + 0.3*overall.
- Flavour was the most important predictor of eating quality in burger products.
- Consumers were wary of the plant-based alternative ingredients list and opted for the more natural beef ingredient type lists.
- There were some interesting correlations between sensory, demographic, attitudinal and purchasing variables.

6. Future research and recommendations

6.1 Future research and development

The project has revealed that plant-based products are not well liked by Australian consumers being scored lower than beef and beef blends and having a far greater % judged unsatisfactory. However, these alternatives are rapidly improving and seeking to mimic meat including flavour, texture and cooked appearance. These market changes, and in particular aggressive promotion of an anti-meat agenda linked to claims relating to climate change, human health and animal welfare, represent a well-funded challenge to the industry.

We must as an industry, listen to the consumer and ensure we deliver consistent high value products within a sustainable framework. Given the alternative products are likely to be promoted on unsubstantiated but common claims relating to diet, climate and welfare benefits it is vital that industry continues to improve in these aspects and, critically, to successfully communicate from a solid science base that results in a balanced factual appreciation at farm and consumer level. The project has reported relationships between the purchasing, attitudinal, demographic and sensory responses which provide insight into what the consumer considers important when looking at purchasing alternative proteins and their current view on such products.

This project only represents a small number of samples and consumers, so some more work in this space would lead to more conclusive results and increased reliability. It is recommended that further work be conducted to better define relationships to fat level in high beef content burgers and to both minor ingredient additions and cooking regimes that may reduce cook loss which was correlated strongly with reduced tenderness and juiciness in this study.

It is also strongly recommended that detailed chemical analysis of the trial products be considered to establish the human dietary implications and relative quantity and bioavailability of key dietary components. The profiles of fatty acids, proteins and amino acids, micronutrient levels and bioavailability of each in alternative protein products relative to the beef and beef blends are currently not known. This analysis could provide the information to determine which of the products are nutritionally superior for human consumption and reveal which ingredients may not add any additional health benefits despite their packaging claims. It is suggested that 3 replicates of each of the 7 products (n = 21) be sent for chemical analysis of the following:

- Fat profile (37 fatty acids including omega 3, 6 and linoleic acid)
- Detailed Fat profile (LCMS)
- Amino acid profile with other metabolites (LCMS)
- Minerals ICPMS
- Crude protein
- Crude protein + stable isotopes
- Crude fat

This additional research may provide insightful ingredient information that could be used in other MLA projects regarding flexitarian and meat-less products such as (V.RMH.0003)

7. References

Heinz, Gunter and Hautzinger, Peter. "Meat Processing Technology for Small to Medium Scale Producers." Food and Agriculture Organization of the United Nations (FAO), 2007. pp.195-199.http://www.fao.org/docrep/010/ai407e/ai407e00.HTM

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8. Appendix

8.1 Products

8.1.1 The beyond burger

Coles Beyond Burger product label.

Coles Beyond Burger raw patty with non-stick film.

Beyond burger cooked as packaged patty.

8.1.2 NextGen2 burger

Woolworths NextGen2 burger product label.

Woolworths NextGen2 Burger raw patty with non-stick film.

NextGen2 burger cooked as packaged patty.

8.1.3 Type A prototype mince blend

Type A prototype raw mince prototype.

Type A prototype cooked as 60gram sample.

8.1.4 Beef BBQ burger

Coles Beef BBQ product label.

Coles Beef BBQ product raw patties.

Beef BBQ burgers cooked as packaged patty.

8.1.5 Cleaver's chuck and brisket burger

Cleaver's Chuck and Brisket Burger product label.

Cleaver's Chuck and Brisket Burger raw patties.

Cleaver's chuck and brisket cooked as packaged patty.

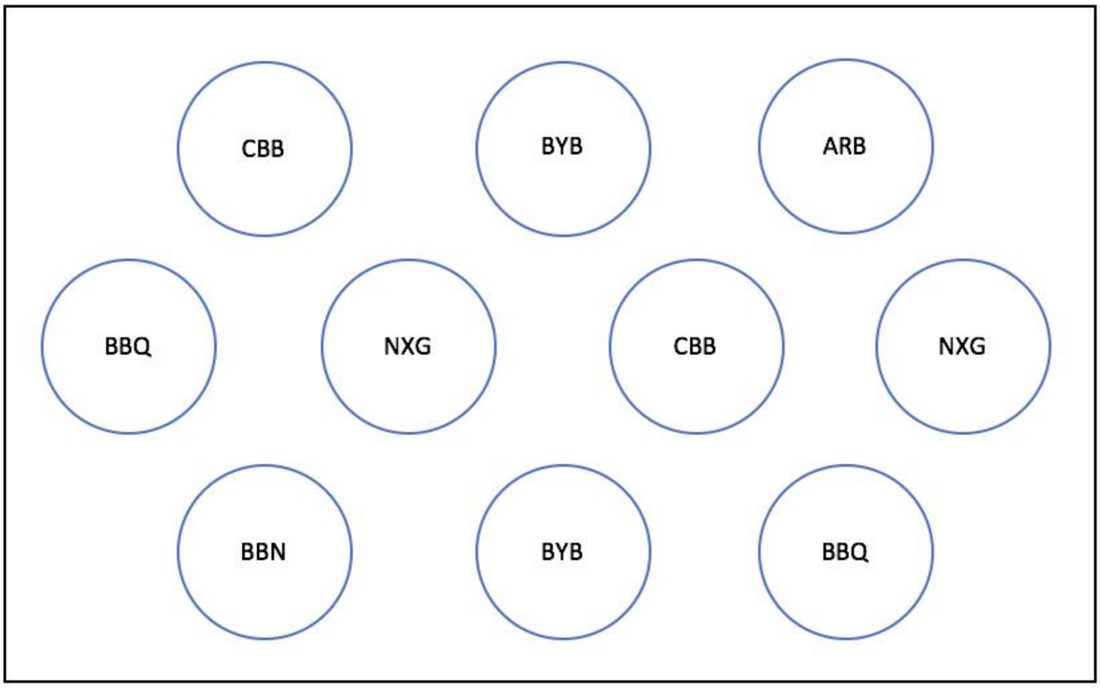
8.1.6 85/95VL burger

95 VL mince with 10% of fat added (left) to produce the 85 VL mince (right).

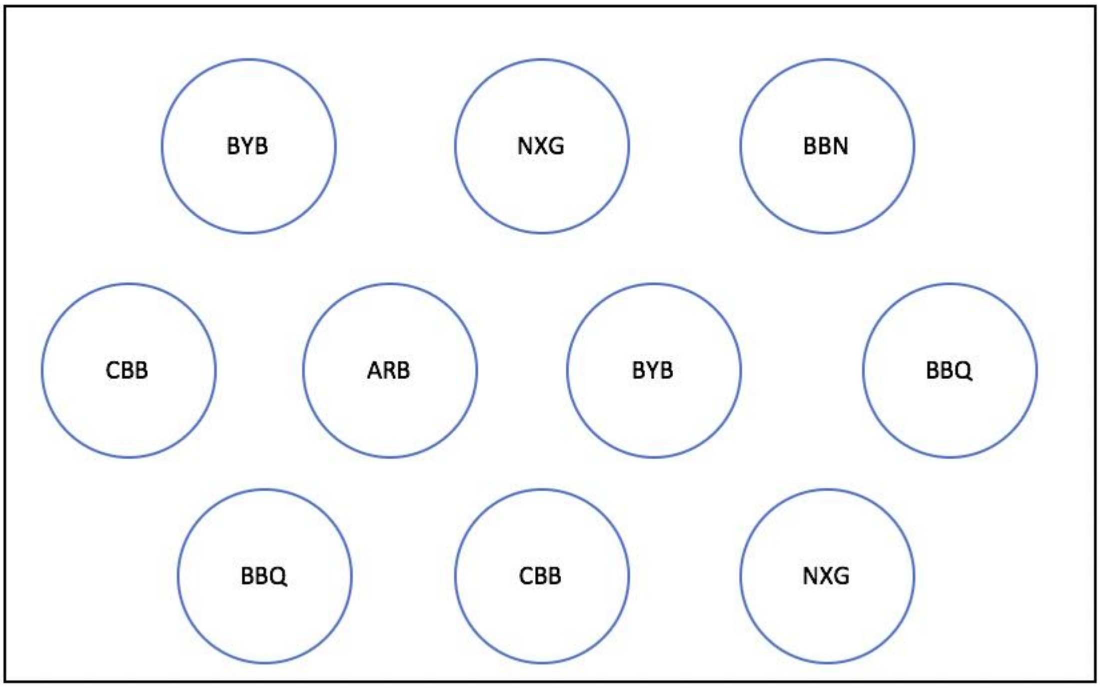
95VL link product cooked as 60gram sample patty.

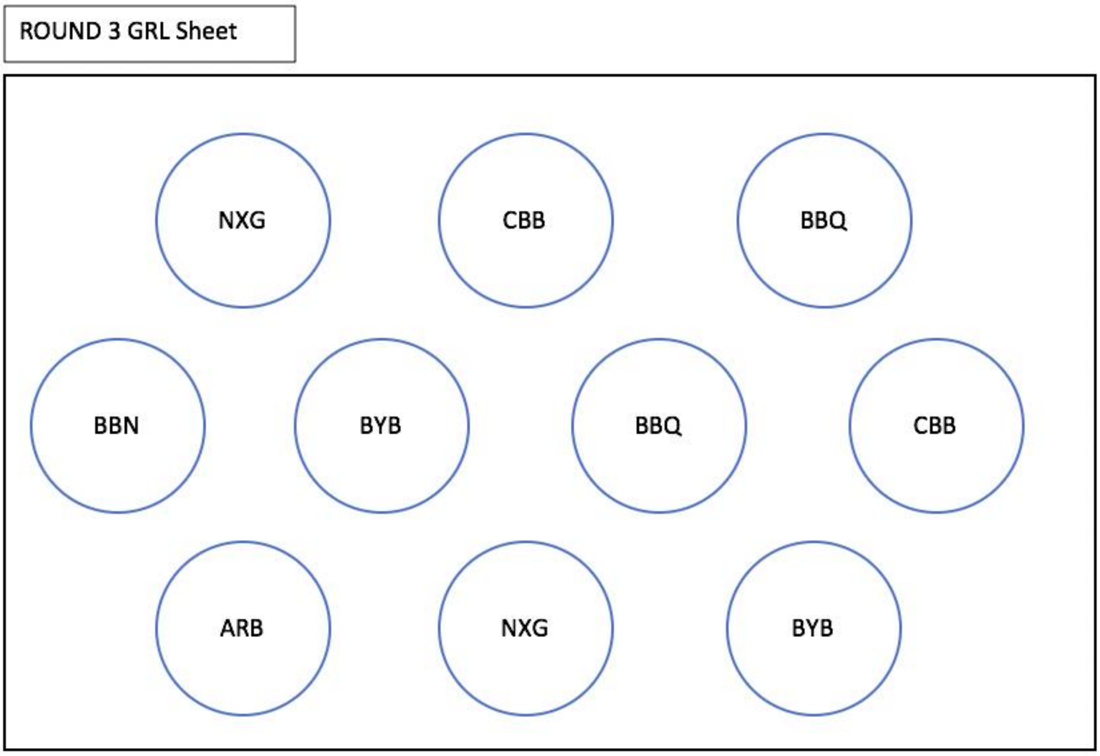
8.2 Round sheets

ROUND 1 GRL Sheet



ROUND 2 GRL Sheet





Rounds 1-3 grill sheets for cook timing trial of 60gram sample patties.

8.3 Consumer sensory questionnaire

Thank you for your participation today with our meat tasting

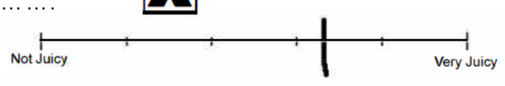
Our team is here to help you during your session and make this easy for you.

Before you start please listen to the instructions on how to use the scales contained in this questionnaire

Please use a blue pen to fill in the form and where asked:

Write crosses in boxes like this………… . ☒

Mark on the line scale like this….



In between each sample please cleanse your palate by:

* first……. Taking a sip of diluted apple juice

* then……… Chew a piece of cracker

* and then……… Take another sip of diluted apple juice

We are after YOUR opinion and therefore ask that you do not talk to anyone else in the room during the research session.

Now just a few questions about yourself (All this information is strictly confidential)

Date | D | D | M | M | Y | Y | Y | Y |

Your Group's Name ______________________

1. **Please write in the boxes the postcode you normally live in** ☐☐☐☐
2. **Age Group:** (Use **X** in one box only)

   18-19 ☐ 20-25 ☐ 26-30 ☐ 31-39 ☐ 40-60 ☐ 61-70 ☐ 70+ ☐
3. **Gender:** (Use **X** in one box only)

   Male ☐ Female ☐ Other ☐
4. **What is the occupation of the main income earner in your household?:** (Use **X** in one box only)

   ☐ Manager
   ☐ Professionals (includes health professionals etc.)
   ☐ Technicians and Trade Workers
   ☐ Community and Personal Services Workers
   ☐ Clerical and Administrative workers
   ☐ Sales Workers (includes retail sales etc.)
   ☐ Machine Operators and Drivers
   ☐ Labourers
   ☐ Home Duties
   ☐ Student
   ☐ Other

MSA sensory survey questions with additional alternative protein specific questions.

Please fill in the form and write crosses in boxes like this ☒

5. How often do you eat Beef?
(in any form such as steaks, roasts, stews, casseroles, kebabs, BBQ etc.)
(Use **X** in one box only)

- ☐ Daily
- ☐ 4-5 times a week
- ☐ 2-3 times a week
- ☐ Weekly
- ☐ Fortnightly
- ☐ Monthly
- ☐ Never eat beef

6.1. How many adults (18 and over) normally live in your household?
(Use **X** in one box only)

- ☐ 1 Adult
- ☐ 2 Adults
- ☐ 3 Adults
- ☐ 4 Adults
- ☐ 5 Adults
- ☐ 6 Adults
- ☐ 7 Adults
- ☐ 8 and over adults

6.2. How many children under 18 years normally live in your household?
(Use **X** in one box only)

- ☐ 0 Children
- ☐ 1 Child
- ☐ 2 Children
- ☐ 3 Children
- ☐ 4 Children
- ☐ 5 Children
- ☐ 6 Children
- ☐ 7 and over children

7. Please read the following statements
and use **X** in one box only for **the one statement** that applies to you

- ☐ I enjoy beef. It's an important part of my diet
- ☐ I like beef well enough. It's a regular part of my diet
- ☐ I do eat some beef although, truthfully it wouldn't worry me if I didn't
- ☐ I rarely / never eat beef

8. When you eat Beef, such as steak what level of cooking do you prefer?
(Use **X** in one box only)

- ☐ Blue
- ☐ Rare
- ☐ Medium / Rare
- ☐ Medium
- ☐ Medium / Well done
- ☐ Well done

9. What level of income best categories your combined household income?
(Use **X** in one box only)

- ☐ Below $25, 000 per year
- ☐ $25,001 - $50,000 per year
- ☐ $50,001 - $75,000 per year
- ☐ $75,001 - $100,000 per year
- ☐ $100,001 - $125,000 per year
- ☐ $125,001 - $150,000 per year
- ☐ More than $150,000 per year
- ☐ Prefer not to say

10. What level of education have you reached?
(Use **X** in one box only for the highest level achieved)

- ☐ Did not complete Secondary School
- ☐ Completed Secondary School
- ☐ A College/ TAFE course
- ☐ University Graduate

11. What is your cultural heritage?
(Use **X** in one box only)

- ☐ Australian
- ☐ British descent
- ☐ European descent
- ☐ Asian descent
- ☐ Other
- ☐ Prefer not to say

MSA sensory survey questions with additional alternative protein specific questions.

All information collected in this survey is strictly confidential

PRODUCT:

Tenderness

Not Tender — Very Tender

Juiciness

Not Juicy — Very Juicy

Liking of Flavour

Dislike Extremely — Like Extremely

Overall Liking

Dislike Extremely — Like Extremely

Please mark **X** in one of the following boxes to rate the quality of the burger patty you have just eaten

Choose **one** only (you must make a choice)

- ☐ Unsatisfactory
- ☐ Good everyday quality
- ☐ Better than everyday quality
- ☐ Premium quality

MSA sensory survey questions with additional alternative protein specific questions.

Based on the range of burger patty samples you have just consumed:

Please mark the line at the price per 4 pack of burger patties (500g) you believe best reflects the value for each category.

For the sort of patties you rated "Unsatisfactory Quality"

\$0/ 500g **\$10/ 500g** **\$20/ 500g** **\$30/ 500g** **\$40/ 500g**

For the sort of patties you rated "Good Everyday Quality"

\$0/ 500g **\$10/ 500g** **\$20/ 500g** **\$30/ 500g** **\$40/ 500g**

For the sort of patties you rated "Better Than Everyday Quality"

\$0/ 500g **\$10/ 500g** **\$20/ 500g** **\$30/ 500g** **\$40/ 500g**

For the sort of patties you rated "Premium Quality"

\$0/ 500g **\$10/ 500g** **\$20/ 500g** **\$30/ 500g** **\$40/ 500g**

Are you the regular purchaser for your family ? *(Use **X** in one box only)*

☐ Yes

☐ No

MSA sensory survey questions with additional alternative protein specific questions.

Please fill in the form and write crosses in boxes like this ☒

1. Of the protein types below which are you most likely to purchase?
(Use **X** in one box only)

- ☐ Meat-based (i.e. beef burger, lamb burger)
- ☐ Blended (i.e. beef and vegetable burger mixed)
- ☐ Plant-based (i.e. vegetable burger)
- ☐ All of the above

2. How likely are you to purchase a plant-based protein as a substitute for meat?
(Use **X** in one box only)

- ☐ Never
- ☐ Unlikely
- ☐ Somewhat
- ☐ Likely
- ☐ Definitely

3. Based on the ingredients list, which of the products would you be most likely to purchase?
(Use **X** in one box only)

- ☐ Product 1 or
- ☐ Product 2 or
- ☐ Product 3 or
- ☐ Product 4 or
- ☐ Product 5 or
- ☐ Product 6

MSA sensory survey questions with additional alternative protein specific questions.

Please mark the line at the point that best reflects the importance to you of each category.

4. **How important are the following to you when purchasing protein products?**

Eating Satisfaction

Not Important — Very Important

Price

Not Important — Very Important

Health and Wellness

Not Important — Very Important

Nutritional Value

Not Important — Very Important

Allergens & Food Intolerances

Not Important — Very Important

Natural v Highly Processed

Not Important — Very Important

Environmental Impact

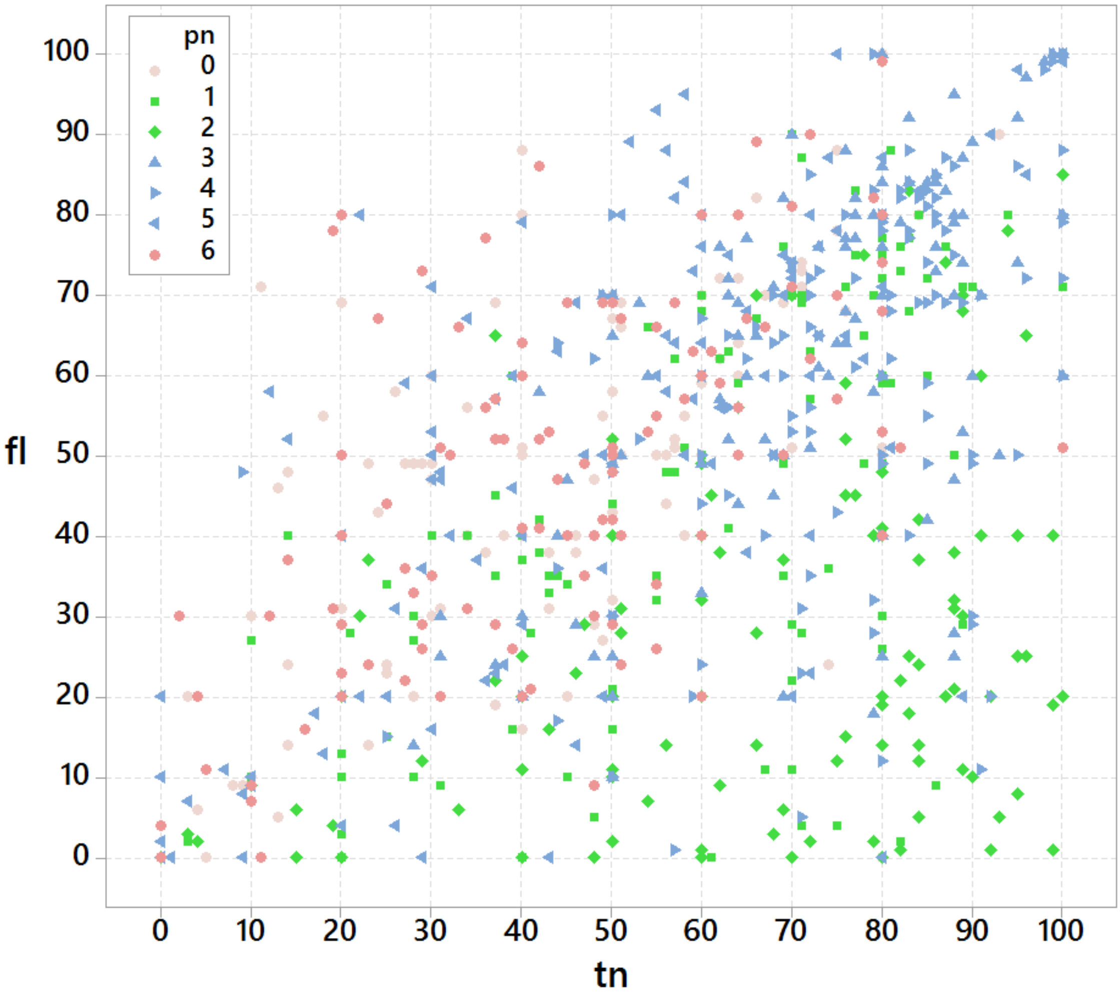
Not Important — Very Important

MSA sensory survey questions with additional alternative protein specific questions.

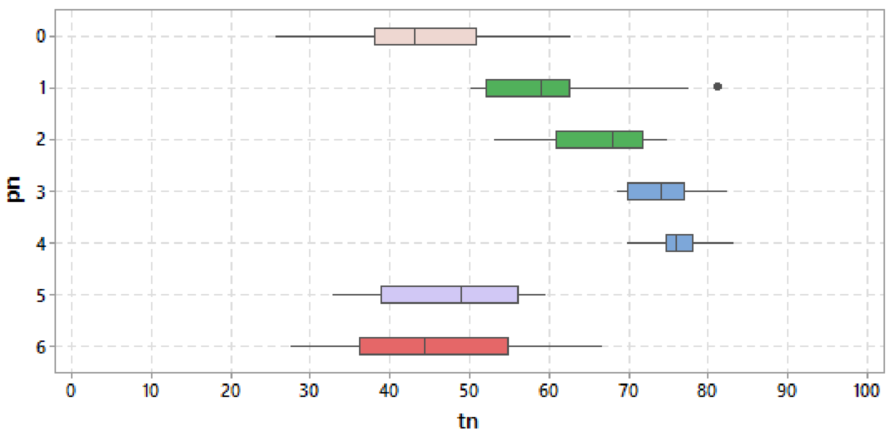
8.4 Additional results detail

Id	line xline locn EQSref.id EQSRef id* sess	 *1-60 Deepwater, 61-120 Helensburgh*
Demographic	pc age gdr occ oft ad ch stt pref inc pch ed htg	*Postcode* *age (category)* *gender (category)* *occupation (category)* *how often do you eat beef? (category)* *number of adults in household* *number of children in household* *non-beef preference (category)* *beef cooking level (category)* *income (category)* *regular purchaser (yes/no)* *education level (category)* *heritage (category)*
Sensory	tn ju fl ov MQ BQ st	 *standard MQ (3133)* *Nonstandard burger weightings BQ (1153)*
willing to pay	wtp2 wtp3 wtp4 wtp5	
	date	
purchase preference	prot plant ingred	*which protein type is preferred* *how likely to purchase plant as meat subsittute* *code changed to match product numbers*
purchase principles	eats price hwell nutrn allg proc env	*eating satisfaction* *price [note: high/low unspecified]* *health and wellness* *nutritional value* *allergens and food intolerances* *natural vs highly processed [direction?]* *environmental impact [direction?]*
Id	EQSref.id sess round id posn EQSref	
Product	pn NB	*product number (0123456) link=0=7* *product category (N,BX, B)*
sample characteristics	temp weight ckloss	*measured product cooking temperature* *cooked weight* *percentage loss in cooking = 100(60-w)/60*

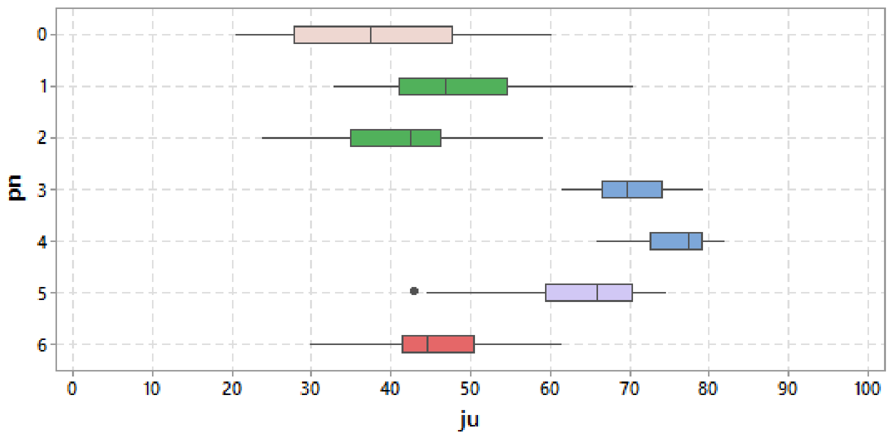
Appendix 8.4.1: Coding sheet for abbreviations used throughout the MSA sensory survey.



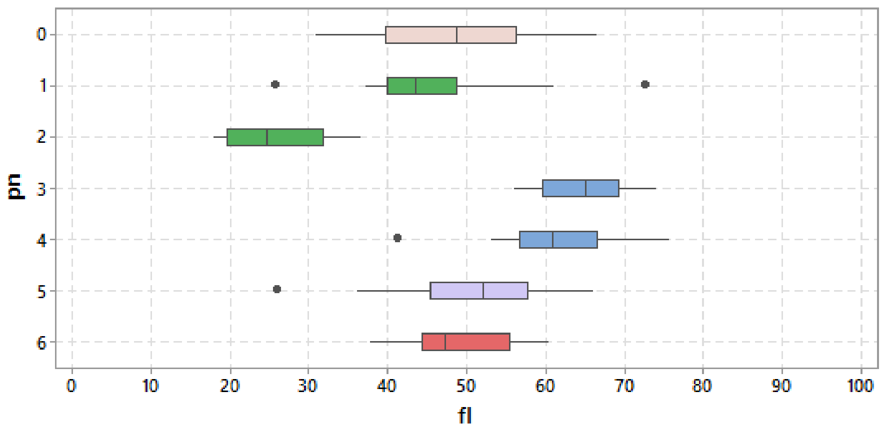
Appendix 8.4.2: Scatter plot of sensory variables flavour (fl) and tenderness (tn) categorised by burger product.



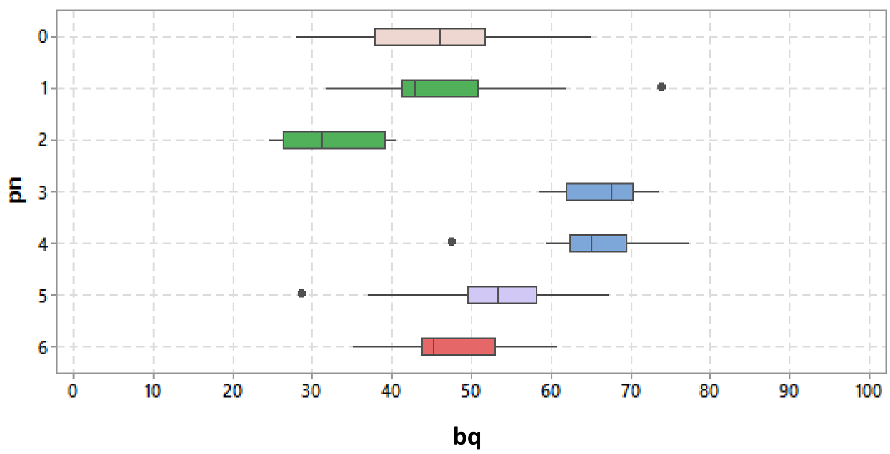
Appendix 8.4.3: Boxplot of the average tenderness of 10 consumers that ranked burger products from 0-100.



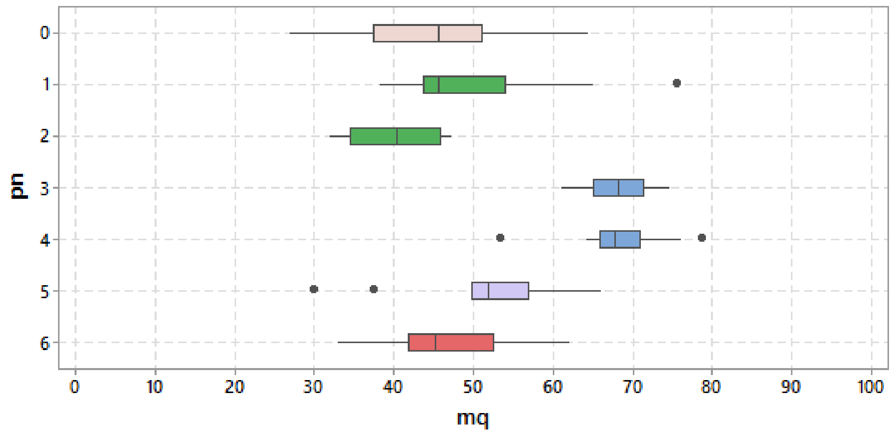
Appendix 8.4.4: Boxplot of the average juiciness of 10 consumers that ranked burger products from 0-100.



Appendix 8.4.5 Boxplot of the average flavour of 10 consumers that ranked burger products from 0-100.



Appendix 8.4.6: Boxplot of the average BQ of 10 consumers that ranked burger products from 0-100.



Appendix 8.4.7: Boxplot of the average MQ of 10 consumers that ranked burger products from 0-100.

	pn	n	mean	sd	min	Q1	med	Q3	max
tn	0	12	43.6	10.9	26	38	43	51	63
	1	12	60.1	9.9	50	52	59	63	81
	2	12	66.0	6.7	53	61	68	72	75
	3	12	74.2	4.2	69	70	74	77	82
	4	12	76.2	3.7	70	75	76	78	83
	5	12	47.9	9.2	33	39	49	56	59
	6	12	45.4	11.3	28	36	44	55	67
ju	0	12	37.6	12.2	20	28	37	48	60
	1	12	48.1	9.8	33	41	47	55	70
	2	12	40.8	9.5	24	35	42	46	59
	3	12	69.8	5.1	62	66	70	74	79
	4	12	76.1	4.4	66	73	77	79	82
	5	12	62.9	10.3	43	59	66	70	75
	6	12	46.0	8.7	30	41	45	50	61
fl	0	12	48.2	10.9	31	40	49	56	66
	1	12	45.5	11.8	26	40	43	49	72
	2	12	25.6	6.5	18	20	25	32	36
	3	12	64.6	5.5	56	60	65	69	74
	4	12	61.1	8.9	41	57	61	67	76
	5	12	50.3	10.9	26	45	52	58	66
	6	12	48.9	7.1	38	44	47	55	60
ov	0	12	44.0	10.5	27	36	45	51	65
	1	12	45.5	12.4	28	38	42	51	75
	2	12	28.8	7.1	19	24	26	37	39
	3	12	65.8	5.3	57	61	66	70	74
	4	12	64.1	8.7	44	60	64	71	77
	5	12	51.3	11.2	27	47	53	58	69
	6	12	47.0	7.6	35	41	45	53	60

BQ	0	12	45.4	10.4	28	38	46	52	65
	1	12	47.2	11.1	32	41	43	51	74
	2	12	32.1	6.0	25	26	31	39	40
	3	12	66.4	4.6	59	62	68	70	74
	4	12	65.0	7.6	47	62	65	69	77
	5	12	51.6	10.2	28	49	53	58	67
	6	12	47.7	7.3	35	44	45	53	61
MQ	0	12	44.5	10.2	27	38	46	51	64
	1	12	50.2	10.5	38	44	46	54	75
	2	12	40.2	5.5	32	35	40	46	47
	3	12	68.4	4.0	61	65	68	71	74
	4	12	68.0	6.3	53	66	68	71	79
	5	12	51.1	9.4	30	50	52	57	66
	6	12	47.0	8.0	33	42	45	53	62

Appendix 8.4.8: Descriptive statistics on sensory variable average from 10 consumers on each of the burger products.

Correlations with MQ, by product number

	1	2	3	4	5	6	0
age	0.18	0.22	-0.10	-0.20	-0.14	0.02	0.11
gdr	0.03	0.11	0.12	-0.09	-0.18	-0.09	0.04
oft	0.02	0.26	-0.09	-0.07	-0.05	-0.24	-0.22
stt	-0.18	0.04	-0.07	-0.06	-0.16	-0.27	-0.26
inc	-0.05	-0.14	-0.02	0.09	0.14	0.04	-0.07
prot	-0.01	0.23	0.13	0.01	-0.04	-0.04	-0.10
plant	-0.07	0.11	0.12	0.04	0.01	-0.07	-0.16
ingred*	-0.04	0.05	0.11	0.04	0.02	-0.13	-0.27
eats	0.05	0.03	0.09	0.06	0.17	0.10	-0.02
price	0.14	0.17	0.25	-0.01	0.07	0.11	0.13
hwell	-0.01	0.14	0.05	0.01	0.06	-0.03	0.09
nutrn	-0.04	0.12	0.04	-0.03	0.04	-0.03	0.04
allg	0.04	0.02	-0.02	-0.01	0.06	-0.04	0.10
proc	0.09	0.13	-0.05	0.01	0.02	-0.13	-0.04
env	0.02	0.22	0.01	-0.18	-0.07	-0.12	0.08

Correlations with tenderness, by product number

	1	2	3	4	5	6	0
age	0.21	0.21	0.01	-0.15	-0.03	0.16	0.23
gdr	0.07	0.11	0.18	0.02	-0.16	-0.07	0.01
oft	0.03	0.21	-0.10	-0.10	-0.12	-0.26	-0.12
stt	-0.16	0.07	-0.01	0.00	-0.18	-0.20	-0.15
inc	-0.02	-0.08	-0.04	0.04	0.15	-0.11	-0.12
prot	0.08	0.18	0.16	0.06	-0.05	-0.01	-0.07
plant	-0.02	0.23	0.12	0.13	0.07	-0.01	-0.11
ingred	-0.07	0.11	0.01	0.09	-0.01	-0.11	-0.30
eats	0.14	0.16	0.11	0.14	0.15	0.09	-0.04
price	0.05	0.02	0.20	0.02	0.03	0.12	0.12

hwell	0.04	0.13	0.11	0.05	0.05	-0.02	0.16
nutrn	0.01	0.11	0.14	0.06	0.05	0.01	0.12
allg	0.07	-0.01	0.04	0.05	0.01	0.06	0.13
proc	0.06	0.09	-0.01	0.00	0.00	-0.02	0.12
env	0.00	0.17	0.05	-0.10	-0.04	0.02	0.15

Correlations with juiciness, by product number

	1	2	3	4	5	6	0
age	0.11	0.15	0.04	-0.18	-0.18	-0.02	0.17
gdr	0.14	0.13	0.09	0.03	-0.18	-0.11	0.02
oft	0.04	0.14	-0.08	-0.04	-0.05	-0.15	-0.31
stt	-0.19	-0.11	-0.08	-0.09	-0.14	-0.14	-0.24
inc	-0.01	0.00	-0.03	0.10	0.10	-0.01	-0.14
prot	0.01	0.09	0.04	0.09	0.09	-0.05	-0.12
plant	-0.04	0.10	0.04	0.08	0.07	-0.09	-0.19
ingred	-0.07	-0.07	-0.03	0.17	0.08	-0.08	-0.22
eats	0.14	0.08	0.23	0.27	0.24	0.15	0.02
price	0.09	-0.01	0.18	0.08	0.08	0.16	0.14
hwell	-0.07	0.10	0.13	0.03	0.03	0.01	0.14
nutrn	-0.11	0.12	0.12	0.00	-0.02	0.01	0.09
allg	0.01	0.07	0.08	-0.08	0.04	0.08	0.14
proc	0.01	0.04	0.01	-0.03	-0.01	-0.11	0.03
env	0.03	0.14	-0.02	-0.10	-0.08	-0.01	0.13

Correlations with flavour, by product number

	1	2	3	4	5	6	0
age	0.15	0.15	-0.16	-0.16	-0.18	-0.04	-0.03
gdr	-0.03	0.05	0.10	-0.14	-0.16	-0.06	0.06
oft	0.02	0.23	-0.06	-0.07	0.00	-0.19	-0.19
stt	-0.17	0.05	-0.06	-0.07	-0.13	-0.30	-0.24
inc	-0.06	-0.13	0.01	0.10	0.13	0.13	-0.03
prot	-0.06	0.22	0.11	-0.03	-0.08	-0.04	-0.11
plant	-0.11	-0.01	0.12	-0.01	-0.02	-0.08	-0.12
ingred	-0.01	0.02	0.16	-0.03	0.04	-0.10	-0.18
eats	-0.01	-0.07	0.05	-0.02	0.15	0.07	-0.02
price	0.15	0.22	0.23	-0.05	0.09	0.06	0.11
hwell	-0.01	0.11	0.02	0.01	0.07	-0.05	-0.02
nutrn	-0.04	0.08	-0.01	-0.05	0.05	-0.07	-0.05
allg	0.02	0.02	-0.05	0.02	0.09	-0.10	0.07
proc	0.10	0.12	-0.06	0.00	0.01	-0.19	-0.14
env	0.02	0.17	-0.01	-0.18	-0.08	-0.21	-0.01

Appendix 8.4.9: Correlation matrix of attitudinal and demographic variables against the sensory variables (mq, tn, ju, fl) by product. Pink = corr > 0.2, yellow = 0.1<corr<0.2, blue = corr<-0.2, green = -0.2<corr<-0.1.