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Understanding consumer liking of beef using hierarchical cluster analysis and external preference mapping

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Abstract

Background: This study was conducted to assess if there are differences in consumer liking of beef. Samples were collected from different groups and analyses were conducted, including quantitative descriptive analysis, consumer panels and instrumental analyses. Palatability traits, such as aroma liking (AL), tenderness (TE), juiciness (JU), flavour liking (FL) and overall liking (OL) were rated by consumers.

Results: Warner Bratzler shear force was negatively associated with *tender mouthfeel* and consumer *tenderness* score. Cluster analysis identified 4 groups of clusters, which were described as "easily-pleased", "bull beef liker", "tender beef liker" and "fastidious" consumers. Cluster group 2 awarded higher score for bulls and located in a separate region on external preference map.

Conclusion: External preference mapping showed the association between consumer liking of beef and sensory attributes.

Keywords: preferences, Hierarchical cluster analysis, Preference mapping, Consumer acceptability

Declaration of interest: none.

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1.0 **Introduction**

One of the challenges faced by the beef industry in determining consumer desires regarding beef eating quality is the fact that consumers may vary in their preferences. While many papers have evaluated the average sensory scores for beef from different sources or sample groups (1-4), it is evident that few individuals may be regarded as "average".

Aroma, tenderness, juiciness and flavour are all important sensory attributes of meat (5). However, different studies have indicated that these traits have differing importance (6-9). It is likely that the relative importance of sensory attributes depends not only on the range of qualities presented but also on the preferences of the consumers sampled. A study on the impact of the three regions of Northern Ireland, Republic of Ireland and Great Britain by Chong, Farmer (10) and Chong, Farmer (11) on consumer liking for grilled beef with a total of 360 consumers provided an opportunity to investigate the differences and similarities between subgroups or "clusters" of this population.

The purposes of this study were (a) to confirm that the beef selected for this experiment from different sexes, hanging methods, breeds and sample position could be differentiated by consumers; (b) to identify cluster groups and characterise how they differ in respect to consumer scores and (c) to determine the relationship between descriptive sensory characteristics and consumer liking using internal and external preference mapping.

2.0 **Literature on the differences in consumer liking of beef**

Customer assessments on intrinsic quality attributes for beef products have a direct relationship with sensory attributes, visual characteristics and structural characteristics (12, 13). Sensory profiling attributes are assessed by trained panellists using Quantitative Descriptive Analysis (QDA). This technique provides detailed information about sensory properties of a product and it's a most sophisticated way for product characterisation (14). Preference mapping is very helpful in elucidate the differences in consumer perception (15). In external preference map, consumer sensory scores are regressed onto the principal component analysis (PCA) of beef sensory characteristics (16).

Since consumers are highly variable, hierarchical cluster analysis, a long established method, can be used to differentiate human behaviour and identify consumer preference (17, 18). It has been used in multiple food sectors such as genetically modified food (19), organic food (20) and low fat salami (21). This approach has been combined with external preference mapping to identify the sensory attributes that impact cheddar cheese acceptability among cluster groups (22). The technique of

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external preference map was previously used by Oltra, Farmer (23) to demonstrate the relationship between consumer overall liking of beef with sensory attributes by profiling panel, instrumental measurements of texture and flavour. A study conducted by Schmidt, Schilling (24) revealed that consumers could be categorised together based on their liking, descriptive sensory attributes and preference of end-point temperature. Cluster groups identified by Oltra, Farmer (25) and Oltra (26) on consumer liking of grilled lamb *longissimus lumborum* and grilled beef steaks *longissimus dorsi* showed that the cluster groups were segregated by their liking of lamb or beef instead of demographic factors (age, gender, income, occupation, number of children or adults in the household). In addition, preference in meat packaging and store format choice of consumers was investigated by using cluster analysis and only a small preference for unpackaged meat products was found in the target market (27).

3.0 **Materials and Methods**

3.1 Source of beef and sample selection

Beef striploins (n=72) were sampled from animals from twelve groups (Table 1). These sample groups were selected to provide a wide range of eating qualities for consumers and it was not the primary objective for this study to examine the effects of the sample groups. For this reason the sample numbers are small from each sample group and the production methods were not intended to be directly comparable.

Four of the twelve groups (T1b, T2b, T3b and T4b) were collected from Teagasc Ashtown in Republic of Ireland (ROI). Twelve animals were reared and randomly assigned to 24 months dairy steer and 19 months dairy bull production system. After slaughtering, the two sides of each carcase were hung using straight hung (AT) and tenderstretch (TS) methods, respectively. Carcasses were held at under 4°C for 2 days before being divided into fore and hind quarters. The striploins were removed, vacuum packed and delivered to Teagasc Ashtown (ROI) to age for 19 days to achieve 21 days aging period. The striploins were stored at -20°C until further cut up. The frozen striploins were sliced into 25mm steaks using a bandsaw and transported to Agri-Food Bioscience Institute (AFBI) in polystyrene box with ice packs (journey time: 5 hours). The sliced steaks were labelled with number 1 to 15 from the anterior to posterior of the striploin. Steaks 1 and 11 were stored as spare steaks. Steak 6 was used for instrumental analysis. All the other steaks were classified into three positions; anterior (steak 2 to 5), middle (steak 7 to 10), posterior (steak 12 to 15). These frozen steaks (except steaks 1, 6 and 11) were partially thawed for 30 minutes and further cut into smaller samples (ca. 50 x 50 x

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25mm) for sensory and consumer panels. The samples were transferred to a commercial freezer immediately after portioning.

Striploins from the remaining groups (T1a, T2a, T3a, T4a, T5a, T5b, T6a and T6b) were identified from commercial throughput and purchased from a local abattoir in Northern Ireland (NI). It is important to note that, for the NI animals, the AT and TS sides were from different animals. Average age for continental bulls (T1a and T2a) and continental steers (T3a and T4a) were 15 months and 24 months, respectively. Older cows (T5a, T5b, T6a and T6b) ranged in age from 35 to 188 months. The chilled striploins were transported to AFBI in polystyrene box (journey time: 30 minutes). The striploins were sliced into 25mm steaks using a sharp knife. The steaks were labelled, classified into three positions and further cut into smaller samples similarly to the steaks from UCC. The samples were aged until 21 days postmortem and transferred to a commercial freezer and held at -20°C until further analysis.

3.2 Instrumental analysis

The ultimate pH was measured from each striploin using a calibrated pH meter (Extech instrument, Waltham, MA) between 96 to 120 hours post-mortem at 7.5°C. Warner Bratzler shear force (WBSF) measurements were performed on the first slice of the anterior end of every striploin using an Instron 2350-416 (Instron Calibration Laboratory, Norwood, United State) following a standard procedure (28). Steaks were tempered at 2°C for 24 hours prior to the experiment. The outer fat of the steaks was trimmed off and the pre-cooked weight was recorded. Steaks were then vacuum-packed and cooked in a waterbath for 50 minutes to achieve an internal temperature of 75°C. This cooking method was selected because it is a standard method for WBSF analysis (28, 29). After cooking, the steaks were immersed into a basin filled with ice water for 30 minutes. Cooked weight was recorded and the steaks were stored at 2°C overnight. A minimum of eight sample cores (13mm diameter) were obtained from each steak at a parallel angle to the muscle fibres. The crosshead speed of the Instron device was set as 100mm/min with 550kgf load cell and V shaped blade. The V shaped blade cut the cores at a perpendicular angle to the muscle fibres. Data was exported from BlueHill 3 (Instron software). Cooking loss was calculated with the equation: Cooking loss= [(pre-cooked weight of steak- cooked weight of the steak)/ pre-cooked weight of steak]*100.

3.3 Quantitative Descriptive Analysis (QDA)

Eight panellists (4 males and 4 females) were trained for QDA. Extra samples were used in training sessions for sample familiarisation and generation of attributes. Three training sessions were

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conducted with a system adapted from Labbe, Rytz (4) and each session lasted for 2 hours. Attributes were generated for appearance, texture, aroma, flavour and aftertaste (Table 2).

Steak samples were prepared and presented to panellists according to a Latin square design using Biosystem Fizz Acquisition (Biosystem, Dijon, France). Frozen samples (50 x 50 x 25mm) were tempered at 2°C for 24 hours prior to the session. The cooking protocol was adapted from that described for "medium"-cooked beef by Watson, Gee (30) to generate well-done steak as follows. Preliminary trials were conducted using a SILEX grill (S-143, SILEXIA UK. Ltd, Oxon, United Kingdom) to determine the cooking time needed to deliver steak with an internal temperature of 72^{o}C – this was found to require 4 minutes. Four samples were cooked in each round. The internal temperature was recorded for each steak and a small sample was collected for microbiological assessment, if required. After a 2 minutes of resting period, samples were cut in half and served to 2 panellists. Samples were presented on a white ceramic plates labelled with 3 random digit codes. The panellists rated the intensities of attributes on a line scale (0= low intensity; 100= high intensity). Water was provided as palate cleanser between samples.

3.4 Consumer panels

A total of 360 consumers were recruited from three different locations, Northern Ireland, Republic of Ireland and Great Britain, as described elsewhere (11). All consumers were over 18 and consumed beef regularly. Participants were recruited from charity groups, societies, recruitment website, local forum and poster advertising. Clear instructions including location of the study, arrival information, allocated session time and allergens information were given to participants prior to the panel commenced. Consumers were asked to complete a questionnaire (11) prior to the tasting, which included 12 questions on socio-demographic and consumer behaviour.

Samples from different groups were assigned to 360 consumers using latin square design to reduce the potential of order effect (31). Portioned samples were thawed at 2°C for 24 hours prior to the consumer session. Seven samples were tested by every consumer, with the first sample being used as "link sample" that was not statistically analysed. The remaining six samples were one sample from each of the 6 groups (Table 1), with either (a) continental breed or (b) dairy breed. Samples were cooked following the same method as described for sensory profiling, except that ten samples were cooked in each round. The samples were identified by a random code. For each sample, consumers were asked to rate for *aroma liking (AL)*, *tenderness (TE)*, *juiciness (JU)*, *flavour liking (FL)* and *overall liking (OL)* on a line scale (0= low liking/low satisfaction; 100= high liking/ high satisfaction). MQ4 score was calculated for each sample using the Australian MSA model (0.3 TE+ 0.1 JU+ 0.3

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FL+ 0.3 OL). Water and cream crackers (Jacobs cream cracker, United Biscuits UK Ltd, Leicestershire, United Kingdom) were provided as palate cleanser.

3.5 Statistical analysis

Cluster groups were generated using hierarchical cluster analysis using the complete linkage methods. The similarity matrix used by the clustering algorithm was calculated using Euclidian distance (25). Random Effect Model variance component (REML) analysis was conducted using linear mixed model methodology to analyse the results of instrumental analysis, QDA and consumer panel. Factors of interest were fitted as fixed effects while nuisance factors (test session, consumer number and animal) were fitted a random effects (Ahrens, 1974). Cluster groups were characterised using sociodemographic information, and the association between sociodemographic groups were analysed using chi-squared analysis. In addition, preference mapping was performed on consumer acceptability scores, descriptive panel, instrument analysis and hierarchical cluster analysis to establish the relationship between consumer acceptability, sensory attributes, WBSF and cluster groups (32). All statistical analysis was carried out using GenStat (GenStat 16.2.0.11713, VSN International Ltd, Hemel Hempstead, United Kingdom). Results were considered significantly different if $P<0.05$.

4 Results and Discussion

4.1 Warner Bratzler Shear Force, Cooking Loss and pHu

Cooking loss, pHu and WBSF are commonly used to measure meat quality (33, 34) and the results from these instrumental analyses are shown in Table 3. Surprisingly, there was no significant difference ($P>0.05$) in pHu, WBSF or cook loss between the hanging methods (Table 3). In contrast, Ahnström, Hunt (35) and Lively, Moss (28) reported that pelvic suspension reduced the WBSF of *M. longissimus dorsi*.

Table 3 shows that breed x sex interaction had significant impacts on pHu ($P<0.05$). The pHu of meat from continental steers was lower than all meat from bulls and cows while the pHu of continental bulls was significantly higher than all meat from steers (Figure 1). The pHu of the meat is related to the postmortem glycolytic changes. Insufficient glycogen content or low glycolytic capacity can result in high pH meat (36). The higher pH observed in the meat of continental bulls may result from the

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fact that bulls are more sensitive to different stress factors and sexual activity (37, 38). These findings agree with the study conducted by Węglarz (39), who reported a higher pH value of 6.1 for summer season young bulls (24 months old) and bulls (above 24 months) suggested to be because male cattle had a higher sensitivity to hot temperature. The pHu of cows were significantly higher than continental steers, possibly due to the older slaughter age of cows, ranging between 35 months and 188 months. This agrees with the finding of Yim, Park (40) but Ahnström, Hessle (1) and Runowska, Grześ (41) did not find any pH difference due to animal age.

In the current study, cooking loss was associated with both breed and gender (Table 3). Cooking loss of meat from dairy steers were significantly ($P<0.001$) lower than that from meat from other sample groups (Figure 1). Lively, Keady (42) also reported that Holstein (dairy) beef had significantly lower cook loss than Charolais (continental) beef. Many studies have also reported lower cooking loss for steers compared to bulls (43-45).

Tenderness is one of the most important eating quality characteristics of meat (46). In this study, animal sex had a significant impact on WBSF ($P<0.05$), where beef from steers had lower WBSF compared to cows but not bulls. These results were supported by Peachey, Purchas (47) and Purchas and Aungsupakorn (48) but Moran, O'Sullivan (45) found no difference between bulls and steers for WBSF.

4.2 Confirmation of differences between sample groups for sensory profiling attributes

A total of 48 attributes were scored for the beef samples by the trained panellists. The REML analysis showed significant differences in the intensities of 35 attributes and these are shown in Table 4. The sensory attributes that received the highest scores were *grilled steak aroma, beefy flavour, tender texture on cutting, tender mouthfeel, charred external appearance, tight internal appearance* and *intensity of aftertaste*. Similarly, a study conducted by Oltra (26) reported that *charred aroma, beefy aroma, caramel appearance, char-grilled flavour, roast beef flavour* and *tender texture* received highest score in QDA. These data reveal those sensory attributes of grilled beef that differed between these samples in aroma, flavour, mouthfeel, appearance and aftertaste.

Table 4 shows that the breed and sex interactions showed the most significant results. Figure 2 illustrates those interactions where $P<0.01$. Interactions where $P>0.01$ and/or which have a lower P-value compared to the first order effects are shown in Table 4 but will not be discussed further. Both dairy steers and bulls had higher *juicy external appearance* compared to all other sample groups and had higher *red juice external appearance* compared to continental steers and dairy cows. This result was unexpected because the frozen dairy steers and bulls steaks underwent a process of partially

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thawed for further portioning, which might cause some juice loss. This indicated that the partial thawed process has limited changes on the meat. Meat from dairy steers had higher *succulence mouthfeel* compared to all other groups and had higher *greasy external appearance* compared to dairy cows, continental steers and bulls. Meat from dairy bulls had significantly higher *bloody aroma* (except continental cows) and *bloody external appearance* (except continental cows and dairy steers). Continental bulls had lower *tight internal appearance*, except for dairy steer. These differences highlighted the variation between sample groups.

A total of 22 attributes were significantly affected by breed, with 18 of them were significant at $P<0.01$ or $P<0.001$. These were especially related to appearance, aroma and flavour. For example, beef from dairy breeds received higher scores for *charred aroma, grilled steak flavour, beefy flavour, greasy mouthfeel, intensity of aftertaste* than continental breed. Monsón, Sañudo (49) reported that breed had significant ($P<0.01$) impacts on *quantity of residual after chewing* and *tenderness* for trained panellists. A total of 22 attributes were affected by gender, with 15 of these were significant at $P<0.01$ or $P<0.001$. Texture attributes were most affected, though some flavour attributes were also affected. For example, beef from steers received lower scores than bulls and cows for *fibrous* and *spongy mouthfeel* and higher scores for *tender mouthfeel, crumbly mouthfeel, intensity of flavour, grilled steak flavour, and intensity of aftertaste*. Other study also showed that meat from steers were tendered, less hard and firm while have higher acceptability (45).

Hanging method had significant effects on seven attributes, mostly related to texture on cutting and mouthfeel. For example, tenderstretch beef received higher scores for *tender mouthfeel, spongy mouthfeel, tender* and *crumbly texture on cutting* than straight hung beef. Surprisingly, however, hip hanging gave a higher score for *roast beef aroma* ($P<0.001$) and *beefy flavour* ($P<0.05$). While it is possible that, despite training, the panellists assessing beefy flavour were influenced by the texture, this did not apply to roast beef aroma which was assessed before the sample was transferred to the mouth. Therefore, there appears to be a real effect of hanging on flavour and aroma that justifies further investigation.

The data reported in Table 4 confirm that there were substantial and significant differences between the groups assessed by the panellists, and that this data set is therefore suitable for further evaluation of the likes and dislikes of sub-groups of the populations using cluster analysis.

4.3 Understanding differences in consumer liking using hierarchical cluster analysis

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Hierarchical cluster analysis was applied to categorise consumers according to their overall liking score. Four cluster groups were identified with 60% of similarity in the consumer overall liking score for beef striploin. The number of consumers in group 1, group 2, group 3, group 4 were 121, 85, 96 and 58, respectively, and there were no unassigned consumers. The answers to the consumer questionnaire on socioeconomic factors and attitudes to beef consumption showed that no significant ($P>0.05$) differences were observed in socioeconomic status and consumers' habit between cluster groups with the exception of frequency of consumption of minced beef ($P<0.05$; appendix 1). Therefore, neither age, gender, income range nor preferred "doneness" differed between cluster groups. Interestingly, a chi-square test ($\chi^2=13.82$) showed that the distribution of region where the panels were conducted differed significantly ($P<0.05$) between cluster groups (Figure 3), with more consumers from Republic of Ireland categorised in CG3 and higher percentage of consumers from GB categorised in CG1.

The effects of cluster group, hanging method, animal breed, animal sex and sample position on the consumer sensory scores, as determined by REML analysis, are presented in Table 5. This data shows that cluster group, hanging method, animal breed type and sex had significant ($P<0.001$) impacts on some or all of the consumer palatability traits. There were also second and third order effects (Table 5).

A comparison of sample groups was not the primary aim of this trial, and the two separate sources for the beef will have influenced the results. Nevertheless, the data in Table 5 show that there were some significant effects on consumer scores, and that the consumer readily differentiated between the sample groups. Only three interactions between animal effects were significant, with the highest significant effects observed for breed type and sex interaction (Table 5). Significant differences were observed for all sensory attributes for breed x sex interaction. Figure 4 shows that for steers all eating quality attributes were consistently better for dairy-bred beef than continental beef. Cow beef showed a similar trend, but this was only significant for juiciness, flavour liking and overall liking. For bulls the trend was for improved scores for continental beef, but this was only significant for tenderness. However, this disparity can be explained by the younger age of the continental bulls (14-15 months) compared to the dairy bulls (19 months).

Tenderness, overall liking and MQ4 scores were significantly affected by interactions between hang and sex and between sex and sample position (Table 5). The results showed that hanging method only had significant impact on bulls for tenderness, overall liking and MQ4 (Figure 5a). This result was supported by Ahnström, Hunt (35), which implies that tenderstretch can be used as a strategy to improve eating quality of bulls. Again, the lower scores for tenderness, overall liking and MQ4 score for the posterior region of the striploin was only significant ($P<0.05$) for bulls, while the anterior portion was better than the middle and posterior regions for steers only for MQ4 (Figure 5b).

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The first order effects of animal-treatments (Table 5) highlighted the differences between hanging method, breed, sex and sample position. Firstly, tenderstretch beef showed better eating quality than straight hung beef. The differences were highest for tenderness, where tenderstretch beef rated 5.8 points compared to straight hung beef (Table 5). This concurred with the QDA result, where TS beef had higher ($P<0.01$) scores for tenderness. Another study also showed that consumer scored tenderstretch higher than pelvic suspension beef (1). Previous studies have showed that shear force was highly correlated with tenderness rating (50). However, there was no difference found in shear force between both hanging methods, suggesting that consumer was more sensitive than objective measurements. Consumers preferred dairy breed beef over that from a continental breed, and the impacts were significant on juiciness ($P<0.001$), flavour liking ($P<0.01$) and overall liking ($P<0.05$). This concurred with the study conducted by Moss, Farmer (51), which showed that Holstein (dairy) beef received significantly ($P<0.05$) higher scores for tenderness, juiciness, flavour liking and overall acceptability. As expected, beef from steers had higher overall liking and MQ4 scores than bulls or cows (Table 5), which concurred with the study conducted by Venkata Reddy, Sivakumar (2). Several studies have reported that eating quality of bulls is lower (52-54). A similar conclusion was drawn by a Meat and Livestock Commission (MLC) study, which reported that suckled bulls were more tender than weaned animals (55). Therefore, the MLC Blueprint stated that young bulls are recommended to be slaughtered at less than 15 months old (56). On the other hand, position within the striploin had less impact on consumer palatability traits. As expected, the biggest impact was tenderness, where anterior sample was approximately 4 points difference with posterior sample. Likewise, another study also showed that the MSA palatability scores for striploin (*Longissimus dorsi*) were higher for anterior samples compared to posterior samples (57)

The four cluster groups can be categorised according to the scoring pattern and preferences that they exhibit (Table 5). Cluster group significantly ($P<0.001$) affected all palatability traits. There were several third order effects, with the highest significance observed for cluster group x hang x sex (Table 5); the remaining third order interactions are of lower significance. There are also several significant second order effects, with cluster group x hang and cluster group x sex showing widespread significance and cluster group x position in the muscle being significant for tenderness and MQ4. These effects are illustrated in Figures 6 and 7. Consumers in CG4 and GC1 differed mainly in overall scores, with CG4 giving average scores lower than 50 and CG1 giving average scores higher than 60 (Table 5). In addition, CG4 differentiates between AT bulls and steers and positions in the muscle, while CG1 does not (Figures 6 and 7iii). In CG1, CG3 and CG4, consumers generally rated beef from steers significantly higher ($P<0.05$) than that from bulls and cows (Figures 6 and 7ii). In contrast, consumers in CG2 liked bull beef as much as or (for TS hanging) better than steer beef, and scored cow beef the lowest (Figure 7ii). MQ4 score for bulls was greater than 50 for consumers in CG1, CG2 and CG3 (76.4% of consumers), suggesting that meat from bulls had

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acceptable eating quality, despite the fact that bulls were excluded from MSA grading system in Australia (58). CG3 was the only cluster group that consistently perceived a significant effect of hanging method for beef from all sexes, though CG1 perceived an effect for steers only (Figures 6 and 7i). Position within the striploin muscle had significant ($P<0.05$) impacts in CG3 and CG4 only, for which anterior samples scored higher than middle samples or posterior samples, respectively (Figure 7iii). These trends highlight the variation between groups of consumers and the fact that there is no "average" consumer.

These results indicate that consumer cluster groups had different scoring patterns and liking of beef. For example, CG1 consumers could be described as "easily-pleased" as the overall average score for all palatability traits was over 60 points. CG2 was described as "bull beef likers", as this group scored TS bulls the highest (Figure 7ii). Consumers in CG3 were considered as "tender beef likers", as they preferred ($P<0.05$) TS beef than AT beef for all animal sexes (Figure 6) and they also preferred ($P<0.05$) steers to the other animal sexes (Figure 7ii). CG4 consumers were considered as "fastidious" consumers, as the average score of all palatability traits were under 50, which was significantly ($P<0.001$) lower than other cluster groups (Table 5).

4.4 Understanding the relationship between instrumental measurements, QDA and consumer liking of beef using external preference mapping

Figure 8 presents an external preference map, where the principal components are based on the scores for sensory attributes from quantitative descriptive analysis. PC1 and PC2 explain 50.7% and 27.8% of the variation, respectively, and differentiates the beef striploin on flavour, appearance, mouthfeel and texture attributes. PC3 (not shown), explained a further 8.5% and differentiated primarily on aroma and flavour. The internal preference map based on consumer scores was also analysed and showed the same relationships. This is not presented as no extra information was derived.

External preference mapping showed the key drivers of liking and which beef was favoured by consumers. The average consumer scores and overall liking cluster groups are correlated on the same axes. Figure 8 shows that the average consumer overall liking score was closest to T3b and T4b, which were dairy steers. Indeed, it is notable that the trained panel differentiated the beef samples very clearly with breed separated by the continuous line (continental breed distributed on the left and dairy breed distributed on the right) and quality on the cattle's sex separated by the two dashed lines (cows located in the top region, bulls in the middle region and steers in the bottom region).

Consumer scores for *overall liking, aroma liking, tenderness, juiciness* and *flavour liking* are highly related to profiling attributes from QDA, including *tender mouth-feel, tender texture on cutting, intensity of flavour, intensity of aftertaste, succulence mouth-feel, sweet flavour, beefy flavour* and

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roast beef flavour. Negative attributes, such as *spongy mouth-feel* and *fibrous texture on cutting*, were located at the opposite regions to the consumer overall liking score on the preference maps. The results obtained from this study appear to be in agreement with those reported by Oltra, Farmer (25) using lamb meat, where consumer preferences were closely associated with *meat aftertaste, roast lamb flavour, tenderness, sweet flavour,* while *rubbery texture* appeared in the opposite direction. A study conducted by Oltra, Farmer (23) also showed that consumers' overall liking of beef was highly associated with tender texture, sweet flavour and juiciness. Furthermore, in Figure 8, WBSF was situated opposite to *tenderness* and *overall liking* while cooking loss was negatively associated with *juiciness* or *succulence MOU*. Even though the endpoint temperatures of samples for instrumental analysis and sensory analyses were different, it appears that the relative tenderness between samples is discerned by both methods. This concurred with the results reported by Oltra, Farmer (23), where WBSF was situated opposite to *overall liking* and related with *chewy, rubbery* and *stringy*. The fact that tenderness was only partially explained by WBSF supports the findings of Caine, Aalhus (59) who stated that WBSF only accounted for 37% and 36% of initial and overall tenderness of trained panel sensory characteristics. Perry, Thompson (60) concluded that shear force had a quadratic relationship with tenderness score by trained panel.

The cluster groups, CG1, CG3 and CG4 cluster groups were located close together, clustered around the average consumer palatability traits. Consumers in these cluster groups were highly associated with steers. However, the scoring patterns of consumers varied as shown in Table 5. The consumers in CG1, CG3 and CG4 were described as "easy-pleased", "tender beef liker" and "fastidious" consumers respectively. In contrast, CG2 was separated from other cluster groups and located in a different region that associated with bulls. This agreed with the result showed in Figure 6 and Figure 7ii. Therefore, CG2 consumers were described as "bull beef liker".

These result show that cluster analysis provides suggestions about consumer liking of beef associated with sensory attributes. Such categorisation could be very useful for classifying consumers' liking and understanding consumers' attitudes towards beef attributes, particularly for the implementation of the marketing strategies and the development of meat products.

5.0 Conclusion

External preference mapping showed that consumers' overall liking of beef was associated *with intensity of flavour, tender mouthfeel, succulence mouthfeel* and *roast beef flavour*. In contrast, mouthfeel attributes such as *spongy* and *form balls* had negative influences on consumer perceptions. Animal sex and breed were separated across the external preference map with a distinct pattern and

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demonstrated relationships with different sensory attributes. Four cluster groups were derived, with distinctive differences in mean sensory score and liking of beef. CG1, CG2, CG3, CG4 represented "easily-pleased", "bull beef liker", "tender beef liker" and "fastidious" consumers respectively. Most consumers liked TS steers the most, except for consumers in CG2.

This study showed that the technique of cluster analysis can categorise consumers into groups according to their scoring pattern or liking of beef. The technique of external preference mapping outlined the relationship between consumers' overall liking, instrumental measurements, specific sensory attributes and cluster groups.

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Table 1

Sample group information.

Group	Animal Sex	Hanging method	Breed	Number of striploins
T1a	Bulls	AT	Continental	6
T1b	Bulls	AT	Dairy	6
T2a	Bulls	TS	Continental	6
T2b	Bulls	TS	Dairy	6
T3a	Steers	AT	Continental	6
T3b	Steers	AT	Dairy	6
T4a	Steers	TS	Continental	6
T4b	Steers	TS	Dairy	6
T5a	Cows	AT	Continental	6
T5b	Cows	AT	Dairy	6
T6a	Cows	TS	Continental	6
T6b	Cows	TS	Dairy	6

AT: Straight Hung, TS: Tenderstretch

Table 2

Abbreviation and definition for sensory attributes.

Group	Attributes	Abbreviations	Definition
Aroma (AR)	Roast Beef	RstBf AR	Aroma of outside of roasted joint
	Grilled steak	GrilStk AR	Aroma reminiscent of meat browned on grill
	Beefy	Beefy AR	Aroma of inner core of roast beef
	Charred	Char AR	Burnt charcoal aroma
	Fatty	Fatty AR	Aroma of fatty animal or lard
	Bloody	Bloody AR	Aroma of reminiscent of metallic, blood
	Mealy	Mealy AR	Aroma related to cooked animal feed
	Herby	Herby AR	Herbs, green aroma
	Acrid	Acrid AR	Pungent, acrid aroma
	Farmyard	Farmyard AR	Animal, farmyard odour
	Spice	Spice AR	Sausage spice aroma

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Flavour (FL)	Intensity of Flavour	Intensity FL	Strength of flavour
	Grilled Steak	GrilStk FL	Flavour reminiscent of meat browned on grill
	Roast Beef	RstBf FL	Flavour of outer 1cm of roasted joint
	Beefy	Beefy FL	Flavour of inner core of roast beef
	Char Grilled	CharGrill FL	Burnt charcoal-like flavour
	Metallic/ Bloody	Metallic FL	Flavour of reminiscent of blood
	Saltiness	Salty FL	Salt flavour in the mouth
	Sour/ Acidic	Sour FL	Sour milk, lactic flavour
	Bitterness	Bitter FL	Bitter flavour in the mouth
	Sweetness	Sweet FL	Sweet beef flavour
	Earthy	Earthy FL	Root vegetable flavour
	Rancid	Rancid FL	Rancid oil, distinct rancid flavour
Texture on cutting (TC)	Tenderness	Tender TC	Easily cut, soft texture
	Crumbly/ Dry	Crumbly TC	Sample separates, crumbs form during cutting
	Fibrous/ Stringy	Fibrous TC	Long strands in the meat on cutting
Mouth-feel (MOU)	Tenderness	Tender MOU	Soft and easy to chew before swallowing
	Spongy/Rubbery	Spongy MOU	Rubbery, keeps its shape, chewy
	Succulence	Succule MOU	Juicy mouthfeel
	Sticky/ Clingy	Sticky MOU	Sticks to teeth and roof of the mouth
	Forms Balls	Balls MOU	Forms balls when chewing
	Crumbly	Crumbly MOU	Sample separates after chewing
	Greasy	Greasy MOU	Oil coating on the roof of the mouth
External appearance (EXAP)	Pale colour	Pale EXAP	Pale colour of meat
	Chestnut colour/ Brownness	Chestnut EXAP	Brown colour of cooked meat
	Juicy	Juicy EXAP	Liquid juice around the meat
	Charred	Char EXAP	Black or well-cooked on outer surface
	Bloody	Bloody EXAP	Pink and undercooked bloody outer surface
	Redness of juice	RedJui EXAP	Red juice on surface and plate
	Brownness of juice	BrownJui EXAP	Brown juices on surface and plate
	Greasy/ Oily/ Fatty	Greasy EXAP	Overall oily bright surface
Internal appearance (INAP)	Tight	Tight INAP	Closely packed between fibres, close grain
	Lean	Lean INAP	No obvious internal fat

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Aftertaste (AF)	Intensity of Aftertaste	Intensity AF	Strength of aftertaste
	Roast Beef	RstBf AF	Aftertaste of outside of roasted joint
	Acidic	Acidic AF	Sour aftertaste in the mouth
	Bitterness	Bitter AF	Bitter aftertaste in the mouth
	Saltiness	Salty AF	Salty aftertaste in the mouth

Table 3

Predicted means and average standard deviation of the pH, WBSF and cook loss from 12 sample groups.

	pHu	WBSF (kgf)	Cook loss (%)
Hang (H)			
AT	5.57	4.67	26.89
TS	5.52	4.47	26.74
SED	0.030	0.151	0.452
P	0.120	0.207	0.751
Breed (B)			
Continental	5.56	4.59	27.76
Dairy	5.53	4.55	25.88
SED	0.030	0.151	0.452
P	0.407	0.816	<0.001
Sex (S)			
Steers	5.47^{a}	4.29^{a}	25.52^{a}
Bulls	5.59^{b}	4.66^{ab}	27.70^{b}
Cows	5.58^{b}	4.77^{b}	27.23^{b}
SED	0.037	0.185	0.554
P	0.003	0.034	<0.001
Interaction			
H x B	0.163	0.403	0.735
H x S	0.266	0.792	0.736
B x S	0.028	0.083	<0.001
H x B x S	0.377	0.948	0.604

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a,b,c: Numbers in the same column which do not share a common superscript are significantly different (P<0.05). SED= average standard error, *P*= probability, pHu=ultimate pH, WBSF= Warner Bratzler Shear Force.

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Table 4

Predicted means and average standard deviation of the intensity scores for the sensory attributes.

	First order effects																		Interactions						
	Hang (H)				Breed (B)				Sex (S)					Sample Position (P)					H.B	H.S	B.S	S.P	H.B.P	B.S.P	H.B.S.P
	AT	TS	SED	***P***	Con	Dai	SED	***P***	Bulls	Cows	Steers	SED	***P***	An	Mi	Po	SED	***P***	***P***	***P***	***P***	***P***	***P***	***P***	***P***
RstBfAR	27.5	31.3	1.26	**0.002**	29.4	29.4	1.36	0.994	29.3	29.5	29.4	1.67	0.992	29.5	29.2	29.4	1.41	0.988	0.193	0.749	0.995	0.892	0.845	0.518	0.892
GrilStkAR	34.9	34.6	1.28	0.853	33.0	36.5	1.33	**0.009**	32.9^{a}	34.2^{ab}	37.3^{b}	1.63	**0.027**	36.0	33.4	34.9	1.55	0.232	0.399	0.369	0.718	0.226	0.945	0.761	0.226
BeefyAR	29.4	32.1	1.12	**0.011**	29.1	32.4	1.21	**0.009**	31.9	30.6	29.8	1.48	0.333	31.2	30.1	31.1	1.27	0.604	0.172	0.437	0.305	0.427	0.901	0.078	0.427
CharAR	27.9	26.1	1.44	0.268	22.2	31.8	1.59	**<0.001**	24.4	27.0	29.6	1.94	0.080	26.1	26.3	28.5	1.59	0.200	0.995	0.187	**0.023**	0.578	**0.010**	0.936	0.578
FattyAR	6.8	6.8	0.51	0.844	6.1	7.5	0.56	**0.032**	7.5	5.9	7.0	0.69	0.079	6.7	7.0	6.7	0.55	0.813	0.211	0.664	0.099	0.510	0.119	0.771	0.510
BloodyAR	6.9	6.9	0.80	0.953	6.5	7.3	0.82	0.377	8.9^{b}	6.2^{a}	5.6^{a}	1.00	**0.003**	7.0	6.2	7.6	0.97	0.414	**0.017**	0.963	**0.001**	0.444	0.351	0.207	0.444
IntensityFL	48.0	49.7	1.49	0.220	45.7	52.0	1.76	**0.001**	49.4^{ab}	45.8^{a}	51.4^{b}	2.16	**0.035**	49.2	48.0	49.4	1.45	0.605	0.556	0.053	0.484	0.140	0.467	0.597	0.140
GrilStkFL	32.1	31.0	1.27	0.389	29.0	34.2	1.30	**<0.001**	29.4^{a}	30.4^{a}	34.9^{b}	1.59	**0.001**	31.4	31.0	32.4	1.54	0.636	0.755	0.746	0.400	0.390	0.970	0.805	0.390
RstBfFL	26.9	28.9	1.03	0.057	26.5	29.3	1.03	**0.009**	27.5^{ab}	26.6^{a}	29.6^{b}	1.27	**0.048**	27.8	28.3	27.6	1.28	0.860	0.682	0.304	0.526	0.463	0.445	0.567	0.463
BeefyFL	32.8	35.1	1.14	**0.038**	32.3	35.6	1.23	**0.011**	33.1	32.8	36.0	1.51	0.088	33.7	33.7	34.5	1.29	0.816	0.275	0.184	0.098	0.514	0.049	0.068	0.514
CharGrillFL	25.5	25.5	1.31	0.940	20.9	30.0	1.37	**<0.001**	23.2^{a}	24.5^{a}	28.7^{b}	1.68	**0.005**	23.0^{a}	25.0^{a}	28.4^{b}	1.56	**0.002**	0.755	0.952	0.163	0.994	0.739	0.660	0.994
MetallicFL	12.0	11.2	0.59	0.181	11.3	11.9	0.63	0.374	13.4^{b}	10.2^{a}	11.1^{a}	0.77	**<0.001**	12.3	11.1	11.4	0.67	0.158	0.183	0.300	0.622	0.723	0.780	0.328	0.723
SweetFL	12.0	11.7	0.62	0.687	10.9	12.8	0.65	**0.004**	11.9	11.4	12.3	0.79	0.559	11.7	12.2	11.7	0.73	0.742	0.224	0.858	**0.010**	0.229	0.572	0.060	0.229
TenderTXC	47.4	51.1	1.68	**0.006**	47.9	50.7	2.03	0.473	50.6^{b}	40.0^{a}	57.2^{c}	2.49	**<0.001**	49.7	49.7	48.4	1.55	0.629	0.213	0.534	0.314	0.217	0.691	0.438	0.217
CrumblyTXC	19.2	14.4	1.29	**<0.001**	18.1	15.5	1.47	**0.039**	17.9^{b}	13.0^{a}	19.5^{b}	1.80	**<0.001**	17.4	16.3	16.7	1.35	0.740	0.656	0.328	0.721	0.726	0.437	0.639	0.726
FibrousTXC	23.2	22.1	1.11	0.336	23.8	21.6	1.16	0.081	21.8^{a}	26.9^{b}	19.2^{a}	1.43	**<0.001**	24.0	21.7	22.3	1.31	0.182	0.906	0.578	0.311	0.078	0.157	0.938	0.078
TenderMOU	43.6	47.4	1.84	**0.009**	44.9	46.1	2.26	0.807	46.9^{b}	35.0^{a}	54.7^{c}	2.76	**<0.001**	45.4	46.1	45.1	1.62	0.749	0.585	0.498	0.303	0.085	0.799	0.465	0.085
SpongyMOU	30.9	26.5	1.31	**<0.001**	28.6	28.9	1.43	0.603	29.7^{b}	34.1^{c}	22.4^{a}	1.75	**<0.001**	28.5	29.2	28.4	1.44	0.851	0.833	0.466	0.971	0.659	0.488	0.314	0.659
SuctileMOU	25.6	27.0	1.62	0.067	23.0	29.5	1.94	**0.006**	26.4^{ab}	22.3^{a}	30.2^{b}	2.38	**0.011**	26.7	25.1	27.2	1.50	0.384	0.022	0.389	**<0.001**	0.509	0.574	0.465	0.509
StickyMOU	17.9	17.5	0.77	0.616	18.5	17.0	0.77	0.053	18.0^{b}	15.9^{a}	19.4^{b}	0.95	**0.001**	17.9	17.4	17.9	0.96	0.801	0.697	0.720	0.898	0.866	0.955	0.292	0.866
BalMOU	24.2	24.6	1.18	0.806	25.3	23.5	1.23	0.162	24.7^{b}	27.4^{b}	21.1^{a}	1.51	**<0.001**	24.7	23.8	24.7	1.39	0.786	0.470	0.254	0.784	0.606	0.577	0.670	0.606
CrumblyMOU	20.1	20.2	1.62	0.992	22.7	17.7	2.00	**0.006**	19.6^{a}	15.1^{a}	25.7^{b}	2.45	**<0.001**	19.5	21.3	19.7	1.37	0.382	0.941	0.360	0.181	0.695	0.751	0.952	0.695
ChewyMOU	14.2	13.8	0.59	0.683	12.9	15.2	0.66	**<0.001**	13.8	13.5	14.7	0.81	0.393	13.8	14.2	14.0	0.62	0.794	0.426	0.325	0.081	0.340	0.886	0.304	0.340

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PaleEXAP	22.0	22.3	1.68	0.799	28.3	16.1	2.06	**<0.001**	25.6	19.6	21.4	2.52	0.063	22.0	23.4	21.1	1.47	0.305	0.951	0.859	**0.020**	0.652	0.193	0.813	0.652
NutEXAP	55.7	54.5	1.68	0.621	48.7	61.5	2.00	**<0.001**	50.7^{a}	58.2^{b}	56.3^{b}	2.45	**0.008**	55.7^{b}	52.4^{a}	57.2^{b}	1.60	**0.008**	0.420	0.535	0.236	0.240	0.047	0.991	0.240
JuicyEXAP	18.5	18.8	1.16	0.784	16.0	21.3	1.16	**<0.001**	21.0^{b}	16.0^{a}	18.9^{b}	1.43	**0.002**	19.2	17.2	19.5	1.45	0.287	**0.005**	0.350	**<0.001**	0.370	0.317	**0.041**	0.370
ChewEXAP	35.1	34.0	1.64	0.647	28.8	40.3	1.86	**<0.001**	32.8	33.4	37.5	2.28	0.144	33.3^{a}	33.1^{a}	37.3^{b}	1.72	**0.022**	0.502	0.075	0.191	0.966	0.070	0.253	0.966
BloodyEXAP	5.2	5.0	0.94	0.955	4.3	5.9	1.04	0.175	6.8	4.3	4.2	1.27	0.091	4.9	4.3	6.1	1.04	0.260	0.381	0.234	**0.004**	0.161	0.659	**0.005**	0.161
RedJuiEXAP	7.2	6.3	1.12	0.632	5.6	8.0	1.23	0.099	8.9^{b}	5.0^{a}	6.4^{ab}	1.51	**0.029**	5.9	6.4	8.0	1.24	0.261	0.344	**0.016**	**0.009**	0.468	0.619	0.092	0.468
BrownJuiEXAP	18.6	18.4	1.25	0.863	15.9	21.2	1.35	**<0.001**	18.0	17.2	20.4	1.66	0.191	19.8	17.0	18.8	1.43	0.112	0.733	0.911	**0.005**	0.530	0.241	**0.006**	0.530
GreasyEXAP	11.3	10.6	0.59	0.339	10.0	11.8	0.65	**0.011**	10.5	10.9	11.3	0.80	0.707	11.1	11.1	10.5	0.65	0.511	0.344	0.763	**0.009**	0.455	0.424	0.710	0.455
TightINAP	58.2	58.5	1.53	0.841	57.8	59.0	1.61	0.419	55.8^{a}	60.1^{b}	59.2^{ab}	1.97	**0.042**	58.0	59.4	57.7	1.78	0.583	0.733	0.109	**0.005**	0.693	0.679	0.839	0.693
FatINAP	75.2	75.5	1.06	0.750	76.1	74.6	1.08	0.166	74.4	75.2	76.5	1.32	0.276	74.5	75.9	75.8	1.29	0.468	0.710	0.710	**0.014**	**0.026**	0.483	0.619	**0.026**
IntensityAT	28.3	28.5	1.04	0.658	26.0	30.8	1.17	**<0.001**	28.4^{ab}	26.0^{a}	30.8^{b}	1.43	**0.005**	29.2	27.5	28.4	1.11	0.301	0.209	0.446	0.103	0.893	0.292	0.288	0.893
RstFAT	17.0	17.3	0.81	0.653	16.0	18.4	0.85	**0.006**	17.0^{ab}	15.8^{a}	18.7^{b}	1.04	**0.023**	17.4	17.5	16.7	0.95	0.654	0.375	0.616	0.421	0.870	0.157	0.755	0.870

Significance results are highlighted in bold. a,b,c: Numbers in the same row which do not share a common superscript are significantly different. Attributes' abbreviation and definition may be referred to Table 2. SED: standard error, P: probability, AT: straight hung, TS: tenderstretch, Cont: continental, Dai: dairy, An: anterior, Mi: middle, Po: posterior, H: hanging method, B: breed, S: sex, P: sample position

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Table 5
Effects of cluster group, hanging method, breed, animal sex and sample position on consumer sensory scores.

	AL	TE	JU	FL	OL	MQ4
Cluster group (CG)						
CG1 (121 consumers)	66.5^{c}	61.8^{c}	62.6^{c}	66.7^{c}	66.8^{c}	64.8^{c}
CG2 (85 consumers)	57.9^{b}	52.3^{b}	52.4^{b}	56.3^{b}	55.4^{b}	54.4^{b}
CG3 (96 consumers)	56.8^{b}	52.3^{b}	51.8^{b}	55.0^{b}	54.9^{b}	53.8^{b}
CG4 (58 consumers)	46.7^{a}	41.2^{a}	39.4^{a}	40.8^{a}	39.7^{a}	40.5^{a}
SED	1.88	1.66	1.82	1.54	1.39	1.35
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hang (H)						
AT	55.8	49.4	50.2	52.7	52.0	51.2
TS	58.1	54.4	52.9	56.7	56.4	55.6
SED	0.97	1.72	1.33	1.19	1.29	1.30
P	0.017	<0.001	0.017	<0.001	<0.001	<0.001
Breed (B)						
Continental	55.7	50.9	48.2	52.6	52.2	51.5
Dairy	58.2	52.9	54.9	56.8	56.2	55.3
SED	1.16	2.25	1.66	1.45	1.62	1.66
P	0.052	0.782	<0.001	0.009	0.044	0.079
Sex (S)						
Bulls	57.9^{b}	55.1^{b}	52.5^{b}	55.7^{b}	55.9^{b}	55.2^{b}
Cows	53.3^{a}	38.3^{a}	44.6^{a}	47.3^{a}	45.1^{a}	43.7^{a}
Steers	59.6^{b}	62.3^{c}	57.6^{c}	61.1^{c}	61.6^{c}	61.2^{c}
SED	1.41	2.74	2.03	1.77	1.98	2.03
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Position (P)						
Anterior	58.1	54.6^{b}	52.5^{b}	56.2	55.9^{b}	55.3^{b}
Middle	56.5	50.9^{a}	52.5^{b}	54.4	53.7^{a}	52.9^{a}
Posterior	56.3	50.2^{a}	49.6^{a}	53.5	52.9^{a}	52.0^{a}
SED	1.00	1.19	1.17	1.09	1.05	0.99
P	0.446	<0.001	0.043	0.092	0.033	0.008
Interaction (without CG)						
H.B	0.998	0.484	0.697	0.208	0.143	0.266
H.S	0.889	0.026	0.053	0.079	0.027	0.017
B.S	0.041	0.004	<0.001	0.001	<0.001	<0.001
H.P	0.904	0.031	0.540	0.789	0.394	0.244
B.P	0.747	0.190	0.819	0.969	0.915	0.716
S.P	0.358	0.002	0.146	0.079	0.005	0.008
H.B.S	0.545	0.320	0.162	0.425	0.148	0.222
H.B.P	0.930	0.668	0.690	0.956	0.983	0.881
H.S.P	0.656	0.066	0.337	0.215	0.112	0.090
B.S.P	0.325	0.698	0.787	0.792	0.945	0.928
Interaction (with CG)						

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CG.H	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CG.B	0.231	0.500	0.923	0.671	0.650	0.758
CG.S	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
CG.P	0.180	0.031	0.054	0.072	0.090	0.029
CG.H.B	0.668	0.053	0.375	0.298	0.220	0.133
CG.H.S	0.112	<0.001	0.012	0.004	<0.001	<0.001
CG.B.S	0.117	0.260	0.084	0.181	0.107	0.088
CG.H.P	0.033	0.348	0.046	0.277	0.030	0.161
CG.B.P	0.984	0.017	0.175	0.774	0.171	0.112
CG.S.P	0.583	0.241	0.035	0.008	0.054	0.038

a,b,c,..,f: Numbers in the same column which do not share a common superscript are significantly different (P<0.05). $ ***AL:*** aroma liking, ***TE***: tenderness, ***JU***: juiciness, ***FL***: flavour liking, ***OL***: overall liking. Group information may be found in Table 1. SED= standard error, ***P***= probability.

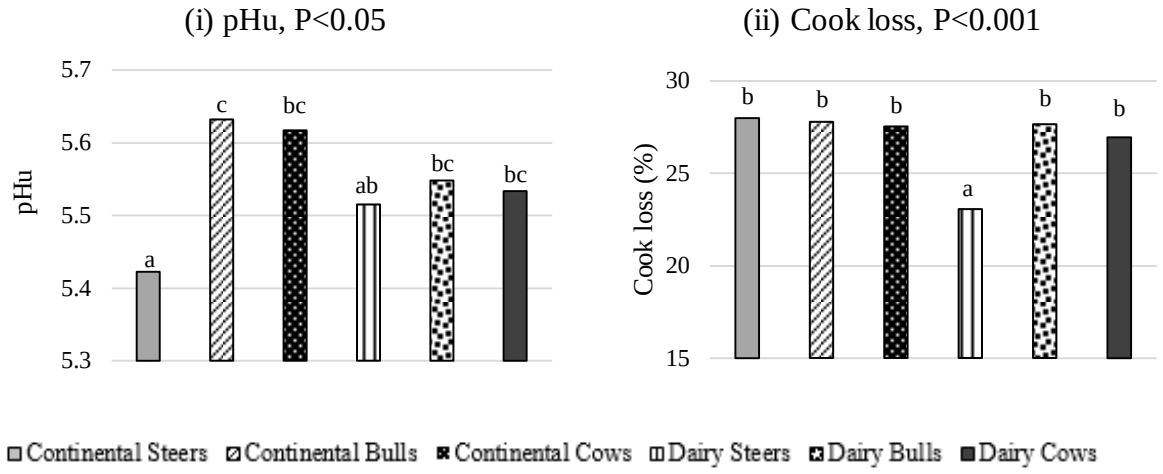


Figure 1 Effect of breed x sex interaction on pHu and cook loss.

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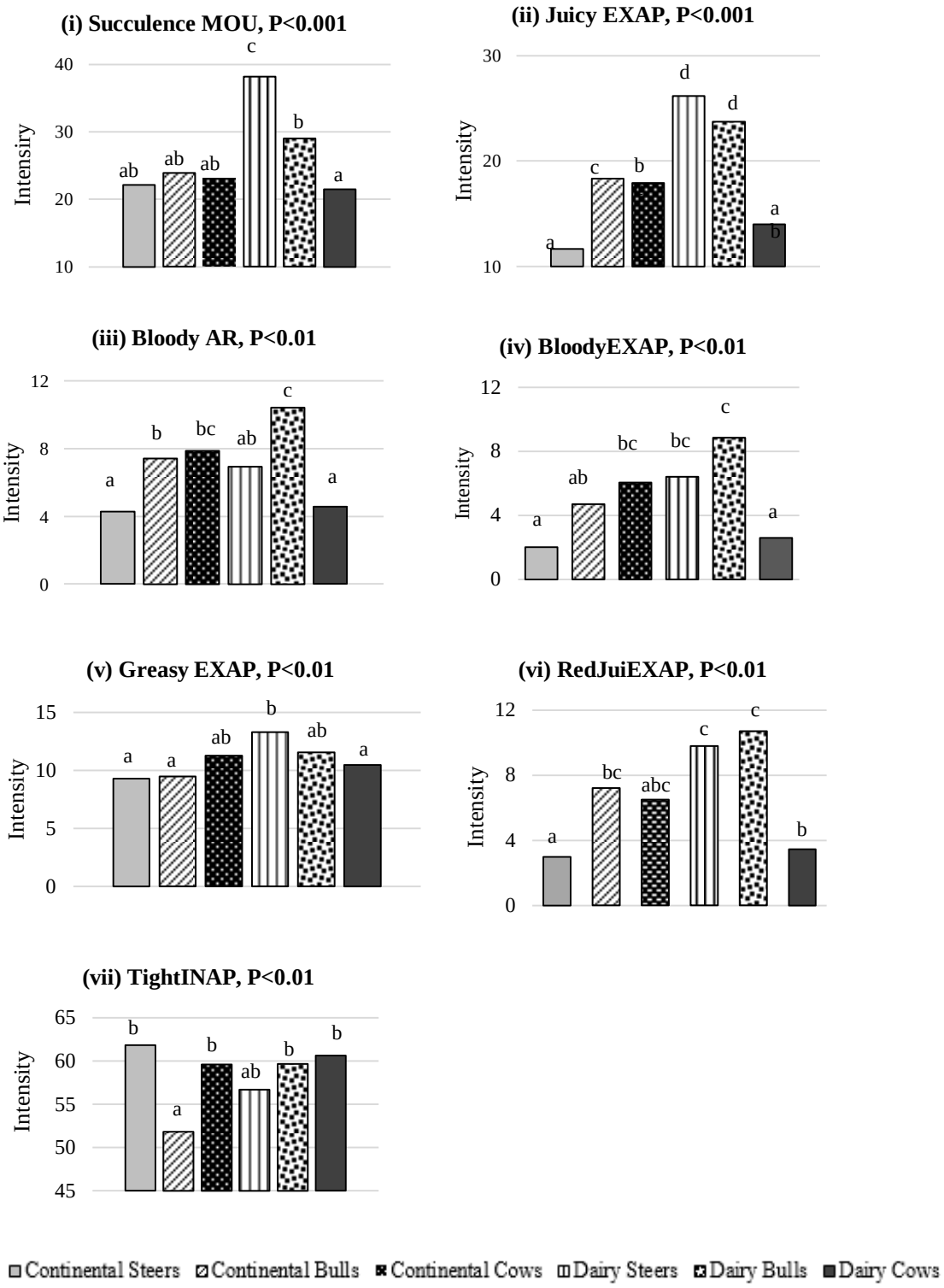


Figure 2 Effect of breed x sex interaction on (i) *succulence mouthfeel*, (ii) *juicy external appearance* and (iii)*bloody aroma*, (iv) *bloody external appearance*, (v) *greasy external appearance*, (vi) *red juice external appearance* and (vii) *tight internal appearance*.

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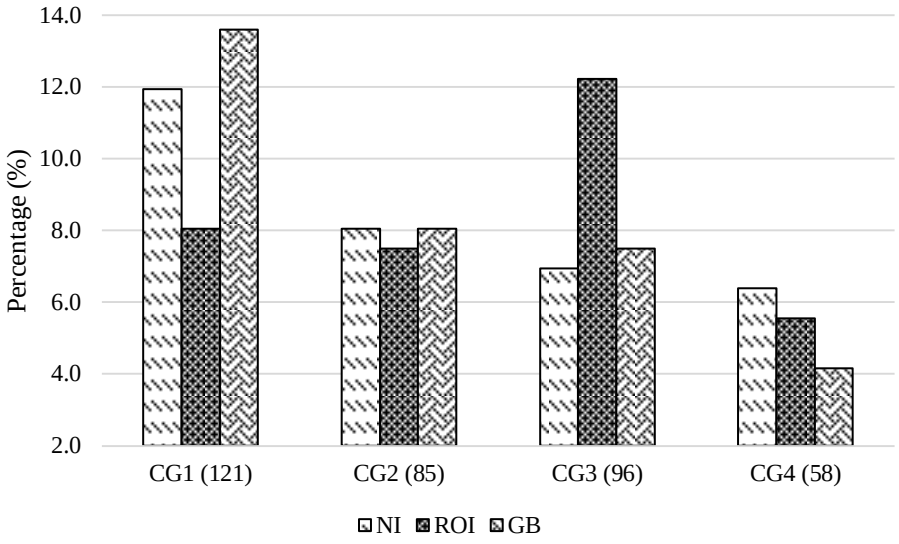


Figure 3 Regional distribution of members of cluster groups (CG).
χ^2= 13.82 (P<0.05).The data is presented in percentage of 360 consumers.

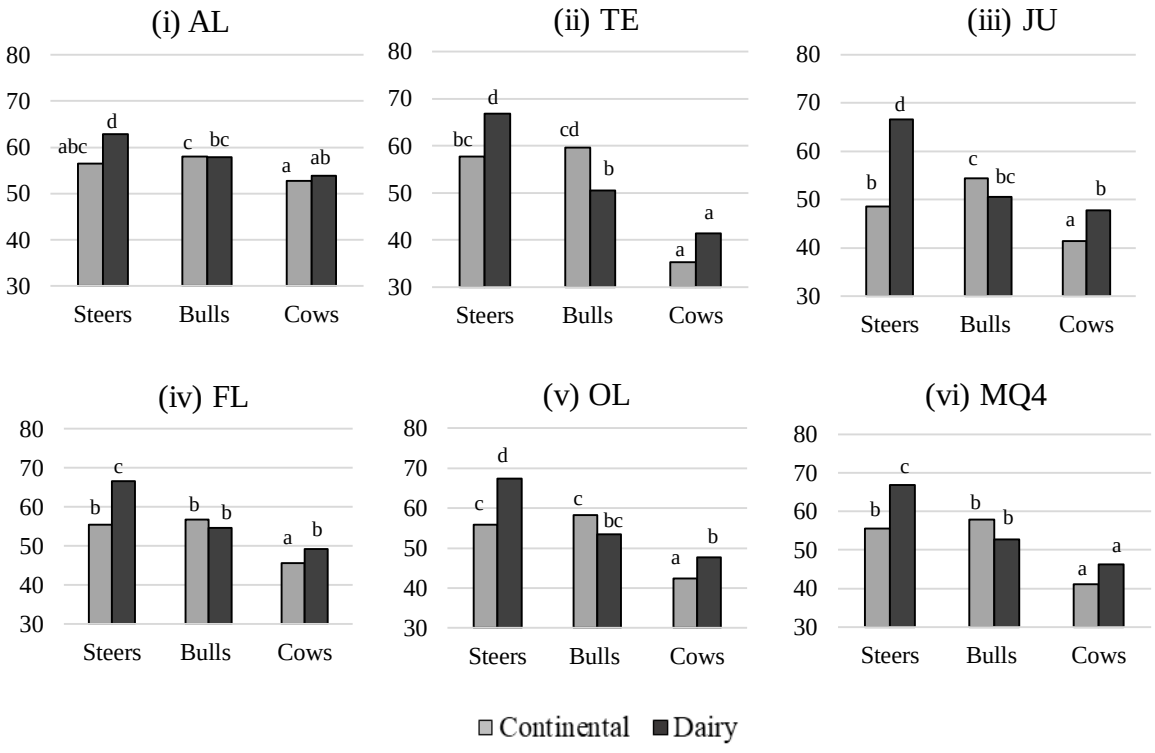


Figure 4 Effect of breed and sex interaction on (i) aroma liking (AL), (ii) tenderness (TE), (iii) juiciness (JU), (iv) flavour liking (FL), (v) overall liking (OL) and (vi) MQ4 scores of consumer panel. For significance, see Table 5.

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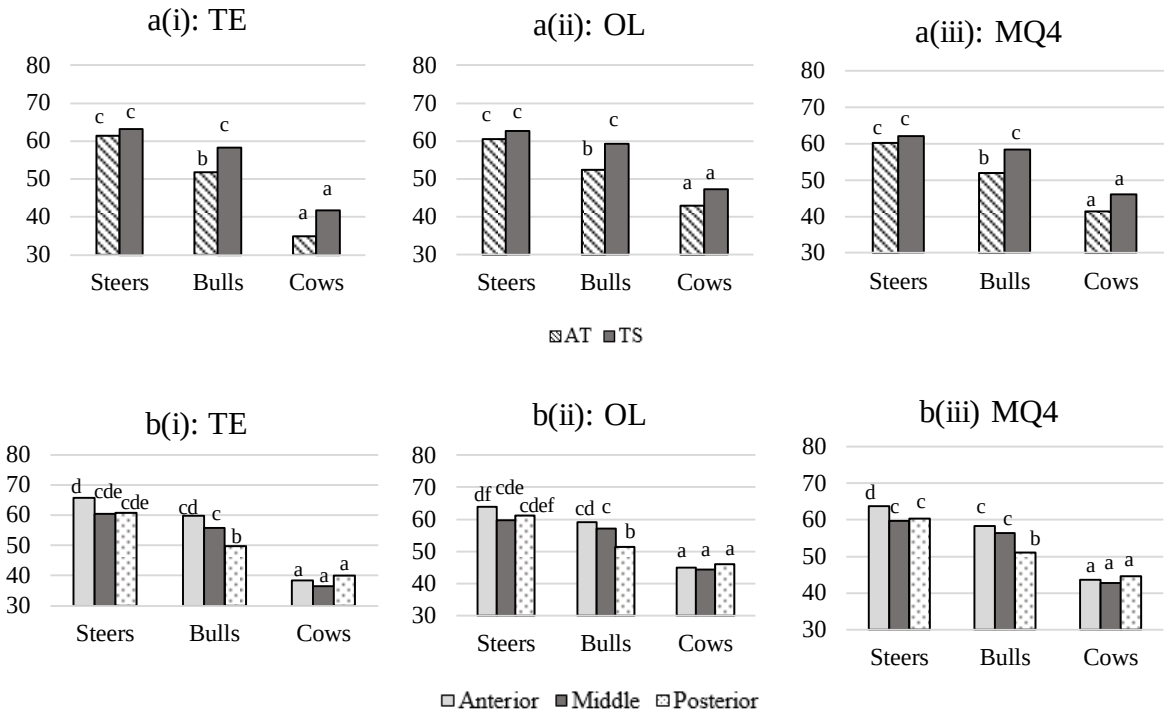


Figure 5 Effects of (a) hang and sex interaction and (b) sex and sample position interaction on (i) tenderness (TE), (ii) overall liking (OL) and (iii) MQ4 score. For significance, see Table 5.

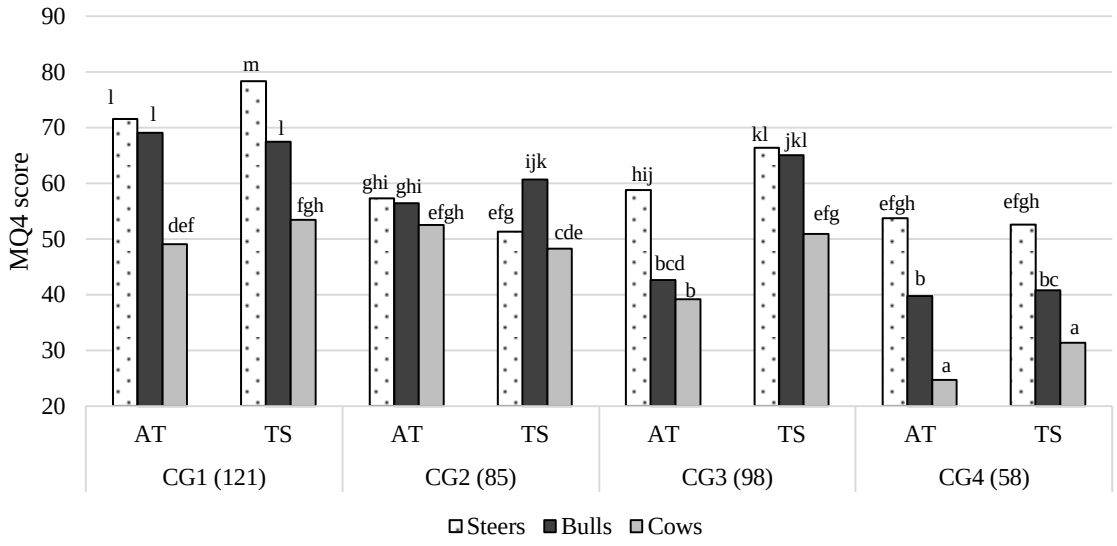


Figure 6 Effect of cluster group x hanging method x animal sex on MQ4 score. Number of consumer in each cluster group is included in bracket. For significance, see Table 5.

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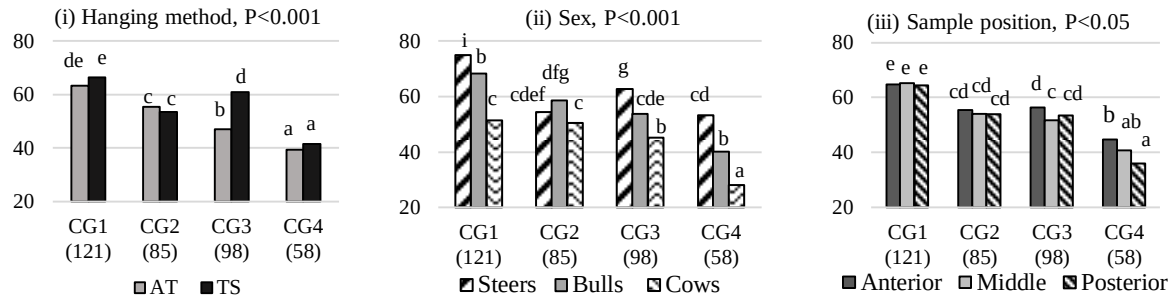


Figure 7 Effect of interactions of cluster group with (i) hanging method, (ii) sex and (iii) sample position interactions on MQ4 score. Number of consumer in each cluster group is included in bracket.

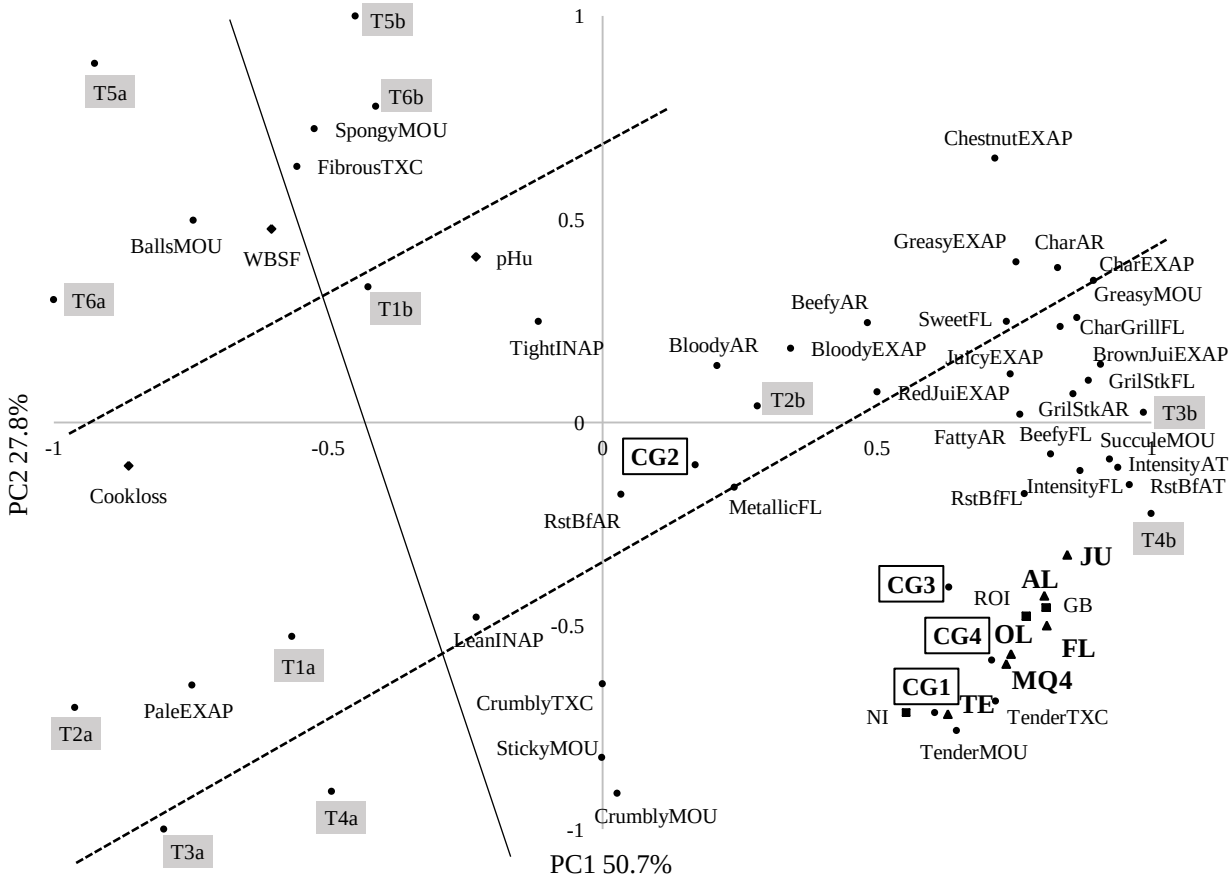


Figure 8 External preference map. Consumer sensory scores (triangle), sensory profiling panel attributes (circle) and instrumental analysis (diamond), region (square), cluster groups (square background). Groups (grey background) are listed on the map. Abbreviations: AR= Aroma, FL= Flavour, EXAP= External appearance, INAP= Internal appearance, TC=Texture on cutting, MOU= Mouth-feel, AF= Aftertaste, CG=cluster group, NI= Northern Ireland, ROI= Republic of Ireland, GB= Great Britain. Consumer scores were highlighted in bold, AL= aroma liking, TE= tenderness, FL= flavour liking, JU=juiciness, OL= overall liking and MQ4 scores.

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