Effect of Age and Cut on Cooking Loss, Juiciness and Flavour of South African Beef

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ABSTRACT

The juiciness and flavour characteristics of 15 aged primal beef cuts of electrically stimulated carcasses, from three different age groups, were assessed (n = 61). Cooking losses were determined and proximate analyses (moisture, fat, nitrogen and ash) were performed. Tender cuts were cooked by a dry heat method, and less tender cuts were cooked by moist heat methods. A trained panel (n=10) evaluated sensory quality characteristics including initial and sustained juiciness, aroma and flavour. Flavour intensity was the biggest discriminant between the three age groups and declined with an increase in age. Initial impression of juiciness decreased with increased age of the animal and cooking losses increased nonlinear with age, irrespective of the muscle. In contrast sustained juiciness increased with increased age. Cuts cooked according to a dry heat cooking method were reported juicier (both initial and sustained) than those cooked according to moist heat methods.

Keywords: age; beef; cooking loss; juiciness; flavour

INTRODUCTION

The results of a survey (Shorthose and Harris (1990)) on consumer preferences for the physical properties

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of beef loin and topside steaks from animals of different ages (dentition groups), fat classes, gender and breeds, indicated that consumers generally preferred electrically stimulated meat of 0 - 2 tooth animals. Consumers preferred steaks from steers (compared to heifers) for flavour and overall satisfaction. Touraille (1992) found in a consumer evaluation study (n = 1 000) of meat quality criteria that consumers (87%) considered sensory properties to be the most important. The sensory properties of taste, tenderness and aroma were very important, 83%, 78% and 77% respectively, to consumers, compared to 37% for juiciness. In a series of surveys carried out at a pan-European level (Becker, 2000; Glitsch, 2000) it was concluded that consumers select meat in terms of characteristics such as its tenderness and juiciness, and the anticipated taste following to its overall appearance. Scheeder and Langholz (1996) found that younger animals scored significantly better in juiciness and texture (tenderness) traits and, therefore, in acceptance. Risvik (1994) proposed a simple model for texture perception, where juiciness and tenderness were the most important attributes both in terms of description and in terms of preference. In attempting to determine the relative importance of appearance, flavour and texture in perceived quality, Schutz and Wahl (1981) found that 240 respondents scored these attributes for meat and fish products as 2.57, 4.90 and 2.51, respectively.

The action and interaction of several ante-mortem and post-mortem factors affect the development of meat flavour. Ante-mortem factors include age, breed and gender, as well as the nutritional status and composition of the animal. The type of feed (e.g. grass vs. grain) also contributes significantly to flavour. Post-mortem factors include the length of ageing, ultimate pH and method of cooking. Of all these factors the final end-point temperature is considered the most important in producing flavour in beef (Spanier & Miller, 1996). The flavour of meat is not necessarily a linear function of the fat percentage (Risvik, 1994). However, it is widely accepted that cooking alters the flavour precursors of food to yield a product with a more pleasing taste (Spanier & Miller, 1996).

The sensation of flavour arises from a complex interaction of stimuli activating the taste (sweetness, saltiness, sourness and bitterness), olfactory (smell or odour) and trigemental (general pain and tactile receptors) sensory systems.

Three categories of compounds stand out as particularly important for meat flavour, namely carbonyls, sulphurous compounds and pyrazine. Carbonyls rise from among other lipids, and are therefore found in

the volatile compounds of fat and fatty meat. During cooking these carbonyls go through a condensation reaction with amino acids to form cyclic carbonyls. Sulphur is formed from the degradation of the S-containing amino acids in meat protein, and this formation is not only time and temperature (of cooking) related, but also related to the effects of ultimate pH. Compounds like sugars and S-containing amino acids form thiols, which possess meaty flavours. Pyrazine are only formed during the heating of meat (significant only from 70°C) and are generally found in the browned surface of the meat (Smulders *et al.*, 1991).

The relationship of beef flavour and juiciness to particular muscles and animal age, as defined by dentition, has never been investigated in the South African context, even though age is one of the two variables (the other being carcass fat cover) included in the South African beef carcass classification system. The effect of feed on flavour could also be deduced to a certain extend, as within the South African production system young animals (age A) are mostly grain fed in feeding pins, while older animals (Age B) are mostly grass fed while old animals (Age C) are culled old animals which were almost exclusively grass fed, e.g. older dairy cows and stud animals. In order to make meaningful recommendations to the consumer, it was decided to investigate these aspects which influence cooking loss, juiciness and flavour of South African beef. As overall lean-meat aroma (Wasserman & Talley, 1968) and flavour are not determined by the degree of fatness (Patterson, 1975), this variable as such was not investigated. The objective of this study was therefore to determine the effect of age on cooking, juiciness and flavour related quality characteristics of seven and eight primal cuts of beef, cooked according to either dry or moist heat method, from beef animals of three different age groups (according to the South African classification system). As the beef carcass classification system in South Africa is a dynamic system and, therefore, changes according to consumer demand, it would be useful to develop statistical models that could be adapted to changes in the age groupings. Therefore, a second objective, namely the prediction of juiciness characteristics for the various age groups, was identified.

MATERIALS AND METHODS

Source of materials

The beef carcasses (n = 61) used in this study had a mass range of 190 kg to 240 kg. No specific breed was chosen. The three age groups were A (no permanent incisors) (n = 21), B (2 or more permanent incisors) (n = 20) and C (≥8-toothed) (n = 20). Due to the fact that carcass fatness could influence (but not determine according to Patterson, 1975) juiciness and flavour, carcasses representing the full spectrum within each age group were selected.

The carcasses were selected by qualified classifiers on the commercial market. They were electrically stimulated (500 V) within 10 minutes of stunning, dressed, halved, chilled overnight at between 0°C and 5°C, labelled and transported to the Animal Nutrition Animal Products Institute of the Agricultural Research Council (ARC-ANPI) in a refrigerated truck at between 5°C and 7°C.

Sample preparation

Each of the right sides of beef was subdivided into 15 wholesale cuts. The cuts were dissected into subcutaneous fat, meat and bone. The meat plus subcutaneous fat were cubed, thoroughly mixed and then minced; first through a 5 mm and then through a 2 mm mesh plate. A representative sample of 300 g of the meat plus subcutaneous fat obtained from each cut was analysed (AOAC methods, 1995) to determine the percentages of total moisture, fat, nitrogen (N x 6,25 = protein) and ash. The chemical results were combined with the subcutaneous fat and meat content results for the calculation of muscle and total fat content of each cut, expressed as a percentage of carcass mass (Carroll & Conniffe, 1967).

Cuts of sixty-one left sides were used to determine cooking losses and sensory analysis. The left sides were portioned into 15 wholesale cuts with the rump and topside deboned. The cuts were then vacuum-packed, aged at 4°C for 10 days post-slaughter and then stored at -40°C prior to cooking and sensory analysis. The cuts were thawed at 6°C to 8°C for periods varying between 24 and 36 hours

(depending on mass), until the internal temperature reached 2°C to 5°C (American Meat Science Association (AMSA), 1978).

Cooking methods

Dry heat cooking method

The following cuts (*muscles*) were used: prime rib - 8th to 10th rib (*M. longissimus thoracis* (LTP)); loin (*M. longissimus lumborum* (LL)); wing rib - 11th to 13th rib (*M. longissimus thoracis* (LTW)); rump (*M. gluteus medius* (GM)); topside (*M. semimembranosus* (SM)); silverside (*M. semitendinosus* (ST)) and fillet (*M. psoas major* (PM)) (Nomina Anatomica Veterinaria, 1983). All these cuts, excluding the loin, were cooked in their primal form. The cuts were roasted whole at 160°C, on a rack in an open oven pan, until the muscle to be evaluated had reached an internal temperature of 70°C. A hand-model Kane-Mane probe equipped with a T-type thermocouple was used to check the final temperature (70°C) of the cut prior to removal from the oven. The loin cuts were portioned into 25 mm thick steaks (AMSA, 1978), vacuum-packed and stored at -40°C. The defrosted steaks were cooked according to an oven-broiling method (on a rack) where the meat is cooked by direct radiant heat (> 200°C) to an internal temperature of 70°C.

Moist heat cooking

The following cuts (muscles) were used: silverside (*M. gluteobiceps* (GB)); thick flank (*M. vastus lateralis* (VL)); chuck (*M. serratus ventralis* (SV)); brisket (*M. pectoralis profundus* (PP)); neck (*M. biventer cervicis* (BC)); shoulder (*M. triceps brachii caput longum* (TBCL)); thin flank (*M. obliquus abdominis externus* (OAE)) and shins (*M. extensor carpi radialis* (ECR) and *M. flexor digitorum medialis* (FDM)) (Nomina Anatomica Veterinaria, 1983). The silverside, thick flank, chuck, shoulder and neck were cooked in primal form. The brisket and thin flank were formed into a meat roll and covered with mesh before ageing. Prior to cooking, the frozen fore and hind shins were portioned into 5 cm thick cuts. All cuts were broiled at 160°C on a rack in a covered stainless steel casserole dish until the muscle to be evaluated reached an internal temperature of 70°C. Distilled water (100 ml) at room temperature was added to each

dish before cooking commenced.

All the cuts (dry and moist) were kept at room temperature for a standing period of 10 minutes after cooking. The different muscles were then dissected and halved for sensory analysis and were immediately cut up. Ten cubed samples were taken from the middle of each muscle and immediately individually wrapped in foil marked with random three-digit codes. These samples were served at an internal temperature of 60°C within 30 minutes after removing the whole cut from the oven. A 100 g sample of the cooked muscle was analysed according to AOAC methods (1995) to determine the percentages of total moisture, fat and nitrogen (N *x* 6,25 = protein).

In order to compare age effects, the sensory panel was presented with samples of identical muscle from the three age groups with comparable fatness levels. Samples were tasted at each of the 20 sessions on seven consecutive working days, with the order of the age groups randomised for each session. Cooking and sensory analyses were then performed on the subsequent cuts without any particular order of cooking for the various cuts (3 samples *x* 20 sessions *x* 15 cuts = 900 samples tasted) over a period of seven months.

Data recorded during the study

Total cooking losses

All the cuts were weighed pre- and post-thawing and pre- and post-cooking. Total cooking losses were calculated, using the initial (pre-cooking) and final total mass (post-cooking) of each cut and the volume of drip from each sample expressed as mass. Evaporation losses were then calculated as the difference between the total cooking loss and drip losses (AMSA, 1978). Evaporation, drip and total cooking loss were expressed as a percentage of the initial raw mass.

Descriptive palatability attributes

A ten-member, trained, descriptive sensory panel was used to evaluate the palatability attributes of each cut. Panellists were selected and trained over a two-month period in accordance with the AMSA Guidelines for Cooking and Sensory Evaluation of Meat (AMSA, 1978) and the procedures of Cross *et al.* (1978). Reliability and validity of the sensory results were used as criteria for selecting members. Samples

(1 cm^3) were evaluated on an 8-point scale (1 denoting the least favourable and 8 the most favourable condition) for aroma (volatile substances perceptible to the olfactory organ), initial juiciness (amount of fluid on the cut surface when pressed between thumb and forefinger), sustained juiciness (impression of juiciness as panellists started chewing) and flavour (combination of taste while chewing and swallowing). Distilled water at room temperature was used to cleanse the palate between samples.

STATISTICAL ANALYSIS

Although principal component analyses (PCA) (GENSTAT 5, 1996) were performed on all the variates for each of the 15 cuts, the results are not presented due to limited space (n = 7 juiciness and flavour parameters x 15 cuts = 105 plots). However, fatness of the carcass was identified as one of the most important gradients in this multivariate data space (data matrix). It was therefore decided to include fatness of the carcass as a covariant in a PROC GLM procedure (SAS, 1996) for the analyses of variance performed on the data.

CVA (GENSTAT 5, 1996), also known as linear discriminant analysis, was used to determine groupings in the different age groups (A, B and C) and/or the 15 cuts. In this study the variates were the aroma, flavour, juiciness and cooking losses that were assessed or measured for each cut. The scores found for each of the canonical variates were then correlated with the original variates to establish which were the most important in discriminating between the age groups and/or cuts (Digby & Kempthorne, 1987). The logarithms of the variates were used to stabilise the variances.

As only the directions of the main variability in the data matrix are obvious in these analyses, the more subtle sources of variation were investigated by ANOVA (SAS, 1996), as proposed by Næs *et al.* (1996). A correlation matrix was constructed to test for correlations between the different variables. To ensure that the effect of animal age was determined and not the effect of fatness of the carcass, the total fat content of the carcass (as determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut) was used as covariant (X), both as natural X and $X^{2,}$ in a PROC GLM (SAS, 1996) procedure. In searching for the simplest model the covariant was removed from the model if not significant (very generously at $p \geq 0{,}15$), starting with X^2 and continuing with X. Separation

of the mean scores for interaction of the different variables for the various cuts from the three age groups was achieved by the application of Tukey's method (SAS, 1996).

In order to attain the second objective, namely the prediction of the juiciness of the cuts from the various age groups, regression equations ($Y = A + BX$) were used for the main model. In the regression equation the age of the animal (X) was tested against the various characteristics (Y) of each cut and of the entire carcass. As most of the data were not normally distributed, the dependent variates in the equation (Y) were transformed to Y^2, Y^3, $\sqrt{Y}$ and $ln\ Y$ (natural log). These four transformations, together with the natural Y, were combined in forward stepwise regression analyses and tested against juiciness as analysed by the taste panel. The accuracy of such models is determined by the R^2 (percentage variation) and the residual standard deviation or RSD (error variance around the regression line). As very few of the R^2 values were ≥ 50% this was not considered a reliable method of predicting juiciness in meat. The data were, therefore, studied by analyses of variance for the three age groups as described above, where the R^2 and p-value of the model are also presented. This was again found not to be a reliable method for predicting juiciness. Therefore no satisfactory statistical model was identified in this study for the accurate prediction of juiciness of the meat of animals in different age groups.

Cuts were ranked in descending order according to the percentage thawing, evaporation, drip and total cooking loss, as well as according to sensory evaluation scores.

RESULTS AND DISCUSSION

Effect of age on cooking, juiciness and flavour

It is important to note that, although primal cuts were cooked, the panel tasted individual muscles. The results of the canonical variate analyses showed that the first canonical variate (CV1) accounted for 84,7% of the total variation in the data but that the latent root was less than 1 (0,0494), and, therefore, the results should be considered as just a general trend. The canonical variate means for thawing loss, aroma, flavour, initial impression of juiciness and sustained juiciness were positive and negative for all the cooking losses, thus CV1 contrasted between these variables. The main discriminant attribute was flavour (r = 0,600) as it

correlated the strongest with the CV scores on the CV1 horizontal axis.

The dimensional graphic presentation of the series highlighted the ordination and/or grouping of similar ages (points close together are similar and those far apart dissimilar). The CV mean scores are presented in Figure 1. Flavour intensity was the largest discriminant in the three age groups and it declined with age. These results were probably due to changes in the amino acid, protein and nucleotide metabolism (Smulders *et al.*, 1991) with increased animal age. According to Sink (1979), age affects the "water-soluble, meaty" aspect more than the "lipid-soluble, species-specific" flavour. The decline in flavour with age corresponds with the findings of Cross *et al.* (1973b) who found that flavour ratings were highest for steaks in the A (very young) maturity group, compared to the C to E (older) maturity groups. It also corresponds with the findings of Moloney, Mooney, Kerry and Tray (2001) who found that the flavour intensity decrease as the maturity of the lean tissue increase.

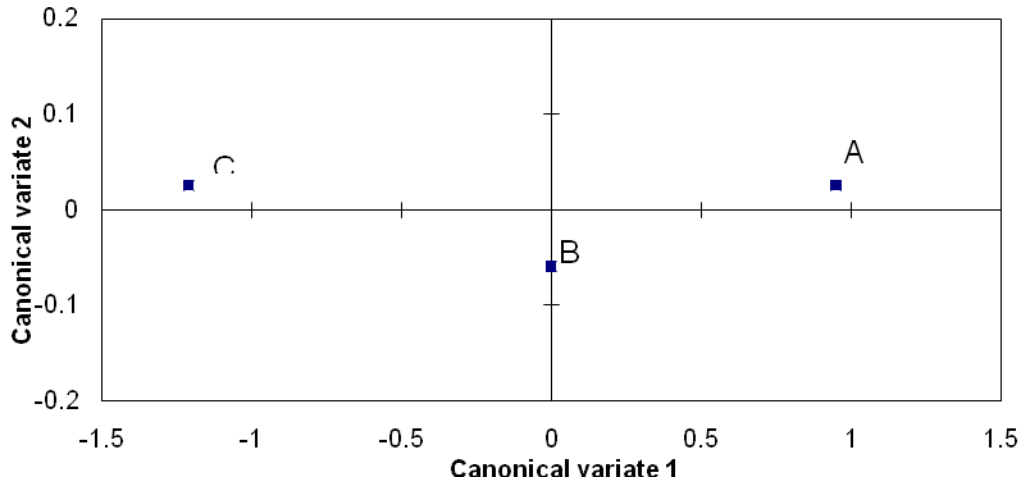

Figure 1: Plot of CV mean scores of three age groups

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

For the analyses of variance (ANOVA), the chemical analysis data were combined with the subcutaneous fat, meat (muscle and intermuscular fat) and bone content results obtained from the physical dissections for the calculation of percentages of meat, total fat and bone content of each specific cut (Carroll & Conniffe,

1967). These values were summed to obtain the chemical (fat, protein and moisture) and physical (meat, total fat and bone) composition of the carcass. This percentage total fat content of the carcass was used as a covariant in the PROC GLM procedure to adjust for differences between initial fat content and was 15,74% with a minimum of 8,03% and a maximum of 29,75%. The following other fat attributes were measured for this data set:

- Subcutaneous fat (%) of the carcass: mean = 6,21; minimum = 1,17; maximum = 13,36
- Proximate fat (%) in the carcass: mean = 13,46; minimum = 1,61; maximum = 42,89
- Proximate fat (%) in the cooked muscles: mean = 4,93; minimum = 0,98; maximum = 26,61.

As shown in Table 1, the age of the animal did not show a consistently significant effect on thawing loss, although when significant ($p \leq 0,05$), thawing loss decreased with increased animal age (prime rib, wing rib and GB). The age of the animal did not have a marked influence on evaporation loss, although it increased with increased age of the animal in the wing rib and decreased with increased age in the thin flank. The pH of the muscles, although not measured, could have had an effect on water retention. As older age animals (Age group C) in South Africa are mostly grass fed, their pH would have been higher which would contribute towards better water retention. It should be noted that sarcomere length, as related to age, most probably had little effect on fluid retention, as the carcasses were electrically stimulated to prevent cold shortening.

The drip loss showed an age effect in only two of the 15 cuts, with a significant ($p \leq 0,05$) increase with increased age in the wing rib and thin flank and a decrease with increased age in the topside of the B-and C-age groups. The total cooking loss showed a significant ($p \leq 0,05$) difference in seven of the 15 cuts that were cooked. The total cooking loss for the prime rib, wing rib, rump and topside of the A-age group was significantly ($p \leq 0,05$) less than that of the B-age group. The total cooking loss of the prime rib and wing rib of the B-age group was significantly ($p \leq 0,05$) less than that of the C-age group. The GB, shoulder and thin flank of the A-age group showed significantly ($p \leq 0,05$) less total cooking loss than the cuts from the C-age group. These results contradict observations made by Bertram, Straadt, Jensen and Aaslyng (2007) who observed a non-significant, but clear tendency for an increase in drip loss, but a decreased cooking loss

TABLE 1
Least Square Mean (±Standard Error of Mean) Values of Thawing and Cooking Losses for Cuts Obtained from Three Age Groups (Average Chemical Fat of the Carcass used as Covariant[1] = 15,74 %)

Cut	Cooking method (Moist / Dry heat	Model		Covariant[1]			Age					
								A		B		C	
		R^2 %	p-Value	Raw mass of cut	X p-Value	X^2 p-Value	Age p-Value						
								Mean	SEM	Mean	SEM	Mean	SEM
Thawing loss %													
Prime rib	Dry	19	0,0192	0,8644	0,0707		0,0228	1,02[a]	0,182	0,81[ab]	0,187	0,31[b]	0,178
Loin	Dry	22	0,0073	0,0846	0,0013		0,2679	0,29	0,079	0,31	0,083	0,14	0,079
Wing rib	Dry	25	0,0024	0,6963	0,0197		0,0107	0,88[a]	0,147	0,78[a]	0,154	0,27[b]	0,147
Silverside[2]	Dry	21	0,0108	0,0821	0,0026		0,1254	4,90	0,374	4,47	0,393	3,81	0,375
Rump	Dry	14	0,0313	0,0055			0,8952	2,21	0,449	2,52	0,463	2,36	0,460
Topside	Dry	21	0,0040	0,0056			0,3887	0,45	0,080	0,38	0,085	0,29	0,083
Fillet	Dry	8	0,1710	0,0700			0,2948	3,04	0,573	4,36	0,615	3,51	0,583
Silverside[3]	Moist	27	0,0012	0,1489	0,0164		0,0016	6,15[a]	0,456	5,21[ab]	0,470	3,67[b]	0,469
Thick flank	Moist	6	0,4880	0,6041	0,0798		0,8028	1,17	0,216	0,96	0,226	1,03	0,212
Chuck	Moist	20	0,0294	0,1779	0,0496	0,0979	0,4555	0,91	0,349	1,40	0,339	0,85	0,350
Brisket	Moist	20	0,0054	0,0046			0,4618	0,89	0,172	0,58	0,185	0,68	0,172
Neck	Moist	10	0,2260	0,7155	0,1118		0,2453	0,63	0,143	0,41	0,155	0,30	0,142
Shoulder	Moist	20	0,0049	0,0007			0,6128	3,34	0,532	3,80	0,574	3,01	0,567
Thin flank	Moist	20	0,0249	0,0130	0,1066	0,1147	0,1719	0,91	0,171	0,78	0,179	0,46	0,171
Shins	Moist	39	0,0001	0,0001	0,0281	0,0452	0,2432	0,84	0,205	1,30	0,204	1,24	0,202
Evaporation Loss (%)													
Prime rib	Dry	33	0,0005	0,0544	0,1891	0,0909	0,3269	19,76	0,347	20,10	0,357	20,49	0,338
Loin	Dry	27	0,0042	0,8232	0,0002	0,0003	0,1591	15,38	1,064	17,32	1,192	14,20	1,057
Wing rib	Dry	36	0,0001	0,5434	0,0001		0,0456	16,49[a]	0,438	16,87[a]	0,459	18,06[b]	0,460
Silverside[2]	Dry	13	0,1056	0,7217	0,0150		0,7051	19,55	0,670	19,13	0,706	19,94	0,656
Rump	Dry	35	0,0002	0,2728	0,0311	0,1236	0,0747	27,02	0,666	29,15	0,673	28,68	0,672
Topside	Dry	23	0,0066	0,0007	0,0505		0,3100	20,80	0,895	22,42	0,914	22,63	0,889
Fillet	Dry	0,3	0,9832	0,9221			0,9259	21,54	0,706	21,66	0,758	21,26	0,718
Silverside[3]	Moist	14	0,0353	0,0094			0,5693	5,83	0,429	5,27	0,452	5,88	0,451
Thick flank	Moist	17	0,0664	0,0436	0,0236	0,0491	0,3141	9,61	0,476	10,24	0,496	10,65	0,477
Chuck	Moist	22	0,0066	0,0754	0,0590		0,6623	2,38	0,349	2,72	0,340	2,84	0,351
Brisket	Moist	5	0,6177	0,8814	0,1156		0,9153	8,85	0,618	9,01	0,651	9,22	0,605
Neck	Moist	4	0,4802	0,1509			0,8466	9,32	0,678	9,24	0,759	8,80	0,675

Shoulder	Moist	26	0,0007	0,0013			0,1111	10,61	0,718	10,19	0,755	12,32	0,747
Thin flank	Moist	22	0,0075	0,3285	0,0305		0,0170	11,17[a]	0,539	9,14[b]	0,555	9,30[b]	0,529
Shins	Moist	25	0,0024	0,0011	0,1114		0,4672	1,01	0,166	1,28	0,165	1,06	0,164
Drip Loss (%)													
Prime rib	Dry	68	0,0001	0,0349	0,0001		0,0001	4,76	0,336	6,11	0,345	7,79	0,329
Loin	Dry	29	0,0018	0,2351	0,0006	0,0026	0,5423	9,64	0,463	8,90	0,489	9,43	0,460
Wing rib	Dry	79	0,0001	0,0003	0,0001		0,0001	6,18[a]	0,401	7,80[b]	0,420	10,69[c]	0,420
Silverside[2]	Dry	11	0,1740	0,2701	0,0270		0,4806	5,01	0,361	4,63	0,379	5,26	0,362
Rump	Dry	54	0,0001	0,0010	0,0014	0,0066	0,0901	10,09	0,483	10,57	0,489	11,66	0,488
Topside	Dry	15	0,0318	0,0458			0,0437	15,14[ab]	0,636	15,99[a]	0,677	13,56[b]	0,679
Fillet	Dry	28	0,0003	0,0001			0,1440	5,94	0,451	4,81	0,484	6,01	0,458
Silverside[3]	Moist	18	0,0542	0,4627	0,0283	0,0208	0,1071	23,96	0,598	24,73	0,618	25,80	0,613
Thick flank	Moist	15	0,1197	0,3930	0,0472	0,0817	0,9787	28,80	0,591	28,63	0,617	28,68	0,593
Chuck	Moist	11	0,2650	0,8855	0,2187	0,1211	0,9606	31,42	0,847	31,62	0,823	31,30	0,849
Brisket	Moist	7	0,3937	0,6556	0,0967		0,4610	22,65	1,317	21,72	1,386	24,05	1,287
Neck	Moist	44	0,0001	0,0001	0,2328	0,1122	0,2831	19,50	1,072	21,64	1,172	21,63	1,039
Shoulder	Moist	3	0,6385	0,4778			0,4640	17,89	1,268	19,12	1,333	20,22	1,319
Thin flank	Moist	47	0,0001	0,1227	0,2339	0,0571	0,0001	14,45[a]	0,666	17,75[b]	0,699	18,56[b]	0,666
Shins	Moist	46	0,0001	0,0009	0,0001	0,0001	0,1257	21,32	0,687	19,87	0,684	19,27	0,678
Total Cooking Loss (%)													
Prime rib	Dry	44	0,0001	0,8676	0,0303	0,0907	0,0001	24,54[a]	0,497	26,18[b]	0,511	28,28[c]	0,484
Loin	Dry	15	0,1093	0,3367	0,0268	0,0206	0,3792	25,04	1,055	25,84	1,181	23,67	1,048
Wing rib	Dry	55	0,0001	0,0082	0,0969		0,0001	22,66[a]	0,657	24,67[b]	0,688	28,75[c]	0,689
Silverside[2]	Dry	6	0,3525	0,2525			0,3406	24,30	0,792	23,55	0,854	25,27	0,792
Rump	Dry	30	0,0004	0,1248	0,1327		0,0029	37,10[a]	0,651	39,75[b]	0,656	40,32[b]	0,656
Topside	Dry	22	0,0092	0,0163	0,0722		0,0298	35,75[a]	0,709	38,39[b]	0,723	36,35[a]	0,723
Fillet	Dry	12	0,0653	0,0097			0,6134	27,48	0,719	26,47	0,772	27,27	0,731
Silverside[3]	Moist	29	0,0020	0,0047	0,0258	0,0181	0,0448	29,86[a]	0,547	30,00[a]	0,565	31,68[b]	0,560
Thick flank	Moist	21	0,0036	0,0004			0,2575	38,34	0,416	38,89	0,442	39,35	0,430
Chuck	Moist	9	0,3697	0,5207	0,0908	0,0599	0,9102	33,83	0,821	34,32	0,797	34,12	0,824
Brisket	Moist	12	0,1222	0,6003	0,0165		0,3737	31,51	1,300	30,73	1,368	33,27	1,271
Neck	Moist	38	0,0001	0,0001	0,0535		0,3062	28,91	0,940	30,93	1,028	30,49	0,913
Shoulder	Moist	16	0,0187	0,1834			0,0440	28,50[a]	1,129	29,31[a]	1,187	32,54[b]	1,174
Thin flank	Moist	25	0,0065	0,3371	0,2189	0,0924	0,0492	25,59[a]	0,649	26,90[ab]	0,666	27,88[b]	0,633
Shins	Moist	47	0,0001	0,0002	0,0001	0,0001	0,1944	22,34	0,748	21,14	0,745	20,33	0,738

[1] p-values of the full model; if not significant (p 0,15) covariant was removed from the model starting with X^2 and continuing with X

[2] Silverside: ST - *M. semitendinosus* ; [3] Silverside: GB - *M. gluteobiceps*

[abc] Means in the same row with different superscripts differ significantly (p 0,05)

with an increase in age of pork muscle.

These results were obtained irrespective of the fact that there was no significant difference between the various fat parameters measured for the three age groups and that the raw mass of the cut, was included as a covariant. This suggested that the muscle or protein denatured with animal age, resulting in increased moisture loss upon heating or cooking irrespective of whether dry or moist heat is used, although it could be argued that dry heat had a more pronounced effect. According to Rasmussen and Anderson (1996), moisture loss is a reflection of the inability of meat to hold the natural meat juices in the muscle and muscle fibres. A high loss might be due to both increased denaturation of the protein with age, or increased cross-linking of collagen with age, resulting in decreased water holding capacity (Purslow, 2005). Tuma *et al.* (1963) also reported a significant ($p \leq 0,01$) decrease in moisture content due to increased animal age, Although older carcasses are normally considered to contain greater quantities of fat, it should be noted that within the South African beef production system, older animals (Age C) are mostly culled old animals which are not higher in fat than younger animals. However, intramuscular fat increases with age, and this could have contributed to the decrease in moisture content observed.

The age of the animal (Table 2) showed a significant ($p \leq 0,05$) effect on aroma intensity in three of the 15 cuts that were evaluated. There was a significant ($p \leq 0,01$) difference in aroma intensity in the LTP of the A-age group and that of the same muscle in the C-age group, with aroma intensity decreasing with increased age. The aroma was significantly ($p \leq 0,01$) more intense in the LL and SV of the B-age group than in the same cuts from animals of the A-age group.

Flavour intensity increased significantly ($p \leq 0,05$) with increased age in only one of the seven cuts cooked by a dry heat cooking method, namely the LL. Contrary to general belief (Sink & Caporaso, 1977; Ford & Park, 1987; Calkins & Hodgen, 2007), flavour intensity decreased significantly ($p \leq 0,05$) with increased age in five of the eight cuts cooked by a moist heat cooking method. The flavour of the GB, VL, SV, PP and OAE from the A-age group was significantly ($p \leq 0,05$) more intense than in the same cuts

from the C-age group.

It is, therefore, concluded that the age of the animals did not have a consistently significant effect on the aroma intensity of the 15 cuts that were studied, and flavour intensity increased in only one of the cuts cooked according to a dry heat cooking method. However, the cuts cooked according to a moist heat

TABLE 2
Least Square Mean (±Standard Error of Mean) of Aroma and Flavour for Muscles Obtained from Three Age Groups (Average Chemical Fat of the Carcass used as Covariant = 15,74 %)

		Model		Co-variant[2]			Age					
	Cooking method (Moist / Dry heat)			*X*	X^2	Age	A		B		C	
Muscle[1]		R^2 %	p-Value	p-Value	p-Value	p-Value	Mean	SEM	Mean	SEM	Mean	SEM
Aroma (8=extremely intense; 1=extremely bland):												
LTP	Dry	5	0,0001	0,0389	0,1246	0,0009	5,72[a]	0,081	5,59[a]	0,083	5,30[b]	0,078
LL	Dry	1	0,0360			0,0360	5,55[a]	0,066	5,79[b]	0,071	5,71[ab]	0,068
LTW	Dry	1	0,0960	0,0772	0,1048	0,1598	5,89	0,076	5,75	0,080	5,69	0,076
ST	Dry	0,9	0,2568	0,0658	0,0915	0,3933	5,88	0,061	6,00	0,064	5,93	0,061
GM	Dry	1	0,0838	0,0078	0,0140	0,9661	5,96	0,071	5,98	0,074	5,96	0,070
SM	Dry	3	0,0029	0,0031	0,0105	0,4992	6,13	0,056	6,04	0,061	6,09	0,058
PM	Dry	0,5	0,2249			0,2249	6,19	0,058	6,28	0,063	6,33	0,060
GB	Moist	0,7	0,2128	0,0383		0,8967	6,10	0,065	6,07	0,068	6,06	0,065
VL	Moist	0,3	0,4466			0,4466	6,10	0,057	6,12	0,061	6,02	0,058
SV	Moist	3	0,0006	0,0032	0,0148	0,0344	5,88[a]	0,065	6,07[b]	0,069	5,84[a]	0,065
PP	Moist	1	0,1656	0,0336	0,0344	0,2680	5,49	0,076	5,66	0,080	5,61	0,078
BC	Moist	1	0,0613	0,0794		0,1505	5,89	0,076	5,84	0,082	5,69	0,076
TBCL	Moist	1	0,2039	0,0692	0,0712	0,1913	5,55	0,080	5,88	0,084	5,78	0,080
OAC	Moist	0,7	0,3611	0,1118	0,1239	0,3474	5,53	0,075	5,65	0,079	5,68	0,075
ECR&FDM	Moist	2	0,0151	0,0671	0,0236	0,6058	5,92	0,073	5,84	0,077	5,95	0,073
Flavour (8=extremely intense; 1=extremely bland):												
LTP	Dry	0,9	0,1556	0,0318		0,7926	5,48	0,083	5,44	0,085	5,40	0,081
LL	Dry	7	0,0001	0,0001		0,0410	5,34[a]	0,068	5,39[ab]	0,071	5,57[b]	0,068
LTW	Dry	2	0,0280	0,0234		0,1597	5,78	0,083	5,65	0,088	5,55	0,084
ST	Dry	1	0,0727	0,0183		0,5455	5,72	0,060	5,66	0,063	5,62	0,60
GM	Dry	3	0,0015	0,0011		0,1469	5,67	0,068	5,65	0,072	5,49	0,068
SM	Dry	0,2	0,5132			0,5132	5,54	0,052	5,49	0,057	5,46	0,054
PM	Dry	1	0,1099	0,0176	0,0149	0,3677	6,17	0,060	6,24	0,063	6,29	0,060
GB	Moist	2	0,0374	0,0387	0,0285	0,0536	5,65[a]	0,063	5,53[ab]	0,066	5,44[b]	0,063
VL	Moist	2	0,0155	0,0905		0,0306	5,68[a]	0,056	5,64[ab]	0,059	5,48[b]	0,056
SV	Moist	2	0,0006			0,0006	5,71[a]	0,072	5,66[a]	0,077	5,34[b]	0,073
PP	Moist	4	0,0001	0,0733		0,0002	5,36[a]	0,086	5,36[a]	0,091	4,91[b]	0,089

BC	Moist	1	0,1012	0,0964	0,2256	5,96	0,087	5,94	0,094	5,76	0,087
TBCL	Moist	2	0,0077	0,0006	0,9204	5,72	0,078	5,70	0,082	5,74	0,078
OAE	Moist	1	0,0333		0,0333	5,89[a]	0,078	5,96[a]	0,084	5,67[b]	0,080
ECR&FDM	Moist	0,4	0,3393		0,3393	5,03	0,105	5,16	0,113	4,93	0,108

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] p-values of the full model; if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

cooking method showed a decrease in flavour intensity with increased age in five of the eight cuts. According to Tuma *et al.* (1963), more flavourful meat is normally associated with older animals, although they also found an insignificant decline in flavour with increased animal age from 6 to 90 months. The fact that difference in flavour intensity, found in this study, on the cuts cooked by a moist heat cooking method and not in those cooked by a dry heat cooking method, is ascribed to the presence of moisture in the production or liberation of cooked beef flavour compounds (Ford & Park, 1987).

Although the juiciness of meat was generally expected to decrease with increased animal age (at an equal fatness level), this was not found in this study (Table 3). In all seven of the cuts cooked by a dry heat cooking method, the only significant difference ($p \leq 0,05$) in the initial impression of juiciness was found in the LL. The initial impression of juiciness of the LL of the B-age group was significantly ($p \leq 0,05$) lower than in the LL from the A-and C-age groups. The initial impression and sustained of juiciness of the PP and BC (cooked by a moist heat cooking method) of the A-age group was significantly ($p \leq 0,05$) higher than in the same cuts from the C-age group. The initial impression of juiciness of the VL of the A- and B-age groups was significantly ($p \leq 0,05$) higher than for the C-age group. The initial and sustained juiciness of the ECR and FDM of the A-age group was significantly ($p \leq 0,05$) more noticeable than in the same cuts from the B-age group. Contrary to the expectation that juiciness generally decreases with age, the sustained juiciness of the ST, PM, GB and OAE of the C-age group was significantly ($p \leq 0,05$) higher than for the A-age group. The PM, VL, SV, and OAE of the B-age group was significantly ($p \leq 0,05$) more juicy than the same cuts from the A-age group. The sustained juiciness of the TBCL of the B-age group was significantly ($p \leq 0,05$) more noticeable than in the same cuts from the C-age group. In general, initial

TABLE 3
Least Square Mean (±Standard Errors) of Sustained Juiciness for Muscles Obtained from Three Age Groups (Average Chemical Fat of the Carcass used as Covariant = 15,74 %)

	Cooking method (Moist / Dry heat)	Model		Covariant [2]			Age					
							A		B		C	
Muscle[1]		R^2 %	p-Value	*X* p-Value	X^2 p-Value	Age p-Value	Mean	SEM	Mean	SEM	Mean	SEM
Initial Impression of Juiciness (8 = extremely juicy, 1 = extremely dry)												
LTP	Dry	2	0,0057	0,0023		0,3016	5,75	0,082	5,82	0,084	5,64	0,080
LL	Dry	2	0,0111	0,0180		0,0416	5,70[a]	0,079	5,44[b]	0,083	5,69[a]	0,079
LTW	Dry	2	0,0166	0,0108		0,1946	5,68	0,090	5,59	0,095	5,45	0,090
ST	Dry	5	0,0001	0,0001		0,5121	5,74	0,075	5,76	0,079	5,86	0,075
GM	Dry	6	0,0001	0,0001	0,0001	0,3649	5,85	0,084	5,67	0,089	5,75	0,084
SM	Dry	0,8	0,1804	0,0678		0,5312	5,61	0,071	5,63	0,076	5,52	0,073
PM	Dry	2	0,0239	0,0256		0,0880	6,10	0,074	6,33	0,078	6,22	0,074
GB	Moist	2	0,0214	0,0193	0,0524	0,8089	5,62	0,072	5,68	0,075	5,68	0,071
VL	Moist	3	0,0011	0,0276	0,0234	0,0012	5,55[a]	0,068	5,72[a]	0,071	5,36[b]	0,067
SV	Moist	2	0,0301	0,0385	0,0174	0,2840	5,70	0,079	5,88	0,083	5,76	0,079
PP	Moist	4	0,0001	0,0627		0,0003	4,60[a]	0,083	4,71[a]	0,087	4,23[b]	0,085
BC	Moist	3	0,0004	0,0106	0,0082	0,0017	5,38[a]	0,089	5,29[a]	0,097	4,95[b]	0,089
TBCL	Moist	2	0,0528	0,1012	0,0616	0,1051	5,46	0,084	5,70	0,089	5,48	0,084
OAE	Moist	1	0,0686	0,0450		0,2072	5,46	0,073	5,63	0,077	5,61	0,073
ECR&FDM	Moist	2	0,0058	0,0056		0,0669	3,99[a]	0,096	3,66[b]	0,101	3,83[ab]	0,096
Sustained Juiciness (8 = extremely juicy, 1 = extremely dry)												
LTP	Dry	4	0,0001	0,0001		0,0587	5,18	0,080	5,43	0,082	5,40	0,078
LL	Dry	1	0,0440	0,0377		0,1070	5,05	0,083	4,95	0,088	5,21	0,084
LTW	Dry	2	0,0048	0,0044	0,0134	0,4203	5,35	0,095	5,39	0,100	5,22	0,095
ST	Dry	7	0,0001	0,0001		0,0337	5,12[a]	0,076	5,14[a]	0,080	5,38[b]	0,076
GM	Dry	6	0,0001	0,0001	0,0001	0,8823	5,33	0,086	5,31	0,090	5,37	0,086
SM	Dry	0,04	0,8899			0,8899	5,11	0,068	5,16	0,075	5,16	0,071
PM	Dry	4	0,0001	0,0006		0,0036	5,84[a]	0,070	6,15[b]	0,074	6,11[b]	0,071
GB	Moist	1	0,0509			0,0509	5,11[a]	0,072	5,26[ab]	0,077	5,35[b]	0,074
VL	Moist	2	0,0148	0,1870	0,1366	0,084	4,97[a]	0,078	5,28[b]	0,082	4,98[a]	0,078
SV	Moist	2	0,0223	0,0791	0,0627	0,0141	5,37[a]	0,076	5,68[b]	0,080	5,46[a]	0,076
PP	Moist	4	0,0001	0,2423	0,1266	0,0002	4,13[a]	0,081	4,19[a]	0,086	3,74[b]	0,083
BC	Moist	2	0,0029			0,0029	4,98[a]	0,091	4,96[a]	0,100	4,58[b]	0,093
TBCL	Moist	1	0,0401			0,0401	5,04[ab]	0,086	5,22[b]	0,093	4,89[a]	0,088
OAE	Moist	2	0,0005			0,0005	4,95[a]	0,072	5,35[b]	0,077	5,21[b]	0,073
ECR&FDM	Moist	2	0,0018	0,0021		0,0448	4,10[a]	0,095	3,75[b]	0,101	3,94[ab]	0,096

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] p-values of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

juiciness appears to decrease with increased animal age, and sustained juiciness seems to increase with increased animal age. Similar conclusion can be drawn from Bertram *et al*. (2007) who studied pork muscle and found a decrease in juiciness with an increase in age from 90 days up to 161 days, while thereafter an increase in juiciness was observed with further increase in age. This finding should be further investigated.

Since the influence of fat was taken as a covariant in this study, the major contributor to the sensation of juiciness was the moisture remaining in the cooked product. As the fat-free water content of meat (lean tissue) is uniform, differences in juiciness have to relate to the ability of the muscle to retain water during cooking (Forrest *et. al.*, 1975; Bertram *et al*., 2007). The decrease in initial juiciness with increased animal age could be attributed to the fact that this ability of the muscle to retain water decreased with increased age, with consequently higher cooking losses in cuts from older animals. This is associated with a drier end product, without the rapid release of meat fluid during the first few chews as was found in the meat from young animals.

The result that sustained juiciness increased with increased age may be explained by the fact that more mastication would be required for samples from older animals (due to the increased cross-linking of the collagen with increased age) and, therefore, more saliva would be released to increase the perceived sustained juiciness. This corresponds with the conclusions of Huff and Parrish (1993) that samples from carcasses of older animals (C to E maturity) were juicier ($p \leq 0,05$) than samples from carcasses of young bulls and steers (A maturity). Juiciness in their study was described as an estimation of the amount of free fluids released by chewing and it was, therefore, comparable to sustained juiciness in this study.

Discrimination between cuts/muscles

The first two canonical variates (CV1 and CV2) accounted for 80,9% of the variation in the data, with latent roots 11,7 and 3,0. The canonical variate means for flavour, initial and sustained juiciness, thawing, evaporation and total cooking loss were negative, but positive for aroma and drip loss; CV1 clearly contrasted between these. The main discriminant variates of these characteristics for the different cuts/muscles were evaporation loss (r = -0,978), drip loss (r = 0,710), initial impression of juiciness (r = -0,644), and to a lesser extent juiciness (r = - 0,523) as these correlated the strongest with the CV1 scores (horizontal separation in Figure 2). The total cooking loss (r = -0,797) mainly discriminated between groups in the CV2 for the different cuts (vertical separation in Figure 2).

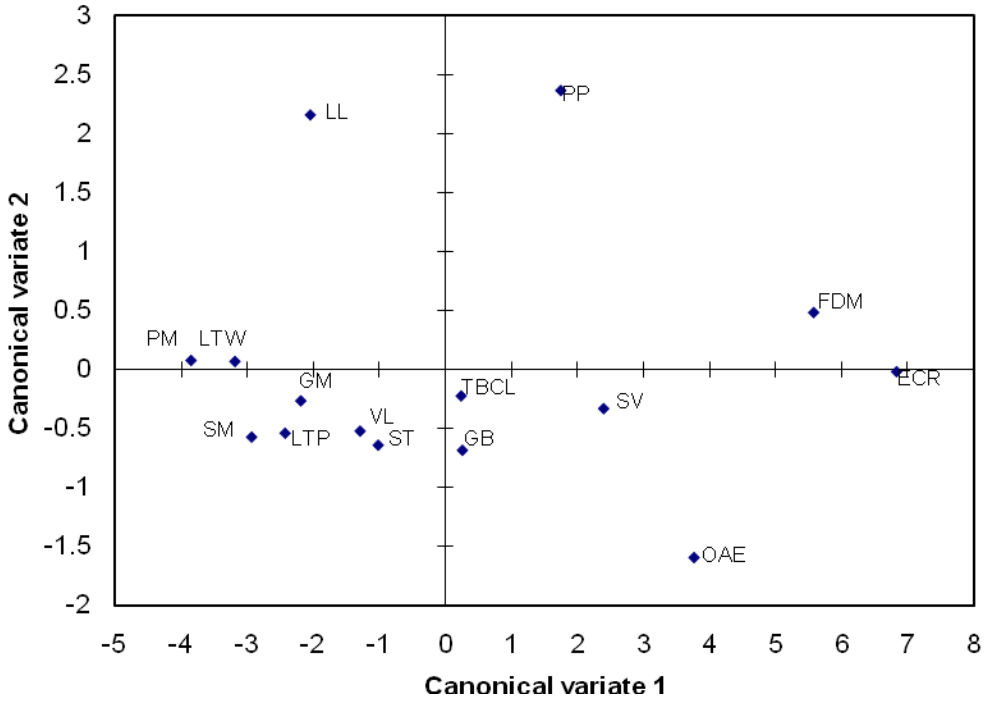

Figure 2: Plot of CV mean scores of various cuts

[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; ST – *M. semitendinosus*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis*

Closer inspection of the graphical presentation of the results shows that, as expected, the cuts cooked by a dry heat cooking method (fillet (PM), rump (GM), ST, prime rib (LTP), wing rib (LTW), topside (SM) and loin (LL)) were contrasted against the cuts cooked by a moist heat cooking method. The shins (ECR & FDM), chuck (SV) and to a lesser extent the GB and brisket (PP) showed the greatest contrast. The cuts cooked by a dry heat cooking method showed less drip loss and more evaporation loss, and gave a more pronounced impression of initial and sustained juiciness than the cuts cooked by a moist heat cooking method.

The difference in cooking losses was due to more moisture being lost when the cuts were surrounded by dry air (dry heat cooking method). The evaporation loss increased, and the loss of moisture when cooking by moist heat was captured, resulting in higher drip loss (moist heat cooking method) (McCrae & Paul, 1974). In studying the CV2 results, the shins, ST, fillet, prime rib, wing rib and loin were contrasted against the thick flank, chuck and GB; the former showed less total cooking loss. On the other hand, the cuts that were cooked by a dry heat cooking method, namely ST, fillet, prime rib, wing rib and loin were contrasted against topside and rump; the former showed the least amount of total cooking loss. Shins cooked according to a moist heat cooking method showed the least amount of total cooking loss, and the thick flank, chuck and GB the most. Spanier and Miller (1996) also described the differences between cuts. They found that different primal cuts react uniquely to heating because of the distinct fibre types, pH, relative fat deposition and intercellular components. Similar results were found by Luchak *et al*. (1998) and Rhee, Wheeler, Shackelford and Koohmaraie (2004).

The CVA mean scores for thawing and cooking losses of the various cuts in the three age groups combined are ranked in Table 4. No ANOVA or similar analysis was performed because the muscles had not been treated similarly. The GB, ST and fillet had the highest thawing losses, and the loin, topside and neck cuts the least. As expected, the cuts cooked according to a dry heat cooking method showed the highest percentage evaporation loss compared to the cuts cooked by a moist heat cooking method, which showed the highest percentage drip loss.

The rump cuts showed the highest percentage total cooking loss at 39,1%, and the shins the lowest at 21,5%. Differences in cooking losses among cuts are also reported by Browning *et al.* (1990) and Jeremiah

and Gibson (2003). The differences between cuts can be attributed to shape and size variations, the composition of the cuts, the spatial distribution of areas of lean meat, fat, connective tissue and bones, the characteristics of the meat surface, and any changes induced in the meat by heat, including protein denaturation, loss of water, ultimate pH and the melting of fat (Seideman & Durland, 1984).

The CVA mean scores for the sensory analysis characteristics of the various cuts in the three age groups are presented in Table 5. The panel described the PM as the muscle with the most intense aroma and flavour, as well as the juiciest (both initial and sustained). This result is contrary to popular belief (as noted

Table 4. Ranking of cuts according to % thawing and cooking losses.

Rank	Thawing loss	Evaporation loss	Drip loss	Total cooking loss
1	GB[1]	Rump	Chuck	Rump
	(5.04)	(28.43)	(31.45)	(39.11)
2	ST[2]	Topside	Thick flank	Thick flank
	(4.44)	(21.95)	(28.67)	(38.84)
3	Fillet	Fillet	GB	Topside
	(3.60)	(21.48)	(24.86)	(36.84)
4	Shoulder	Prime rib	Brisket	Chuck
	(3.37)	(20.16)	(22.92)	(34.09)
5	Rump	ST	Neck	Brisket
	(2.36)	(19.52)	(20.97)	(31.93)
6	Shins	Wing rib	Shins	GB
	(1.12)	(17.12)	(20.18)	(30.52)
7	Thick flank	Loin	Shoulder	Shoulder
	(1.05)	(15.52)	(19.04)	(30.08)
8	Chuck	Shoulder	Thin flank	Neck
	(1.03)	(11.04)	(16.89)	(30.08)
9	Prime rib	Thick flank	Topside	Fillet
	(0.74)	(10.17)	(14.89)	(27.10)
10	Brisket	Thin flank	Rump	Thin flank
	(0.72)	(9.90)	(10.69)	(26.83)
11	Thin flank	Neck	Loin	Prime rib
	(0.71)	(9.11)	(9.36)	(26.37)
12	Wing rib	Brisket	Wing rib	Wing rib
	(0.65)	(9.01)	(8.11)	(25.23)
13	Neck	GB	Prime rib	Loin

Rank	Thawing loss	Evaporation loss	Drip loss	Total cooking loss
	(0.45)	(5.66)	(6.21)	(24.81)
14	Topside	Chuck	Fillet	ST
	(0.38)	(2.64)	(5.62)	(24.41)
15	Loin	Shins	ST	Shins
	(0.24)	(1.27)	(4.94)	(21.46)

[1] Silverside: ST–*M.semitendinosus*..

[2] Silverside: GB – *M. gluteobiceps*

Table 5. Rating of muscles[1] according to sensory evaluation scores.

Rank	Aroma [2]	Flavour [2]	Initial [3] juiciness	Sustained [3] juiciness
1	PM	PM	PM	PM
	(6.27)	(6.24)	(6.22)	(6.03)
2	SM	BC	SV	SV
	(6.09)	(5.88)	(5.78)	(5.50)
3	VL	OAE	ST	LTW
	(6.08)	(5.84)	(5.78)	(5.33)
4	GB	TBCL	LTP	LTP
	(6.07)	(5.72)	(5.72)	(5.32)
5	GM	ST	GM	GM
	(5.96)	(5.66)	(5.72)	(5.30)
6	ST	LTW	GB	GB
	(5.93)	(5.66)	(5.65)	(5.24)
7	SV	GM	LL	ST
	(5.93)	(5.60)	(5.61)	(5.20)
8	ECR&FDM	VL	SM	OAE
	(5.91)	(5.60)	(5.58)	(5.16)
9	BC	SV	LTW	SM
	(5.81)	(5.57)	(5.58)	(5.14)
10	LTW	GB	OAC	VL
	(5.78)	(5.55)	(5.56)	(5.09)
11	TBCL	SM	VL	LL
	(5.78)	(5.50)	(5.55)	(5.07)
12	LL	LTP	TBCL	TBCL
	(5.68)	(5.44)	(5.54)	(5.04)
13	OAE	LL	BC	BC
	(5.62)	(5.43)	(5.21)	(4.83)
14	PP	PP	PP	PP

Rank	Aroma [2]	Flavour [2]	Initial [3] juiciness	Sustained [3] juiciness
	(5.59)	(5.22)	(4.52)	(4.03)
15	LTP	ECR&FDM	ECR&FDM	ECR&FDM
	(5.53)	(5.04)	(3.83)	(3.94)

[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; ST – *M. semitendinosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus;* ECR - *M.extensor carpi radialis* and FDM – *M.flexor digitorum medialis.alis.*

[2] 8 = Extremely intense 1 = extremely bland.

[3] 8 = Extremely juicy, 1 = extremely dry.

by Lawrie, 1979) that the PM is the most tender cut in the carcass but lacking in flavour. The ECR and FDM were the driest cuts and had the blandest flavour compared to all the other cuts. Mc Keith *et al.* (1985) ranked the PM as having the most and the PP the least desirable flavour, but one should consider the fact that higher flavour desirability as measured in their study may not necessarily indicate higher flavour intensity as measured in this study. Yet, Carmack *et al.* (1995) ranked the GB the highest in beef flavour intensity, with the PM second and not statistically different from the GB.

Although the flavour intensity of the PM in Carmack *et al*. (1995) coincided with the results of this study, the GB in this study had much lower flavour intensity. This could be because it had been cooked by using a moist heat cooking method. Scheeder and Langholz (1996) also reported a low ranking for flavour intensity in the GB, similar to the results of this study. The variability in flavour between different muscles can partly be explained by differences in their amino acid and dipeptides content, thus The differences in the flavour intensity between the different cuts could be explained by the different volatile compound profiles present (amino acid and dipeptide content) within each cut (Calkins & Hodgen, 2007). In their study Carmack *et al.* (1995) ranked the SV and PM as the juiciest cuts, and this result corresponded with the findings of this study. In general, the cuts cooked according to a moist heat cooking method ranked lower in initial and sustained juiciness, with the exception of the SV and the GB. Brady and Penfield (1982) also found that samples heated by a moist heat cooking method were judged to be drier ($p \leq 0,01$) than samples cooked in the oven.

Effect of age by cut

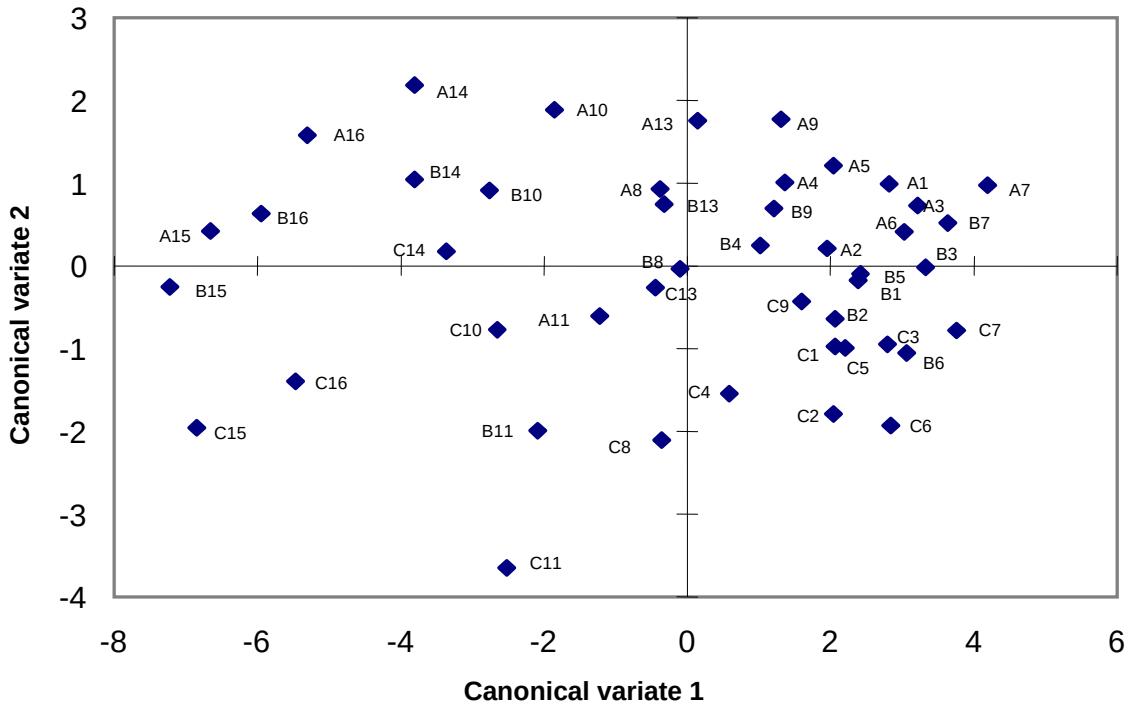

Figure 3: Plot of CV mean scores of age groups by cuts

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

[2] 1 – *M. longissimus thoracis (LTP)*; 2 – *M. longissimus lumborum (LL)*; 3 – *M. longissimus thoracis (LTW)*; 4 – *M. semitendinosus (ST)*; 5 – *M. gluteus medius (GM)*; 6 – *M. semimembranosus (SM)*; 7 – *M. psoas major (PM)*; 8 – *M. gluteobiceps (GB)*; 9 – *M. vastus lateralis (VL)*; 10 – *M. serratus ventralis (SV)*; 11 – *M. pectoralis profundus (PP)*; 12 – *M. biventer cervicis (BC)*; 13 – *M. triceps brachii caput longum (TBCL)*; 14 – *M. obliquus abdominis externus (OAE)*; 15 – *M. extensor carpi radialis (ECR)* and 16 – *M. flexor digitorumi medialis (FDM)*

The first two canonical variates (CV1 and CV2) accounted for 79,8% of the total variation in the data, with latent roots 12,4 and 3,4. The canonical variate means for drip loss were negative, and positive for all the other attributes. The discriminant attributes for the different cuts/muscles were evaporation loss (r = 0,977), drip loss (r = -0,710), initial juiciness (r = 0,647), and sustained juiciness (r = 0,525) that were similar to the findings on cuts alone. Similarly, total cooking loss (r = 0,821) was the main discriminant in CV2. The CV mean scores are presented in Figure 3. The fact that all three age groups are neatly grouped together for each cut/muscle indicated that the differences between cuts were much more discriminating than for age (indicated by the latent root < 1).

Table 6. Correlation coefficient (r) of aroma, flavour and juiciness related characteristics of muscle with age as independent variable.

Muscle [1]	Dependent Variables			
	Aroma [2]	Flavour [2]	Initial juiciness[3]	Sustained juiciness [3]
LTP	-0.442**	-0.146	-0.174	0.045
LL	0.118	0.199	0.053	0.132
LTW	0.144	-0.003	-0.107	-0.070
ST	-0.121	-0.016	0.148	0.243
GM	-0.032	-0.051	-0.078	-0.020
SM	-0.143	-0.120	-0.040	0.180
PM	0.081	0.273*	0.070	0.184
GB	-0.102	-0.251	0.065	0.205
VL	-0.193	-0.393*	-0.228	-0.035
SV	-0.002	-0.247	0.109	0.145
PP	-0.108	-0.437*	-0.430*	-0.426*
BC	-0.504**	-0.200	-0.275	-0.265
TBCL	-0.037	-0.036	-0.537**	-0.521**
OAE	0.246*	0.060	0.214	0.343
ECR	-0.235	-0.219	-0.051	-0.090
FDM	-0.290	-0.295	-0.069	-0.142

* = $p \leq 0.05$; ** = $p \leq 0.01$; *** = $p \leq 0.001$.

[1] Note that thawing, evaporation, drip and total cooking loss analyses were performed on the cuts and aroma and initial juiciness were performed on the muscles; LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; ST – *M. semitendinosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis*.

[2] 8 = Extremely intense, 1 = extremely bland.

[3] 8 = Extremely juicy, 1 = extremely dry.

Correlation between juiciness, aroma and flavour

Correlation of age with juiciness, aroma and flavour

In the previous section it was shown that the aroma, flavour and juiciness of beef carcass muscles were closely and significantly ($p \leq 0,05$) related to animal age. A correlation matrix was constructed to determine whether these relationships were linear and this is summarised in Table 6. With one or two

exceptions per attribute, the characteristics evaluated by the taste panel for the various muscles showed low linear correlation with the age of the animal.

Table 7. Correlation coefficient (r) of thawing and cooking losses, initial juiciness and aroma of muscles/cuts with sustained juiciness as independent variable.

Muscle[1]	Dependent variables					
	Thawing loss[2]	Evaporation loss[2]	Drip loss[2]	Total cooking loss[2]	Aroma[3]	Initial juiciness[4]
LTP	-0.362*	-0.230	0.185	0.011	0.108	0.837***
LL	-0.202	-0.384*	-0.070	-0.445**	0.043	0.921***
LTW	-0.224	-0.569**	0.155	-0.104	0.036	0.805***
ST	-0.241	-0.128	0.292	0.009	-0.203	0.929***
GM	0.074	-0.506***	0.011**	-0.265	-0.149	0.943***
SM	-0.000	-0.005	-0.044	-0.063	-0.025	0.814***
PM	-0.076	-0.158	-0.287	-0.329*	0.013	0.917***
GB	-0.321*	0.061	-0.022	0.027	-0.624***	0.723***
VL	-0.266	-0.158	-0.232	-0.464**	-0.083	0.820***
SV	0.037	0.153	-0.091	-0.029	0.412*	0.825***
PP	0.034	0.075	-0.271	-0.239	-0.045	0.880***
BC	0.051	0.061	-0.467*	-0.512**	0.088	0.864***
TBCL	-0.222	-0.507**	0.066	-0.570**	0.111	0.900***
OAE	0.009	-0.270	0.099	-0.161	0.195	0.828***
ECR&FDM	-0.091	-0.096	-0.029	-0.050	0.154	0.892***

[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; ST – *M. semitendinosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis.*

[2] 8 Percentage (%)

[3] 8 = Extremely intense, 1 = extremely bland.

[4] 8 = Extremely juicy, 1 = extremely dry.

Table 8. Correlation coefficient (r) of aroma and juiciness of muscles with flavour as independent variable.

Muscle[1]	Dependent variables		
	Aroma [2]	Initial juiciness [3]	Sustained juiciness [3]
LTP	0.402**	0.317*	0.276
LL	0.284	0.053	0.105
LTW	-0.070	0.221	0.224
ST	0.103	0.419**	0.344*
GM	-0.022	0.651***	0.641***
SM	0.173	0.174	0.150
PM	-0.105	0.128	0.162
GB	-0.161	0.356*	0.211
VL	0.169	0.013	-0.049
SV	-0.189	-0.019	0.016
PP	0.264	0.492**	0.533**
BC	0.118	0.203	0.418*
TBCL	0.112	0.438*	0.519**
OAE	0.103	0.275	0.408*
ECR&FDM	0.218	0.532**	0.529**

[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; ST – *M. semitendinosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis.*

[2] 8 = Extremely intense, 1 = extremely bland.

[3] 8 = Extremely juicy, 1 = extremely dry.

A correlation matrix was constructed, summarised in Table 7, with sustained juiciness as an independent variable. Initial juiciness showed a constant highly significant correlation ($p \leq 0{,}001$) of between $r = 0{,}723$ in the GB and $r = 0{,}943$ in the GM with sustained juiciness, implying mutual dependency (Cross *et al*., 1973a). In this study aroma showed insignificant correlation with sustained juiciness, with the exception of the GB ($r = -0{,}624$ with $p \leq 0{,}001$) and the SV (with $r = 0{,}412$ and $p \leq 0{,}05$).

Only two significant ($p \leq 0{,}05$) correlations (Table 7) were found between thawing loss and sustained juiciness, namely LTP ($r = -0{,}362$) and GB ($r = -0{,}321$). For evaporation loss, the LTW ($r = -0{,}569$ with $p \leq 0{,}01$), the TBCL ($r = -0{,}507$ with $p \leq 0{,}01$), the GB ($r = -0{,}506$ with $p \leq 0{,}001$) and the LL ($r = -0{,}384$

with $p \leq 0,05$) correlated with sustained juiciness. For drip loss only the BC ($r = -0,467$ with $p \leq 0,05$) and the GM ($r = 0,392$ with $p \leq 0,01$) correlated with sustained juiciness. Regarding total cooking loss the TBCL ($r = -0,570$ with $p \leq 0,01$), the BC ($r = -0,512$ with $p \leq 0,01$), the VL ($r = -0,464$ with $p \leq 0,01$), the LL ($r = -0,445$ with $p \leq 0,01$) and the PM ($r = -0,329$ with $p \leq 0,05$) correlated with juiciness.

Although Bouton *et al.* (1975a) reported low correlation between cooking loss and juiciness; they explained it by means of temperature distribution that varies in samples prepared according to conventional methods. However, Bouton *et al.* (1975b) and Brady and Penfield (1982) reported highly significant ($p \leq 0,001$) correlation between cooking loss and juiciness. With the exception of the LTP ($r = 0,402$ with $p \leq 0,01$) aroma intensity showed a low linear correlation with flavour intensity (Table 8), suggesting independence of the two attributes. Initial juiciness and sustained juiciness correlated significantly ($p \leq 0,05$) with flavour in eight of the 16 muscles that were studied. According to Bouton *et al.* (1975a), flavour changes in cooked meat could well increase salivation and hence apparent juiciness, although these changes would be highly subjective and probably impossible to assess objectively.

CONCLUSIONS AND RECOMMENDATIONS

The South African carcass classification system differentiates carcasses based on fatness and on age group. Due to the design of the project, which included a similar fat range in each age group, and the fact that the percentage chemical fat of the carcass was used as a covariant to adjust for differences between initial fat, the results were meaningful to describe the effect of age alone on cooking loss, juiciness and flavour of beef. Flavour intensity was the main discriminant between the three age groups and it declined with age. This finding was probably due to changes in the amino acid, protein and nucleotide metabolism (Smulders *et al.*, 1991), as well as possible differences in ultimate pH (Yancey, Dikeman, Hachmeister, Chambers IV & Milliken, 2005). Total cooking loss increased with increased age of the animal, suggesting increased denaturation of protein with age, or increased cross-linking of collagen with age, resulting in decreased water-holding capacity with increased moisture loss upon heating or cooking. According to the CVA results, the aroma and flavour decreased with increased age. In general the initial impression of juiciness

decreased with increased age and sustained juiciness increased (although not linearly) with age, irrespective of the muscle. The decrease in initial juiciness with increased animal age could be attributed to the inability of the muscle to retain water with increased age. This in turn results in higher cooking losses in cuts from older animals, with an associated drier end-product, without the rapid release of meat fluid during the first few chews as found in meat from young animals. The result that sustained juiciness increased with increased age in some muscles, may be explained by the fact that more mastication would be required for samples from older animals due to increased cross-linking of the collagen with increased age. Therefore, more saliva is released, increasing the perceived sustained juiciness. This finding that initial juiciness decreased with increased animal age and that sustained juiciness generally increased with increased animal age should be further investigated. As young animals (Age A) are mostly grain fed in feeding pins in South Africa, older animals (Age B) are mostly grass fed and old animal (Age C) are almost exclusively grass fed, the effect of feed on cooking loss, juiciness and flavour could also be considered a reason for differences between cuts from the different age groups. The results from this study, as part of a greater beef composition study, formed the backbone of the South African carcass classification system and a recommendation was made based on these results that an additional age group, namely age AB animals (young animals which are mostly grass fed) should be introduced.

The cuts cooked by a dry heat cooking method were juicier (both initial and sustained) according to the CVA than those cooked by a moist heat cooking method. The PM was not only the juiciest muscle but also had the most intense aroma and flavour compared to all the other muscles. The ECR and FDM were the least juicy and had the least intense flavour, despite the fact that they were cooked using a moist heat cooking method.

In conclusion, it is recommended that when sets of cuts exhibit similar traits, analysis of only one of these cuts would be sufficient to describe the responses of all the cuts in the set. It is not necessary to differentiate between the FDM and the ECR cooked as 5 cm thick beef retail cuts. The LTW or the LTP alone would be sufficient to describe cuts cooked as intact joints by a dry heat cooking method, and either the GB or the BC would describe the group subjected to a moist heat cooking method in a similar manner. The SV, GM, VL and SM were not included in these groupings. This implied that the 16 cuts could be adequately described by seven cuts in terms of juiciness and flavour-related characteristics, which means a

great saving in costs and time. These groups were more clearly defined by the CVA than by traditional statistical methods such as the PCA and, together with ANOVA analyses, explained more subtle differences. Correlation coefficients could not effectively describe the true groupings of similar cuts.

ACKNOWLEDGEMENTS

This study formed part of a PhD at the University of Pretoria, under the capable leadership of Dr Raymand Naude and Prof Elizebeth Boshoff. The authors would also like to express their gratitude to Ms J M van Niekerk, Ms R E Visser and Ms S M van Heerden for their continued assistance during the project. To Ms H Meyer for the chemical analysis and to Ms M F Smith and Ms E van der Berg for the statistical analyses.

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