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SEASONAL VARIATION IN VENISON QUALITY OF MATURE FARMED RED DEER STAGS IN NEW ZEALAND.

J. M. Stevenson, D. L. Seman[1] and R. P. Littlejohn

Invermay Agricultural Centre, Mosgiel, New Zealand

ABSTRACT

We report on two experiments each with ten sexually mature red deer (Cervus elaphus) stags of which five were slaughtered immediately preceding the rut (autumn) and five after the rut in each experiment. Striploin (M. longissimus = LD) and topside (M. semimembranosus = SM; Exp. 2 only) muscles were removed and analysed for meat quality (yield, colour, palatability and composition). Stags slaughtered post-rut had 25 to 30 % lower carcass weights than those slaughtered pre-rut. Average GR measurements (tissue depth, indicator of fat thickness) were approximately 31 mm pre-rut compared to 3 to 7 mm post-rut. Individual muscles as well as the butcher cuts (which included subcutaneous and intermuscular fat) were heavier pre-rut. There were significant decreases in intramuscular fat, protein and water content over the rut, although the water to protein ratio tended to increase. Pre-rut LD had the highest fat content (2.6%) followed by pre-rut SM (1.4%). Post-rut LD and SM had 0.4% and 0.8% fat content respectively. Post-rut LD steaks appeared brighter and(or) fresher than the other groups and colour acceptability was negatively correlated ($P<.05$) with fat content. Pre-rut steaks from both muscles were found to be more tender than post-rut. Flavour intensity did not appear to be symptomatic of percentage fat

[1]Present address: Oscar Mayer Foods Corp., P.O. Box 7188, Madison, WI 53707.

content and did not vary consistently over the rut. Taste panel ratings for overall desirability were highly related to tenderness, more so than to juiciness or flavour. The lower tenderness scores post-rut may have been due to the difference in fat content and(or) differences in the amount and solubility of collagen resulting from the marked differences in growth rate prior to slaughter.

(Key Words: Venison, Seasonality, Quality, Palatability, Collagen, Growth Rate.)

Introduction

Venison from farmed deer (mainly red deer, Cervus elaphus) in New Zealand is an economically significant export product. The industry is in a phase of rapid expansion where production is expected to increase from c. 3,500 tonnes, earning NZ$32M in 1988, to more than 20,000 tonnes by 1995 (Drew, 1989). Venison is exported as a top quality gourmet food item and with the growth in health consciousness in today's society and concern at fat content in red meats, consumers are interested in the nutrient content of venison as a source of lean meat. Increasing numbers of American farmers are turning to deer production as they recognise the potential economic benefits of farming them and the appeal of venison as a low-calorie, low-cholesterol meat. Along with traditional wild shot game, it is a part of the diet of many people.

Drew & Seman (1987), Marchello et al. (1985) and Miller et al. (1986) have reported data on the nutrient content of venison from red deer, whitetail deer and mule deer, respectively, slaughtered at one particular season of the year, and have reported intramuscular fat contents of 1 to 2%. However, red deer, particularly stags, exhibit a very marked seasonal pattern of feed intake and live weight change, even when fed ad libitum on high quality rations (Fennessy, 1982). Feed intake increases in spring and reaches a peak in summer. During this time stags gain considerable weight, attaining peak condition in late summer prior to the breeding season or rut. At the rut stags reduce feed intake and lose a

considerable amount of weight, even when not used for breeding. After the rut, their intake increases so that, with ad libitum feeding, it is generally possible to maintain their post-rut live weight over the winter. Previous reports have attributed variations in fat content of venison to diet and geographical location (Buege and Nitzke, 1987), but little mention has been made of seasonal influences where deer can undergo 25% weight loss and lose more than 80% of body energy in 6 weeks (Drew, 1985).

The objectives of this study were to examine meat from mature farmed red deer stags pre- and post-rut to determine whether any variation was apparent in meat quality (yield, composition, appearance and palatability) due to seasonality.

Experimental Procedure

Animals and Slaughter Procedure. Five sexually mature red deer (Cervus elaphus) stags were slaughtered before the breeding season or rut and five two months after the rut in each of two consecutive years. All animals were from the same farm and in good condition pre-rut. In the first year (Exp. 1) 9 year old stags were killed and in the second year (Exp. 2) 5 and 6 year old stags were killed. In both experiments the animals were dressed using standard procedures. In addition the animals in Exp. 2 were electrically stimulated (45 volts, 90 sec) immediately after exsanguination. However, it was found that the electrical stimulation unit was malfunctioning after the conclusion of Exp. 2, and may have been doing so during Exp. 2.

Hot carcass weights were recorded approximately 60 mins post-mortem. The carcasses were then placed in a chiller, which was kept at 10°C for 4 hours then lowered to 0°C; cold carcass weights were recorded 24 hours later. The GR measurement (tissue depth over the 12th rib, 16 cm out from the backbone, which is the standard indicator of carcass fatness in New Zealand), was taken 24 hours

after slaughter. At the same time the M. longissimus (LD) muscle was removed from the saddle (striploin or ribeye) in both experiments and the M. semimembranosus (SM) muscle was removed from the leg (topside or toproud) in Exp. 2 only. All extraneous fat and tissue (mainly connective tissue) was removed from the individual muscles.

Storage treatment. The muscles were stored frozen (-25°C) until analysis (3 to 4 months for the pre-rut samples and 1 to 2 months for the post-rut samples). The frozen muscles were cut by band-saw into separate portions for each evaluation (composition, colour, sensory, tenderometer & Warner-Bratzler shear) and remained frozen until their respective analyses.

Composition analysis. Muscle samples for chemical composition analyses were minced (4mm plate) using a table top mincer (Bauknecht) and analysed for water, ether-extractable lipid (referred to as fat content), protein (N x 6.25) and ash (referred to as mineral content) by AOAC (1965) methods.

The percentage of heat soluble collagen was determined on one gram samples of freeze dried muscle (chopped with a Thompson mill) by the method of Hill (1966). Residue samples (insoluble collagen) were hydrolysed by refluxing at 115°C for 16 hours using 6 M HCl. Supernatants (heat soluble collagen) were hydrolysed by heating in an oven (115°C) for 16 hours in 6 M HCl. After adjusting the pH to 8.0 $\pm$ 0.2, hydrolysed samples were decolored by adding 2 ml of a 3% (w/v) activated charcoal in distilled water to the hydrolysates prior to filtering. Hydroxyproline content of both the residues and supernatants was determined according to the method of Bergman and Loxley (1963) modified by Egan et al. (1987). Hydroxyproline was converted to mass (mg) collagen by multiplying the hydroxyproline content of the residues by 7.25 and of the supernatants by 7.52 (Cross et al. 1973).

Color evaluation. (Exp. 2 only) Muscle samples for color evaluation were cut into two 2.5 cm thick steaks after thawing (4°C) overnight. These were

placed on white polystyrene trays with the freshly cut face uppermost, wrapped with polyvinylchloride (PVC) film (oxygen transmission rate of 1100 ml m^{-2} 24 h^{-1} at 20°C and 0% RH) and placed in a refrigerated display case.

Meat color was assessed by a trained panel of 20 staff who viewed the samples in the display case under cool white fluorescent lighting (1800 lux). Color was rated on a scale of 1 to 5 (1 = Extremely dark or brown, 2 = Moderately dark or brown, 3 = Slightly dark or brown, 4 = Bright venison color, 5 = Bright fresh venison color).. The panellists also rated acceptability on a scale of 1 to 3 (1 = Would not purchase, 2 = Purchase with reservation, 3 = Purchase without reservation). Objective measurements were made with a HunterLab LabScan 6000 spectrocolorimeter (Hunter Associates Laboratory Inc.) with 0°/45° geometry - specular component excluded. The cut surface of the wrapped samples was placed over a 25 mm open port with a 20 mm illuminated area. Readings were made at 10 locations on the cut surface of each slice and the L^*, a^*, and b^* values recorded for Standard Source C and the CIE 10° Standard Observer. From these, CIE 1976 a, b chroma and hue-angle were calculated (Hunter & Harold, 1987).

Sensory evaluation. In Experiment 1 the muscles were evaluated using Triangle Tests by two separate sensory panels, an experienced panel of 7 who were familiar at evaluating food samples but not trained specifically for meat, and an inexperienced consumer panel of 14. Each panellist assessed tenderness and flavour on a scale of 1 to 8 (Table 1).

In Experiment 2 the muscles were evaluated by a trained panel of 12 who were selected on their ability to evaluate tenderness and flavour. The sensory traits evaluated by the trained panel were tenderness, flavour intensity, juiciness and overall desirability, assessed on a scale of 1 to 8 (Table 1).

For both experiments, two 2.5 cm thick steaks were cut from each muscle (thawed at 4°C overnight) and cooked in a Luke Sterlec broiler to an internal

temperature of 65°C (approx. 7 to 8 mins first side, 5 mins second) according to the methods of Cross et al. (1978). The steaks were weighed before placing under the grill and immediately after removal and cooking losses were calculated. Meat samples (cubes 1.5 cm x 1.5 cm cross section) were served warm to each panellist under red lights in paper cups coded with a 3 digit random number following the guidelines of the New Zealand Institute of Food Science and Technology (1985) and the American Meat Science Association (1978). The samples were presented in a random order with water and wedges of apple as palate cleansers between samples (Table 1).

Shear force measurement. Two 2.5 cm thick slices were cut from each thawed muscle and cooked in a plastic bag immersed in a water bath at 80°C for 60 minutes (standard MIRINZ Tenderometer cooking procedure). The steaks were allowed to cool, wrapped in aluminium foil and refrigerated overnight (2 to 4°C). Ten sections (1.3 cm X 1.3 cm cross section) from each pair of steaks from Exp. 1 were cut parallel to the muscle fibres and sheared using a Warner-Bratzler shear apparatus and ten sections (1.0 cm x 1.0 cm cross section) using a MIRINZ Tenderometer (Frazerhurst & Macfarlane, 1983). Fifteen sections (1.0 cm x 1.0 cm cross section) from each pair of steaks from Exp. 2 were cut parallel to the muscle fibres and sheared using a MIRINZ Tenderometer.

Statistical analysis. All data from each experiment were analysed using analysis of variance, with muscle type as a split plot treatment with stags as the main plot where appropriate, fitting the effect of rut group, and its interaction with muscle type where appropriate. The exception to this was the data from the sensory panels in Exp. 1 which were analysed using a one-tailed paired comparison test (Roessler et al., 1978).

Relationships between observed variables were assessed using correlations, calculated on animal or muscle means, as appropriate. Statistical significance was assessed at the 5% level, except where othewise stated.

Results

Carcass traits. Mean carcass weight, GR measurement and muscle weight, were all greater for pre-rut stags than for post-rut stags (Table 2). The 25 to 27mm decline in GR between pre- and post-rut stags indicates a major loss of subcutaneous fat. The pre-rut cuts had considerable amounts of fat cover (subcutaneous fat) with the pre-rut striploin having approximately 3 times more trimmable material than that post-rut. .

Muscle composition. Table 3 presents the chemical composition data for the trimmed muscles. Post-rut fat content was about 12% of the pre-rut content in the LD and 50% in the SM. There was also a significant decrease in protein content in both muscles and a significant decrease in water content in the LD. There were increases in the water:protein ratio similar to that found by Drew (1985) in all 3 cases, but only LD in Exp. 2 was significant.

Muscle color (Exp. 2). Mean color scores are shown in Table 4. The trained color panel found that the post-rut LD steaks had a significantly brighter, fresher appearance and greater acceptability than the pre-rut steaks, but found no difference in the SM steaks between rut groups. The post-rut LD muscles rated bright fresh red whereas the pre-rut LD muscles and the SM muscles rated as no longer being bright (halfway between bright and slightly dark or brown). Many of the panellists commented that increased visual fat in the pre-rut LD samples "dulled" the color. In the SM muscles there was a connective tissue network present which appeared to cause the lower ratings. There were moderate correlations between color and acceptability scores with chemical fat content ($r = 0.41$ and 0.49 respectively). Color and acceptability scores were highly correlated ($r = 0.92$).

L^*, a^*, b^* and chroma values did not change significantly over the rut but the SM's had lower L^*, a^*, b^* and chroma values after the rut than before. The

hue-angle values decreased significantly over the rut in the LD's but not in the SM's. Only hue-angle values were significantly correlated with panel color and acceptability scores (r = -0.52 and -0.68 respectively).

Sensory evaluation and shear force measurements. The sensory panels which assessed the Exp. 1 samples (Table 5) found that the post-rut samples were slightly less tender and were less flavoursome than the pre-rut samples. Of the 28 assessments made by the consumer panel for flavour and tenderness, 24 and 19 rated pre-rut samples as having greater flavour intensity and greater tenderness respectively ($p<0.05$). Of the 14 assessments made by the experienced panel for flavour and tenderness, 10 rated pre-rut samples as having greater flavour intensity and 10 greater tenderness ($p<0.05$). The Warner-Bratzler and Tenderometer measurements were not significantly different pre-rut from post-rut. There was a significant correlation (r = 0.94) between the two methods for assessing shear force.

The results from the sensory evaluation and tenderometer measurements for Exp. 2 are shown in Table 6. Pre-rut samples also had greater flavour intensity and greater overall desirability ($P<0.05$). Mean tenderness scored by the trained sensory panel was higher ($P<0.05$) before the rut than after it, while tenderometer score was in the same direction, but did not achieve significance. LD's were significantly more tender than SM's and also had greater flavour intensity, less cooking loss and greater desirability. There was no evidence of a muscle type by rut group interaction for any of these measurements.

Correlation of sensory scores with fat content. The flavour scores from the consumer panel which evaluated the LD's in Exp. 1 were significantly correlated with the muscle fat content (r = 0.86), but the flavour scores evaluated by the trained panel in Exp. 2 were not (Table 7). Tenderness, juiciness and desirability were highly correlated with each other for both the LD and SM, and moderately highly correlated with flavour for the SM but not for the LD. The tenderness

scores from the consumer panel which evaluated the LD's in Exp. 1 were not significantly correlated with the muscle fat content (r = -0.08) or GR measurement (r = -0.13), whereas the tenderness scores from the LD's evaluated by the trained panel in Exp. 2 were.

Collagen measurements. The percent of soluble collagen in the LD was significantly greater pre-rut than post-rut (Table 8), but the difference for the SM was not significant. There were no other significant differences between pre-rut and post-rut for either muscle (Table 8). None of the collagen parameters measured were significantly correlated to tenderometer scores but the insoluble collagen contents were significantly negatively correlated to sensory panel tenderness ratings for both muscles (Table 9).

Discussion

Although total carcass composition was not determined in this study, Drew (1985) found that pre- and post-rut mature red deer stags of 120 kg and 87 kg carcass weights respectively had total carcass fat content of 20.8 and 1.3% respectively. Results from the present work and that of Drew (1985) indicate that carcass weight losses of 25 to 30% of pre-rut weight can be expected during the rut. The decline in GR in the present study, indicating a major loss of subcutaneous fat, is in agreement with the observations of Wallace and Davies (1985), who found that while total fat content declined from 19.0 to 5.2% between pre- and post-rut, subcutaneous fat was the major fat depot contributing to this. Jopson and Fennessy (1990) reported that in years in which nutrition is adequate the loss in liveweight associated with the rut is predominantly due to fat catabolism. However, if stags have stored insufficient energy as fat prior to the rut they are forced to catabolise protein to a far greater extent in order to survive the period of low food intake associated with the rut. The animals in our study were in very good condition prior to the rut and the loss in muscle weight was

predominantly due to fat loss although there was also some protein loss, indicating catabolic mechanisms as suggested by Jopson and Fennessy (1990).

The loss of intramuscular fat in post-rut steaks compared to pre-rut steaks, particularly in the LD's, was associated with a superior visual appearance, but lower flavour desirability and tenderness scores. The pre-rut steaks had a comparable marbling appearance to the USDA Modest degree (USDA, 1988) and were considerably leaner at less than 3% fat than USDA Choice grade raw, trimmed lean beef at 6.9% fat (USDA, 1986). Our figures for fat and protein content are similar to those found in whitetail and mule deer by Marchello et al. (1985) and Miller et al. (1986). Blumer (1963) found that only about 5 and 10% of the variation in tenderness and juiciness, respectively could be accounted for by marbling (intramuscular fat) levels. Work by Jost et al. (1987) indicated that a 16-unit increase in marbling score (scale of 1 to 27) would be needed to improve taste panel tenderness by 1 unit (scale of 1 to 8) in beef. This was similar to results of Grouse et al. (1978) which indicated an increase of 30 units in marbling (same scale as above) was required to improve taste panel tenderness by 1 unit. After an extensive literature review, Parrish (1981) concluded that marbling usually is positively and significantly related to palatability, but only low in magnitude. Research indicates that animal age (Tuma et al., 1962; Blumer, 1963), post mortem carcass treatment (Tuma et al., 1962; Blumer 1963; Hostetler et al., 1970; Parrish et al., 1973 Marsh, 1983) and cooking method and degree of cooking (Cover et al, 1956; Blumer, 1963; Parrish et al., 1969; Parrish, 1981) may have more influence on palatability traits of meat than marbling. In view of the possible malfunctioning of the electrical stimulation unit, the carcasses may have undergone cold-shortening or cold-toughening on being subjected to severely cold temperatures too soon after slaughter. Subsequent work with animals of similar ages which were electrically stimulated has given much more tender meat with lower force scores (J. M. Stevenson, unpublished data).

Large quantities of fat have been found to insulate carcasses and slow post-mortem chilling, which in turn improves tenderness by lessening the extent of cold-induced shortening and/or enhancing post-mortem muscle breakdown (Smith et al., 1974; Lochner et al., 1980; March et al., 1981), and therefore the pre-rut carcasses would have been more affected than the post-rut carcasses. In a review of the influence of nutrition on tenderness, Tatum (1981) concluded that there is a substantial amount of evidence which suggests that pre-slaughter nutrition has a pronounced effect on meat tenderness, although rather than directly influencing various intrinsic properties of postmortem muscle, the bulk of data suggests that intensive feeding improves tenderness by increasing carcass weight and fatness, thereby reducing the susceptibility of the carcass to rapid postmortem chilling and cold-induced toughening. Subcutaneous fat thickness of 7.6 to 12.7 mm (Merkel and Pearson, 1975; Bowling et al., 1977; Bowling et al., 1978; Dolzeal, 1980) in cattle appear to provide maximal protection against rapid postmortem chilling and cold-induced toughening. In the present work, fat cover in the pre-rut animals was higher than this but this was not the case in the post-rut. It is possible in this study that the animals in Exp. 2 suffered cold-toughening and the effect was greater in the animals with less fat cover (post-rut) and more evident in the exposed LD than the SM. Recent evidence has also shown the pre-slaughter feeding regimen may influence directly various properties of postmortem muscle (Aberle et al., 1981). Relationships between pre-slaughter feeding regimen, growth rate and tenderness of beef suggest that growth rate has a direct effect on the physical properties of meat. Cattle fed high-energy diets before slaughter grow more rapidly and may have increased rates of protein turnover, which, in turn, may affect collagen solubility and(or) myofibril fragmentation (Aberle et al., 1981; Wu et al., 1981; Hall and Hunt, 1982; Miller et al., 1983). Fishell et al. (1985) identified tenderness variations in beef from different growth rates that were independent of those caused by different carcass-chilling rates. Bowling et al.

(1977), Aberle et al. (1981) and Fishell et al. (1985) found that cattle from restricted growth rates had lower tenderness ratings and Aberle et al. (1981) hypothesizes that the increased tenderness could be due to more rapid growth rate and increased protein turnover before slaughter. Fishell et al. (1985) found that lower tenderness scores of SM from restricted feed animals were associated with lower percentage soluble collagen and slightly higher total collagen. Aberle et al. (1981) and Wu et al. (1981) reported similar results, but Hall and Hunt (1982) found dietary regimen had little effect on amounts of total collagen or collagen solubility, even though the amount and solubility was related to tenderness as in the previous studies. Results of this study suggest that the dramatic weight loss during the rut in red deer may have a minor effect on collagen solubility which leads to decreased tenderness, but this requires further investigation into the effects of restricted pre-rut growth rates and the effects on collagen and fatness.

Conclusions

This work illustrates that massive declines in carcass weight and fatness occur over the rut which lead to a toughnening effect in post-rut animals. It is unlikely that the decreased fat content of post-rut animals would be regarded as sufficiently desirable to compensate for their loss in tenderness and total carcass yield especially since pre-rut meat is still very lean. However, if slaughter immediately post-rut is deemed desirable, further research needs to be done into ways of enhancing tenderness of post-rut meat, e.g., by avoiding cold-shortening or cold-toughening by effective use of electrical stimulation or delayed chilling.

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TABLE 1: SENSORY EVALUATION SCALES

ATTRIBUTE	Tenderness	Flavour	Juciness	Desirability
RATING				
1	Extremely Tough	Extremely Bland	Extremely Dry	Extremely Undesirable
2	Very Tough	Very Bland	Very Dry	Very Undesirable
3	Moderately Tough	Moderately Bland	Moderately Dry	Moderately Undesirable
4	Slightly Tough	Slightly Bland	Slightly Dry	Slightly Undesirable
5	Extremely Tender	Extremely Strong/Intense	Extremely Juicy	Extremely Desirable
6	Very Tender	Very Strong/Intense	Very Juicy	Very Desirable
7	Moderately Tender	Moderately Strong/Intense	Moderately Juicy	Moderately Desirable
8	Slightly Tender	Slightly Strong/Intense	Slightly Juicy	Slightly Desirable

TABLE 2: CARCASS AND MUSCLE MEASUREMENTS (MEANS FOR EACH AGE GROUP)

	Exp.	Animal Age (years)	Pre-rut	Post-rut	S.E.D.
Hot carcass weight (kg)	1	9	127.9	95.6	6.6
	2	5-6	122.4	85.0	6.3
Cold carcass weight (kg)	1	9	124.7	93.2	6.5
	2	5-6	119.9	82.9	6.1
GR measurement (mm)	1	9	31.2	6.6	2.2
	2	5-6	31.1	3.8	0.6
M. longissimus (kg)	1	9	2.98	2.49	0.16
Striploin* (kg)	2	5-6	4.33	2.50	0.24
M. longissimus (kg)	2	5-6	2.53	1.94	0.16
Topside* (kg)	2	5-6	1.84	1.55	0.10
M. semimembranosus (kg)	2	5-6	1.72	1.47	0.09

* The striploin and topside weights include extraneous tissue and fat.

TABLE 3: WEIGHTS OF MUSCLE COMPONENTS (g)

	Pre-rut	Post-rut	S.E.D.
Exp. 1			
M. longissimus (LD)			
Protein	703	586	54
Fat	79	10	8
Water	2149	1859	83
Ash	46	39	3
Water:protein ratio	3.05	3.17	0.071
Exp. 2			
M. longissimus (LD)			
Protein	602	455	30
Fat	65	8	8
Water	1826	1434	96
Ash	26	19	2
Water:protein ratio	3.03	3.15	0.041
M. semimembranosus (SM)			
Protein	397	335	30
Fat	24	12	8
Water	1273	1102	96
Ash	22	19	2
Water:protein ratio	3.21	3.28	0.043

ABLE 4 (EXP. 2): MEAN PANEL COLOUR AND ACCEPTABILITY SCORES, AND CIE (1976) L^*, A^*, B^*, CHROMA AND HUE-ANGLE VALUES FOR PRE- AND POST-RUT MUSCLES FROM 5 & 6 YEAR OLD RED DEER STAGS.

	LD		SM		S.E.D.
	Pre-rut	Post-rut	Pre-rut	Post-rut	
PANEL					
Colour	3.57	4.21	3.50	3.55	0.17
Acceptability	2.33	2.80	2.28	2.33	0.10
HUNTER LABSCAN					
L^*	29.43	26.94	26.68	25.79	1.28
a^*	13.48	14.35	15.10	13.77	0.51[a]
b^*	12.98	12.27	14.53	13.39	0.80
chroma	18.72	18.90	20.98	19.07	0.85
hue-angle	43.89	40.45	43.83	44.12	1.09

[a] except when comparing means within the same level of rut where S.E.D. = 0.45

TABLE 5: MEAN SENSORY PANEL SCORES AND TENDEROMETER FORCE SCORES FOR 9 YEAR OLD RED DEER STAGS (EXP. 1).

	Pre-rut	Post-rut	S.E.D.
Consumer panel			
Tenderness	5.7	5.0	0.29
Flavour intensity	5.2	4.7	0.18
Experienced panel			
Tenderness	4.7	4.3	0.18
Flavour intensity	4.9	4.1	0.16
Tenderometer (kgF)	4.01	5.92	0.74
Warner-Bratzler (kg F)	4.03	5.17	0.74

TABLE 6: MEAN SENSORY PANEL SCORES USING AN EXPERIENCED 2 PERSON TRAINED PANEL, COOKING LOSS AND TENDEROMETER FORCE SCORES FOR MUSCLE AND RUT TREATMENTS FOR 5 & 6 YEAR OLD RED DEER STAGS (EXP. 2).

	MUSCLE		
	LD	SM	S.E.D.
Tenderness	4.65	4.08	0.23
Juiciness	5.46	5.42	0.16
Flavour intensity	5.32	4.96	0.10
Desirability	5.23	4.50	0.18
Cooking loss (%)	20.6	23.3	0.82
Shear force score (kg F)	9.47	9.51	0.29

	RUT		
	Pre	Post	S.E.D.
Tenderness	4.91	3.82	0.39
Juiciness	5.55	5.33	0.17
Flavour intensity	5.21	5.07	0.07
Desirability	5.14	4.59	0.23
Cooking loss (%)	22.0	21.9	1.06
Shear force score (kg F)	9.08	9.90	0.49

TABLE 7: CORRELATION COEFFICIENTS FOR SENSORY COMPONENTS EVALUATED BY A TRAINED PANEL, COOKING LOSS AND % FAT CONTENT FOR STEAKS FROM 5 & 6 YEAR OLD STAGS (EXP. 2).

LD						
Juiciness	0.79*					
Flavour intensity	0.02	0.07				
Desirability	0.94**	0.83*	0.09			
Cooking loss	-0.37	-0.47	-0.10	-0.40		
% fat	0.70*	0.35	0.19	0.63	-0.29	
GR (mm)	0.78*	0.48	0.18	0.69*	-0.20	0.95**
	Tenderness	Juiciness	Flavour	Desirability	Cooking Loss	%Fat content
SM						
Juiciness	0.71*					
Flavour intensity	0.82*	0.51				
Desirability	0.93**	0.78*	0.75*			
Cooking loss	-0.08	-0.58	0.25	-0.18		
% fat	0.29	-0.01	0.13	0.22	0.14	
GR	0.48	0.16	0.45	0.39	0.28	0.88*
	Tenderness	Juiciness	Flavour	Desirability	Cooking Loss	%Fat content

* indicates significance at $P<.05$, ** indicates significance at $P<.01$.

TABLE 8: INSOLUBLE, HEAT SOLUBLE, TOTAL AND PERCENTAGE SOLUBLE OF TOTAL COLLAGEN CONTENT OF MUSCLES FROM 5 & 6 YEAR OLD RED DEER STAGS (EXP. 2).

	Pre-rut	Post-rut	S.E.D.
LD			
Insoluble (g/100g)	1.23	1.35	0.09
Heat soluble (g/100g)	0.81	0.75	0.10
Total (g/100g)	2.04	2.10	0.19
% soluble	39.5	35.5	0.8
SM			
Insoluble (g/100g)	1.58	1.75	0.09
Heat soluble (g/100g)	2.18	2.38	0.10
Total (g/100g)	3.76	4.13	0.19
% soluble	58.0	57.7	0.8

TABLE 9: CORRELATION COEFFICIENTS FOR SENSORY PANEL TENDERNESS RATINGS, TENDEROMETER FORCE SCORES AND COLLAGEN MEASUREMENTS FOR STEAKS FROM 5 & 6 YEAR OLD STAGS (EXP. 2).

	Force scores	Panel ratings	Total collagen	Soluble collagen	Insoluble collagen
LD					
Panel tenderness	-0.349				
Total collagen	0.445	-0.451			
Soluble collagen	0.336	-0.150	0.919**		
Insoluble collagen	0.482	-0.652*	0.940**	0.729*	
% soluble collagen	-0.034	0.468	0.371	0.705*	0.034
SM					
Panel tenderness	-0.558				
Total collagen	0.611	-0.802*			
Soluble collagen	0.620	-0.801*	0.997**		
Insoluble collagen	0.594	-0.796*	0.995**	0.986**	
% soluble collagen	0.087	0.027	0.017	0.087	-0.080

* indicates significance at $P < .05$, ** indicates significance at $P < .01$.