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Effect of slaughter age between 5 to 14 months of age on the quality of sheep meat

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Abstract

Pasture-raised lamb is considered the highest-quality sheep meat product while hogget is a downgraded product considered to be of poorer quality. This experiment aimed to investigate the difference in meat quality between sheep slaughtered at 5, 8 and 14 months of age. Objective meat quality was measured on the loin of young Romney rams slaughtered at 5 (n=20), 8 (n=20) and 14 (n=20) months old. The loin meat from 14-month-old sheep was redder (P<0.001), yellower (P<0.001) with higher intramuscular fat (P=0.003) and had a shorter sarcomere length (P<0.001) compared to the meat from lambs slaughtered at 5 and 8 months of age. The peak shear force was highest at 8 months (P<0.001). Meat from sheep slaughtered at 8 months had greater drip loss than those at 5 and 14 months (P<0.01). The results suggest that slaughtering sheep at 14 months could have benefits on eating quality due to an increase in intramuscular fat.

Keywords: lamb; slaughter; age; meat; quality

Introduction

New Zealand contributes approximately 47% of the total world sheep-meat exports and 95% of sheep meat produced in New Zealand is exported (Morris 2009). The increase in global population is likely to increase the demand for sources of protein including meat (Godfray et al. 2010). Due to production capacity being limited by land mass it is likely the focus for New Zealand will be top quality and high-value meat products.

In New Zealand, lamb is considered to be the highest-quality sheep-meat product while hogget (defined as a young ovine with two but not more than four incisors in wear) is a downgraded product considered to be of poorer quality (Wiese et al. 2005; Young & Lim 2001). Studies examining the meat quality of lamb and sheep meat from animals slaughtered at different ages have reported an increase in redness, a decline in lightness of colour and increase in shear force in mutton compared to lamb meat (Bouton et al. 1978; Gardner et al. 2007; Hopkins et al. 2007; Jeremiah et al. 1998; Pethick et al. 2005; Warner et al. 2007). The shear force of lamb meat increases as slaughter age increases from 0 to 12 months of age (Young et al. 1993). However, studies in Australia have shown the acceptability of meat from animals classified as hogget, which may mean the penalty placed on hogget carcasses in New Zealand is not valid (Wiese et al. 2005). The objective of this study was to use objective measurements to investigate the differences in meat quality between sheep slaughtered at 5, 8 and 14 months of age, and hence, the possibility of extending lamb meat classification to include older animals than currently classified.

Materials and methods

Sixty (60) Romney ram lambs born in late August and early September (spring) of 2015 were weaned in December and then raised in one group on perennial ryegrass-based pastures following standard commercial farming operations at Massey University's Keebles farm (latitude 40° 24'S, longitude 175° 36'E) 5 km south of Palmerston North, New Zealand. The lambs were allocated to slaughter age-groups of 5, 8 and 14 months of age with 20 lambs in each group. Lambs were balanced across the groups for birth weight. Slaughter occurred on 20th of January, 26th April and 3rd November 2016 when the average age (±SD) of the sheep in each group was 5.1±0.2, 8.2±0.3, and 14.5±0.3 months, respectively. All sheep were weighed prior to being transported to the abattoir to give the final, on-farm live weight.

The sheep were slaughtered and processed at the Alliance Group plant in Dannevirke, (latitude 40° 2'S, longitude 176° 44'E) 58 km east of Palmerston North, New Zealand following standard commercial procedures. Each carcass was given an identification number which was linked to the electronic ID of each sheep to allow tracing of individual sheep information. Hot carcass weight was measured and the GR and lean meat yield were estimated using the Alliance Group VIAscan® system. After the carcasses were chilled at 4°C for 24 hours, the bone-in, short loin *(Longissimus lumborum)* was collected from each carcass, vacuum-packed with the carcass identification tag and transferred to Massey University Food Pilot Plant. The loin samples were frozen at -20°C for three weeks prior to analysis.

Analysis of the samples for each slaughter group was undertaken over a one-week period following the method described by Schreurs et al. (2013). After samples were thawed for 24 hours at 1°C, the loin muscle was removed from the bone. The pH of the loin was measured by pH spear (Eutech Instruments, Singapore) calibrated to pH 4.01, 7.00 and 10.01 standard buffers. A fresh loin slice was made and after 30-minutes exposure to air the muscle lightness *(L*)*, redness *(a*)* and yellowness *(b*)* were measured using a

Minolta CR-200 chromameter. Tenderness was assessed by the peak force required to shear 13 x 13 mm cores from 25 mm loin steaks cooked in a water bath at 70°C for 90 minutes (Warner-Bratzler device, square blade). Weight before and after cooking was recorded to calculate cook loss (%). Sarcomere length was measured by laser diffraction. Myofibrillar fragmentation index was assesed using a filtration method where a muscle homogenate was drained through 230 μm pore filters. Water-holding capacity was measured using the filter-paper press method using a sample size of approximately 0.5g with the exact weight recorded. The results are expressed as the ratio of wetted area to weight of the sample (cm^2/g). Drip loss was measured by suspending a 30 × 30 × 30 mm meat cube with metal hook in a plastic bag and then placing in a chiller at 1°C. Initial weight of sample and the weight after 24 and 48 hours was recorded. Any raw loin tissue that remained after the meat quality analysis was trimmed of fat and visual connective tissue (epimysium), finely minced (Kenwood MG450, 3 mm hole-plate), vacuum-packed and frozen for the subsequent assessment of intramuscular fat by ether extraction (AOAC 991.30).

The live weight, carcass weight, GR, lean meat yield, intramuscular fat and meat quality measurements were analysed using general linear models (PROC GLM, SAS, v. 9.4) with slaughter age group as the fixed effect.

Table 1 Means (±SEM) for final on-farm live weight, carcass weight, dressing out percentage, GR soft tissue depth, lean meat yield and intramuscular fat for Romney rams aged 5, 8 or 14 months (n = 20 per group unless noted).

	Age at slaughter (months)			P- value
	5	8	14	
Final live weight (kg)	42.1 ± 1.0[c]	45.0 ± 1.0[b]	61.6 ± 1.0[a]	<0.001
Carcass weight (kg)	16.8 ± 0.6[b]	18.2 ± 0.6[b]	28.3 ± 0.6[a]	<0.001
Dressing out (%)	40.0 ± 1.3[b]	40.7 ± 1.3[b]	46.2 ± 1.3[a]	0.002
GR (mm)[1]	4.01 ± 0.76[b]	5.64 ± 0.80[b]	11.27 ± 0.80[a]	<0.001
Lean meat yield (%)[1]	54.3 ± 0.8[a]	54.4 ± 0.8[a]	51.6 ± 0.8[b]	0.018
Intramuscular fat (% whole muscle)[2]	2.5 ± 0.3[b]	3.0 ± 0.3[b]	3.8±0.3[a]	0.003

[a,b,c] Within rows, means without superscripts or with common superscript letters are not significantly different at the P<0.05 level.

[1] Sample size (n) for both 8 and 14 months was 18 per treatment. GR and lean meat yield were measured using the VIAscan® system at the Alliance meat processors in Dannevirke, New Zealand.

[2] Ten samples per treatment and was assessed in the *Longissimus lumborum* muscle.

Table 2 Means (±SEM) for meat quality attributes of the *Longissimus lumborum* from Romney rams aged 5, 8 or 14 months (n = 20 per group).

Meat quality attribute	Age at slaughter (month)			P-value
	5	8	14	
pH	5.54 ± 0.02[a]	5.42 ± 0.02[b]	5.45 ± 0.02[b]	<0.001
Meat colour				
*L** (Lightness)	37.76 ± 0.45[b]	39.09 ± 0.45[a]	39.24 ± 0.45[a]	0.045
*a** (Redness)	13.19 ± 0.22[b]	13.34 ± 0.22[b]	15.07 ± 0.22[a]	<0.001
*b** (Yellowness)	3.59 ± 0.15[b]	3.33 ± 0.15[b]	4.53 ± 0.15[a]	<0.001
Water-holding capacity				
Drip loss after 24 h (%)	3.6 ± 0.4[b]	5.7 ± 0.4[a]	4.6 ± 0.4[ab]	0.006
Drip loss after 48 h (%)	5.2 ± 0.5[b]	8.0 ± 0.5[a]	6.0 ± 0.5[b]	0.001
Expressed juice (cm^2/g)	36.7 ± 0.8	35.1 ± 0.8	34.2 ± 0.8	0.101
Cooking loss (%)	30.8 ± 0.5	30.8 ± 0.5	29.7 ± 0.5	0.181
Tenderness				
Shear force (kgF)	6.87 ± 0.35[b]	7.98 ± 0.35[a]	5.72 ± 0.35[c]	<0.001
MFI (%)	95.6 ± 1.0	93.7 ± 1.0	96.0 ± 1.0	0.255
Sarcomere length (μm)	1.84 ± 0.01[a]	1.87 ± 0.01[a]	1.69 ± 0.01[b]	<0.001

[a,b,c] Within rows, means without superscripts or with common superscript letters are not significantly different at the P<0.05 level.

[1] MFI is the Myofibrillar fragmentation index.

Results

Sheep live weight and carcass characteristics

Sheep became heavier as they got older (P<0.001; Table 1). Carcass weight (P<0.001), dressing out percentage (P=0.002), GR soft tissue depth (P<0.001) and intramuscular fat percentage (P=0.003) were greater in the sheep slaughtered at 14 months of age but similar in lambs at 5 and 8 months of age (Table 1). Lean meat yield was lower in 14-month-old sheep but similar in the lambs slaughtered at 5 and 8 months of age (P=0.018; Table 1).

Sheep-meat quality characteristics

The pH was higher in the lamb slaughtered at 5 months old but the same for the sheep slaughtered at 8 and 14 months of age (P<0.001; Table 2). Lambs slaughtered at 5 months of age had meat that was lighter (P=0.045; Table 2). The meat from the sheep slaughtered at 14 months of age was redder and yellower compared to the lambs slaughtered at 5 and 8 months of age (P<0.001). Drip loss after 24 and 48 hours was greater in lamb slaughtered at 8 compared to 5 and 14 months of age (P=0.006; Table 2). Expressed juice, cooking loss and myofibrillar fragmentation index were not affected by slaughter age. The meat from 14 month old sheep had a lower shear force while the meat from lambs slaughtered at 8 months old was greater (P<0.001). Sarcomere length was shorter in sheep slaughtered at 14 months of age (P<0.001).

Discussion

This study evaluated the quality of sheep meat as the slaughter age progressed from 5 to 14 months of age. The increased live weight as the animals got older was expected and contributed to higher carcass weights and dressing-out percentages in the older sheep. Lean meat yield was lower for 14-month-old sheep compared to the lambs slaughtered at 5 and 8 months of age. Lean meat yield will decline as the proportion of fat in the carcass increases (Semts et al. 1982) so, the increased carcass fat in 14-month-old, as evidenced by the greater GR and intramuscular fat, is likely to be the reason for the lower lean meat yields.

Meat from young animals is lighter in colour than that from mature animals or animals that have been growing for long periods of time (Hopkins et al. 2007; Jacob et al. 2007), so lower lightness values for lambs slaughtered 5 months old was unexpected however, the lightness values differ by no more than 2 units and so, this difference is unlikely to be detectable by visual comparison. It is possible that greater fat in the muscle contributed to higher lightness values for the older sheep when measured by chromameter and is also likely to be the reason for the higher yellowness values in the meat from 14-month-old sheep. The higher redness values in the sheep slaughtered at 14 months of age is attributed to the increase in myoglobin concentration that occurs in the muscle as animals get older (Gardner et al. 2007; Hopkins et al. 2007; Warner et al. 2007).

A decline in *Longissimus lumborum* juiciness is reported in sheep slaughtered when they are older than 20 months of age (Pethick et al. 2005). Meat juiciness has been associated with the ability of the meat to hold onto moisture and release it during eating. Meat with a higher drip loss is associated with unpleasant appearance during packaging and a potential drying of the cooked meat product because moisture has been lost from the meat (Otto et al. 2004). The greater drip loss from the meat sheep slaughtered at 8 months of age may implicate a less juicy meat product.

It is known that meat from older sheep is tougher due to the increased level of cross-linking of collagen that reduces solubility of collagen during cooking, making meat more difficult to chew (Light et al. 1985; McCormick 1994; Weston et al. 2002). For sheep slaughtered at 0, 42, 70, 274 and 365 days of age, Young et al. (1993) reported the lowest shear force for meat from sheep at 0 days of age and increasing shear force as slaughter age advanced with the major change occurring between day 0 and 42 of age. Unexpectedly, in the current study the meat from the 14 month group had a lower shear force than the meat from the 5 and 8 month groups. This suggests that other determinants of meat tenderness have reduced the shear force at 14 months and it is likely that the higher intramuscular fat had a role. Intramuscular fat can improve tenderness and reduce shear force values by a dilution of the muscle fibres. Muscle fibres contain the contractile apparatus and collagen tissues that are associated with meat toughness. By having intramuscular fat in the muscle there are fewer muscle fibres in a unit of cross-sectional area and so the toughening effect of the muscle fibres is reduced (Nishimura et al. 1999). Also, intramuscular fat has a lubricating effect, and with cooking, the melted intramuscular fat assists in reducing the force required to chew the meat (Blumer 1963; Wood 1985). In a study by Hopkins et al. (2006) increased intramuscular fat was associated with improved tenderness and eating scores for lamb.

The shorter sarcomere length for the 14-month group is difficult to explain but may be attributable to unknown differences in slaughter conditions. Although the sarcomere length was shorter in the sheep slaughtered at 14 months of age, any influence on the shear force that would be expected due to a shorter sarcomere has been out-weighed by other positive effects (Wheeler & Koohmaraie 1999). It is unlikely that the shortened sarcomere was due to cold shortening as the carcasses for the 14-month group were heavier and had a greater subcutaneous fat depth.

In conclusion, sheep meat from animals that were 14 months old at slaughter was more tender than meat from lambs slaughtered at 5 and 8 months of age and this was attributed to a greater level of intramuscular fat. This suggests that meat from hogget-classified carcasses should not be downgraded on the basis of tenderness if sufficient intramuscular fat is present. Further study is needed to consider other eating qualities of sheep meat from older animals because as the animal becomes older flavour, especially mildness of flavour, can become an issue (Hopkins et al. 2006). The extent to which collagen has a role in the eating quality of sheep meat is also important to consider as it may indicate the extent to which the higher shear force observed at 8 months of age was due to reduced collagen solubility or to an increased collagen concentration.

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