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The effect of conditioning period on loin muscle tenderness in crossbred lambs with or without the Texel muscling QTL (TM-QTL)

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ABSTRACT

A Texel muscling quantitative trait locus (TM-QTL) has been identified on chromosome 18, which increases loin muscling, but may also have a negative impact on mechanically-measured loin tenderness in crossbred lambs, depending on conditioning time. This study investigated the influence of a range of conditioning times (3, 5, 7 or 9 days) on the effect of TM-QTL on loin muscle tenderness. Using Texel rams heterozygous for TM-QTL, mated to non-carrier Mule ewes, heterozygous ($n = 45$) and wild-type ($n = 50$) crossbred lambs were produced. Weight of the valuable *Longissimus lumborum* muscle was higher in TM-QTL carriers than non-carriers, when compared at a fixed age (+11.5%; $P = 0.038$), with the same trend at a fixed carcass weight (+10.2%; $P = 0.064$). Toughness, measured by shear force, was significantly higher in samples from TM-QTL carriers than non-carriers, after conditioning for 3 days ($P = 0.002$), 5 days ($P = 0.003$) or 7 days ($P = 0.03$), but was not significantly different after 9 days of conditioning ($P = 0.32$). Compared to non-carrier lambs, the proportion of samples above consumer acceptability thresholds for toughness was greater in the TM-QTL carrier lambs after 3 and 5 days of conditioning, similar at 7 days, but lower at 9 days. The results suggest that the negative effect of TM-QTL on loin tenderness in crossbred lambs can be overcome by conditioning for more than 7 days. Marketing of TM-QTL carrier lambs through companies that use enhanced processing protocols could be beneficial, due to higher loin muscle weights, without negative effects on meat quality.

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1. Introduction

The majority of slaughter lambs in the UK are from crossbred ewes mated to terminal sire breed rams. Crossbred ewes born to longwool breed sires (e.g. Bluefaced Leicester, Border Leicester) and hill breed dams (e.g. Scottish Blackface, Swaledale) produced over 32% of lambs sold for meat in 2003 (Pollott & Stone, 2006), whilst terminal sire breeds sired 71% of the slaughter population, with Texel rams mated to the largest number of ewes. Any genetic advances achieved in terminal sire breeds that affect slaughter characteristics are therefore likely to have the largest commercial impact if they are expressed in crossbred progeny.

Since the identification of a muscling quantitative trait locus (QTL) on chromosome 18 (OAR18) in Texel sheep (Walling et al., 2004), a collaborative project was set up to fully evaluate the effects of this QTL (known as TM-QTL) in purebred and crossbred lambs. Effects of TM-QTL on a range of carcass traits were investigated in crossbred lambs and results showed significant increases in loin muscling at a given live or carcass weight, as measured by ultrasound, X-ray computed tomography (CT) and carcass dissection, but did not show substantial effects on muscling in other body regions (Macfarlane et al., 2009).

Leg and loin muscle samples from the same lambs were subsequently used to investigate the effects of TM-QTL on key meat quality traits, tenderness and intramuscular fat, after conditioning for at least 7 days (Lambe et al., 2010). The meat quality results, confirmed using different tenderness tests, indicated that male (castrated) lambs that were carriers of the TM-QTL had increased toughness (decreased tenderness) of the loin compared to non-carriers, as well as a decrease in intramuscular fat. However, there were no significant differences in these traits between carrier and non-carrier females, and no significant differences for the leg muscle.

Other results for tenderness of lamb and beef (e.g. Destefanis, Brugiapaglia, Barge, & Dal Molin, 2008; Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Platter et al., 2003; Shorthose, Powell, & Harris, 1986) suggest a Warner–Bratzler shear force threshold of around 5–5.5 kgF (approximately 49–54 N), above which con-

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sumer acceptability declines. For the MIRINZ tenderometer, acceptable values of between 4 and 8 kgF (approximately 39–78.5 N) have been suggested, with those greater than 8 kgF indicating unacceptably tough meat (Jopson et al., 2001). Although the increase in mean shear force for the loin observed in the study by Lambe et al. (2010) was statistically significant, the differences reported may not be of commercial relevance, as means from each group were below these published thresholds, and so within the acceptable range. However, it was noted that there were a few TM-QTL carriers that were outliers in the tougher part of the range (shear force >8.0 kgF) and this degree of toughness is very likely to cause consumer dissatisfaction and would be of concern to retailers who are looking for a consistent product. Carcass processing protocols used in the study by Lambe et al. (2010) equate with the highest industry standard in the UK, with electrical stimulation and 7–12 days ageing. Many slaughter plants will typically age carcasses for around 3–5 days, and do not use electrical stimulation. However, reported results (Lambe et al., 2010) do not show the consequences of the more traditional commercial processing protocols on TM-QTL meat tenderness, and in particular whether the differences would then be of sufficient magnitude to be detected by consumers.

Information from basic meat science suggests that tenderness improves over time after slaughter, with 50% ageing being achieved by 3.3 d and 80% by 7.7 d (Dransfield, Jones, & MacFie, 1981). Taste panel assessments show that lamb loin samples that have been conditioned for 10 days are scored as significantly more tender than those conditioned for 5 days by trained assessors (SEERAD, 2004). However, it is unclear whether the rates of change over time would be the same for carcasses of lambs carrying TM-QTL as those from non-carriers. It is, therefore, vital to understand the effect of the TM-QTL on tenderness in lamb carcasses representing mainstream production, and also to determine the effect of ageing on TM-QTL meat quality, before it is possible to recommend selection for TM-QTL to the wider UK sheep industry.

The *Callipyge* mutation (*CLPG*), which is also found on OAR18, is associated with increased muscularity, lean yield and dressing percentage and reduced carcass fat, but has also been found to substantially increase toughness of meat and lower intramuscular fat content (Cockett et al., 1999; Duckett, Snowder, & Cockett, 2000). Loin chops from *CLPG* carrier lambs were found to be tougher than chops from non-carriers after ageing for 1, 3, 6, 12 or 24 days, although no significant differences were found in toughness of leg muscle samples. Although post-mortem ageing reduced shear force in both *CLPG* carrier and non-carrier lambs, the reduction happened more slowly and over a longer time period in the carrier lambs (Duckett, Klein, Dodson, & Snowder, 1998). Another QTL located in a similar position as TM-QTL on OAR18, termed the rib-eye muscling QTL (also known as LoinMAX or LM-QTL; Masri et al., 2010), was associated with a significant increase in loin shear force in New Zealand lambs that were QTL carriers (+1.54 kgF or 15.1 N) compared to non-carriers, when samples had been frozen immediately after slaughter (Jopson et al., 2001). However, this difference was not significant in samples that had undergone an enhanced post-slaughter regime, where the loin was chilled and aged for six weeks prior to testing. New Zealand lamb is commonly aged for extended periods of several weeks during export of chilled carcasses on ships to other countries. However, in the UK, much shorter ageing times (of 3–5 days) are common, making conditioning effects on meat quality much more important when considering lambs carrying these muscling QTL.

Since the loin is the most valuable meat cut in lamb, and the only significant differences in tenderness between TM-QTL carriers and non-carriers found to date were limited to shear force of this cut (Lambe et al., 2010), the loin was chosen to perform further tenderness tests. The objective of the current study was, therefore, to investigate the influence of a range conditioning times, that were relevant to the UK industry, on the effect of TM-QTL on loin muscle tenderness in crossbred lambs.

2. Materials and methods

2.1. Animals and management

Female and entire male lambs were produced on the commercial farm at Aberystwyth University by mating two known TM-QTL heterozygous carrier rams to 18-month-old Mule ewes in mid- to late-October 2007. Natural mating took place in single-sire mating groups. All lambs were tagged at birth and were managed in a grass-based system of production typical of the UK lowland sector. All procedures involving animals were approved by the SAC and Aberystwyth University animal ethics committees and were performed under UK Home Office license, following the regulations of the Animals (Scientific Procedures) Act 1986.

A power calculation (Rasch, Herrendörfer, Bock, & Busch, 1978), based on the variation in shear force encountered in the previous study (standard deviation 1.35 kgF; Lambe et al., 2010), suggested that 40 lambs per genotype (heterozygous carrier and non-carrier) were sufficient to generate statistically valid data. This calculation used a value of 0.85 kgF as the smallest relevant difference between groups, which was based on data collected at the University of Bristol (A.V. Fisher, personal communication). It had been found that a taste panel difference of half a score unit in an eight point category scale for tenderness equated to approximately 0.85 kgF. To accommodate possible inter-experimental variation, a total of 45 TM-QTL carrier (C) lambs (25 males and 20 females) and 50 non-carrier (NC) lambs (32 males and 18 females) were reared to slaughter. Of these lambs, 25 were reared as singles (9 C, 16 NC) and 70 as twins (36 C, 34 NC). Lambs were sent for slaughter to an abattoir of Welsh Country Foods on Anglesey at approximately 21 weeks. Actual age at slaughter ranged from 148 to 157 days (average 152 days), resulting in carcass weights ranging from 8.2 to 21.8 kg (average 13.7 kg). Carcasses were electrically stimulated post-slaughter (ca. 4 h after slaughter).

2.2. Evaluation of shear force

Both left and right loin muscles (*Longissimus lumborum*) were dissected from all carcasses under commercial conditions 24 h after slaughter and sent in refrigerated transport to the University of Bristol for subsequent evaluation of shear force. On arrival at the laboratory, each of the two loins per animal was weighed, and then cut in half. For each genotype group (C and NC), each of the four loin sections within-animal were allocated to different conditioning treatments (3, 5, 7 or 9 days) using a rotational scheme (Fig. 1).

Once allocated to treatment, each sample was vacuum-packed, labelled with animal identification number, genotype group, conditioning time and date and was aged (at 1 °C) for the appropriate number of days for the treatment to which it was allocated. Samples were then frozen in a blast freezer for subsequent texture measurement at a later date.

Following thawing, samples were cooked (in vacuum pack bags) in water at 80 °C to an internal temperature of 78 °C (Teye et al., 2006). Samples were cooled in ice then held at 4 °C. Ten $10 \times 10 \times 20$ mm blocks were cut from each muscle in the direction of the muscle fibres and sheared, using a TA-XT2 texture analyser (Stable Micro System, Surrey, UK) fitted with Volodkevitch-type jaws. Toughness was recorded as the force (kgF) required to shear the sample, with tougher (less tender) samples resulting in higher values. Results were averaged from a maximum of 10 sub-samples per muscle. However, some samples were not large

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