MODE OF INHERITANCE AND EFFECTS ON MEAT QUALITY OF THE RIB-EYE MUSCLING (REM) QTL IN SHEEP

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SUMMARY
The rib-eye muscling (REM) QTL, identified in descendants of Poll Dorset rams from the Carwell stud, NSW, Australia, is known to be located in the same region of sheep chromosome 18 as the hyper-muscling locus, Callipyge. Callipyge displays a complex inheritance pattern of maternal over-dominance and exhibits detrimental effects on meat tenderness. Carwell has been shown to increase eye muscle area by approximately 10 percent, but its effect on tenderness and its mode of inheritance have not been reported.

Mode of inheritance for REM was estimated by mating five rams heterozygous for REM to heterozygous ewes to produce 221 progeny comprising four genotypes, namely animals with no copies of the REM QTL, animals with REM inherited either maternally or paternally, and those with REM inherited from both sire and dam. Rib-eye muscle area was increased in animals carrying the REM QTL regardless of the source, when compared to their non-REM contemporaries. The mode of inheritance would appear to be dominant.

In a separate experiment, both loins were collected at slaughter from 80 progeny from three sires heterozygous for REM and Romney non-REM ewes. All carcases were subjected to accelerated aging and conditioning. One loin was frozen and the other chilled for six weeks. Tenderness was measured using the MIRINZ tenderometer shear force technique. Frozen loins were tender in non-REM carriers and acceptable in REM carriers (3.11 and 4.65 kgF, respectively; P<0.001). Chilling and aging increased the tenderness in both non-carrier and carrier (2.15 and 2.39 kgF, respectively; NS). Differences in tenderness between REM carriers and non-carriers are therefore small and can be removed by the appropriate post-slaughter treatment.

Keywords: Sheep, Ovis aries, Carwell, rib-eye muscling, REM.

INTRODUCTION
Two distinct muscling phenotypes have been reported in the Poll Dorset breed of sheep, and have been named Callipyge and Carwell. Animals with the Callipyge phenotype have larger muscles in the pelvis and torso, a higher dressing percentage, improved feed efficiency and reduced fatness (in all depots) than their normal contemporaries (reviewed in Cockett et al. 1999). The increased growth of muscle is due to hypertrophy of the fast twitch muscles and develops between 19 to 100 days of postnatal age, or 7 to 20 kg live weight (Duckett et al. 2000). However, several studies have found

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that muscles undergoing this selective hypertrophy, particularly the *Longissimus dorsi* (LD) and *semimembranosus*, are tougher than those from non-*Callipyge* lambs (Duckett *et al.* 2000). Genetic characterization has mapped the QTL to a gene called *Callipyge* on the distal end of sheep chromosome 18 and has demonstrated an unusual mode of inheritance termed polar overdominance. Only heterozygous offspring inheriting the gene from their sire express the phenotype.

A much less dramatic phenotype was characterised in sheep descended from two Australian Poll Dorset rams from the Carwell Stud, NSW, Australia (Nicoll *et al.* 1998). Increased muscle mass in animals carrying this QTL is limited to the LD, with no other muscle group or fatness measure affected. The QTL has also been mapped to the distal end of sheep chromosome 18 where its location overlaps with *Callipyge* (Lord *et al.* 1998). It is not known if this QTL is an allele of *Callipyge (CLPG)*, or if it is a different locus. For this reason it has provisionally been named the Rib-eye muscling (*REM*) locus, with its allele being named *Carwell*.

Given the co-localization of *REM* and *CLPG*, the objective of the present study was to determine the mode of inheritance of *REM* and its effect on meat tenderness. A knowledge of these factors is obviously vital to the future commercial application of *REM*, and in understanding its relationship to *CLPG*.

**MATERIALS AND METHODS**

**Mode of inheritance.** A total of 221 progeny were generated by mating two-tooth ewes and ewe lambs genotyped as carrying a single copy of the *Carwell* gene with five ram lambs also genotyped as single copy *Carwell*. At six months of age, live weight, ultrasonic rib-eye muscle width (A) and depth (B) over the 12th rib, and the depth of fat over the rib-eye at the same site, were measured. A blood sample for DNA extraction was collected at the same time. These samples were genotyped for five flanking DNA microsatellite markers known to be linked with the *Carwell* (Lord *et al.* 1998, Nicoll *et al.* 1998), and the *Carwell* genotype assigned to one of four classes (0 copies of the *Carwell* allele, one paternal copy, one maternal copy, or both paternal and maternal copies) based on the DNA haplotype. The effect of source of inheritance was determined for ultrasonic rib-eye muscle area (EMA) estimated as $0.77 \times A \times B$ using a model including terms for sire, sex, age of dam, live weight and assigned *Carwell* genotype.

**Tenderness.** In a separate experiment, 80 progeny, generated from three heterozygous *Carwell* sires and Romney non-*Carwell* ewes, were slaughtered at seven months of age in a commercial slaughter plant. All carcasses were subjected to an industry standard accelerated conditioning and aging protocol specified for the North American market. Loins from both the left and right half carcasses were recovered at carcass break-down. One loin per animal was stored at -1.5°C for six weeks prior to processing (i.e. chilled), while the other side was stored at -20°C until measurement. For tenderness measurement, samples from the LD were cooked in an 80°C waterbath for one hour, and shear force measured using a MIRINZ tenderometer. Tenderness data were analysed using a model with sex and sire fitted as fixed effects, and live weight and probability of inheriting either paternal grandparents DNA at the Carwell locus nested within sire as covariates. Animals were genotyped with the five markers as above.
RESULTS AND DISCUSSION

Mode of inheritance. The least squares means and standard errors for EMA in the four Carwell genotypes are presented in Table 1. Inheritance of REM increased ultrasonic EMA by approximately 1.1 cm$^2$ (10%; P<0.001). There was no significant difference that could be attributed to the source of REM (i.e. maternal or paternal). The inheritance of a single copy of REM from the sire on EMA was not significantly different from the effect of a single copy from the dam, or from the effect of inheritance of two copies of the QTL. No evidence was found suggesting that REM exhibits any non-Mendelian pattern of inheritance such as that reported for CLPG (Cockett et al. 1999). While the source of REM in the heterozygous genotypes could not be assigned with complete confidence, the uniformity of the standard errors for the four genotypes suggests that assignment errors were small, and REM has a dominant mode of inheritance.

Table 1. Effect of source of the REM QTL (standard errors in parentheses) on ultrasonic rib-eye muscle area

<table>
<thead>
<tr>
<th>Trait</th>
<th>Source of REM QTL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic EMA (cm$^2$)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>11.1 (0.30)</td>
</tr>
</tbody>
</table>

Table 2. Longissimus dorsi shear force tenderness (kgF) in REM QTL carriers and non-carriers

<table>
<thead>
<tr>
<th>Tenderness</th>
<th>Mean non-carrier</th>
<th>Mean carrier</th>
<th>CV%</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frozen</td>
<td>3.11</td>
<td>4.65</td>
<td>25</td>
<td>0.001</td>
</tr>
<tr>
<td>Chilled</td>
<td>2.15</td>
<td>2.39</td>
<td>12</td>
<td>NS</td>
</tr>
</tbody>
</table>

Tenderness. The presence of a single copy of REM resulted in a significant increase in shear force value (+1.54 kgF) in the LD for frozen samples (P<0.001), but not in the chilled and aged product, for all three sires (Table 2). Using the MIRINZ tenderometer shear force technique, meat with a value less than four is considered tender, four to eight is considered acceptable, and greater than eight tough. By these criteria, meat from REM carriers was deemed to be tender, particularly when chilled. While the increase in shear force value in the frozen samples was significant, the mean value of 4.65 kgF was still substantially lower than the ‘acceptable’ threshold of 8 kgF. The decrease in shear force value and the lack of a significant effect in the chilled and aged L. dorsi (2.15 and 2.39 kgF for non-carriers and carriers, respectively) suggests that any tenderness issue associated with Carwell can be treated with appropriate post-slaughter handling of the meat. The chilled storage treatment also reduced tenderness variability between individuals due to other causes as well as that due to the Carwell genotype. The interaction between genotype and post-slaughter treatment may well indicate that that the loins in REM carriers are more sensitive to cold-shortening than their non-REM contemporaries.
Animals exhibiting the Callipyge phenotype have been shown to be unacceptably tough using both shear force and taste panel tenderness assessment methods. Post-slaughter treatments such as electrical stimulation, aging, or injection of calcium chloride have been reported as doing little to improve the quality of the meat (Carpenter et al. 1997). Thus, animals exhibiting the Carwell phenotype should not generate market resistance on the basis of tenderness as has been found in the case of Callipyge.

**CONCLUSIONS**

Carwell offers an increase in EMA of approximately 10% (Nicoll et al. 1998), has little detrimental effect on eating quality, and is likely dominant in its mode of inheritance. This means that while the size of the QTL effect is not as great as that of Callipyge, it does not have the negative eating quality and management implications. Introggression of Carwell into flocks has the potential to improve the quantity of the high-priced loin cuts without negative quality side effects. However, careful examination of the sire’s genetic merit in other economically important traits is required to ensure improvement in the loin is not at the expense of those traits.

**REFERENCES**


