INCREASING THE MUSCULARITY AND INTRAMUSCULAR FAT OF LAMBS WILL REDUCE MEAT REDNESS ON RETAIL DISPLAY

H.B. Calnan[1,2], R.H. Jacob[1], D.W. Pethick[1,2] and G.E. Gardner[1,2]

[1] Cooperative Research Centre for Sheep Industry Innovation, University of New England, Armidale, Australia 2351

[2] Division of Veterinary and Life Sciences, Murdoch University, Murdoch Food Engineering Department, Australia 6150

Abstract – In order to investigate the phenotypic and genetic influences on the redness of lamb meat during retail display 4238 lambs with a diverse range of sire breeding values for post-weaning eye muscle depth (PEMD) were produced from 2007 to 2011 at 5 sites across Australia. One day after slaughter the loin muscle of each lamb was collected to measure isocitrate dehydrogenase activity, intramuscular fat and colour. The loin samples used to measure colour were aged for 5 days and then placed under simulated retail display for 3 days before spectrophotometric measures were taken to determine the redness of the meat. Isocitrate dehydrogenase activity, indicating muscle oxidative capacity, was negatively associated with meat redness. The progeny of sires with high PEMD had redder loin muscle, likely due to changes in muscle oxidative capacity. Intramuscular fat was negatively associated with redness though appears to impact meat colour independently of muscle oxidative capacity. Our findings indicate that breeding from sires with high PEMD could improve the retail colour of lamb meat. By contrast selection for increased muscle oxidative capacity and intramuscular fat in order to improve taste and nutritional qualities could hasten the browning of lamb meat whilst on retail display.

Key Words – Colour, Isocitrate dehydrogenase, Muscle oxidative capacity

- INTRODUCTION

The colour of lamb meat is crucial to customer appeal and strongly contributes to product value. Lamb meat currently has a shelf life of only 1 to 2 days before it is discounted due to browning, representing a major economic limitation to the Australian lamb industry. Lamb browning is dependent on the rate of oxidation of myoglobin pigments, with numerous factors influencing the rate of this oxidative process [1]. Hence, while genetic selection for carcass traits may not be directly focused on the rate of browning of lamb meat, it may still impact upon it due to correlated effects on other factors impacting on myoglobin oxidation.

One intrinsic muscle factor that could be influenced by selection for carcass traits and therefore affect retail meat colour is muscle oxidative capacity. Oxidative capacity is known to vary between different anatomical muscles, with those muscles capable of higher oxidative metabolism more rapidly forming brown pigments (metmyoglobin) creating a surface meat discolouration [1]. These differences between muscle types within a species have been shown previously [2], where the activity of the enzyme isocitrate dehydrogenase was used as an indicator of muscle oxidative capacity.

Muscle oxidative capacity has also been shown to be influenced by selection for muscling. Greenwood et al [3] demonstrated that the progeny of sires with high post-weaning eye muscle depth (PEMD) breeding values had an increased expression of glycolytic and reduced expression of oxidative myofibres [3]. This reduced oxidative capacity may in turn reduce the

rate of browning of lamb meat.

The level of intramuscular fat in lamb meat is also thought to impact on meat colour. Lambs with higher intramuscular fat have been shown to have higher muscle oxidative capacity [5], indirectly increasing the rate of browning. Intramuscular fat levels in lamb meat are being reduced due to selection for improved lean meat yield. This poses a problem as intramuscular fat is crucial to the eating quality of lamb meat. To counter this the Australian lamb industry is developing a sire breeding value for intramuscular fat. But from the perspective of colour stability and browning, this selection may have a detrimental impact. The degree that this selection could influence the retail colour stability of lamb meat is unknown.

We hypothesise that isocitrate dehydrogenase activity and intramuscular fat content will be negatively associated with redness of lamb meat after 3 days of retail display. In addition we hypothesise that the progeny of high PEMD sires will have increased meat redness.

- MATERIALS AND METHODS

Lambs were produced via artificial insemination at 5 sites across Australia from 2007 to 2011. They were of mixed breeds; the progeny of Terminal, Maternal or Merino sires of known pedigree and of Merino or Border-Leicester Merino dams. The sire breeding values for PEMD ranged from -2.9 to 4.9 (Fig. 3). The lambs were maintained on extensive grazing pastures with supplementary feed provided when required to reach target slaughter weights. The lambs were consigned to groups (kill groups) to be slaughtered on the same day at one of four commercial abattoirs at a target carcass weight of approximately 21 - 22 kg.

Loin muscle was sampled from each carcass at 4 hours post-mortem for measurement of isocitrate dehydrogenase activity before an entire loin muscle was dissected 24 hours post mortem and sampled for intramuscular fat and colour. The colour samples were vacuum packed, aged in a chiller for 5 days, re-packaged on Styrofoam trays with 15μm oxygen-permeable polyvinal chloride overwrap and then were placed in a chiller under simulated retail display, where conditions of temperature and light have been designed to simulate those commonly encountered in Australian retail stores.

Surface meat colour was measured after 3 days of simulated display using a Hunter Lab Miniscan. Two reflectance readings of each sample were averaged and used to formulate a ratio (reflectance at 630nm / reflectance at 580 nm). As red and purple myoglobin pigments reflect highly at 630nm and brown myoglobin pigments reflect highly at 580nm, this ratio represents the redness of a meat surface. On retail display this value progressively decreases as increasing surface browning reduces the redness of the meat surface. Previous work by Khliji et al [6] has demonstrated that redness values $\geq$ 3.3 units are required for customer acceptance of meat. Values below this indicate significant surface browning and thus a high chance that a consumer would reject the meat.

The redness ratio values were analysed using a linear mixed effects model with fixed effects for site, year, kill group within site by year, sire type, sex within sire type and dam breed within sire type, and random terms for sire and dam. Isocitrate dehydrogenase activity, intramuscular fat content and sire PEMD estimates were included as covariates in this model, both individually and concurrently, to assess their association with meat redness.

- RESULTS AND DISCUSSION

The average redness after 3 days retail display for all lamb loins was 3.05 ± 0.01 units. Falling only 0.25 units below the cited level required for average consumer acceptance [6], relatively

small increases in redness are needed to extend the shelf life of lamb meat from less than 2 days to closer to 3 days. Increasing isocitrate dehydrogenase activity across a range from 3 to 7.5 µmol/min/g of tissue was associated with a 0.51 unit decrease in redness ($P<0.05$) of the loin muscle (Fig. 1).

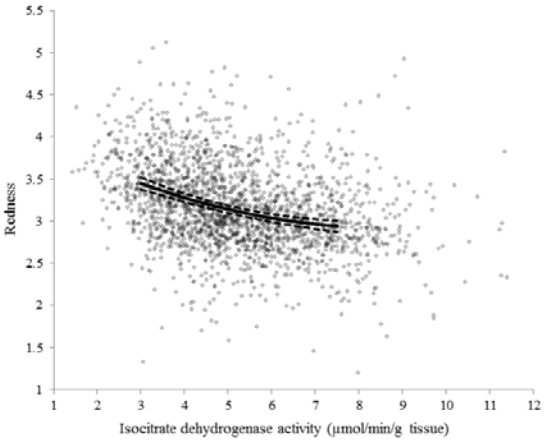

Figure 1. Effect of isocitrate dehydrogenase activity in µmol/min/g of tissue on redness. Lines represent least square means ±SE. Markers represent individual animal residuals from the least squared means.

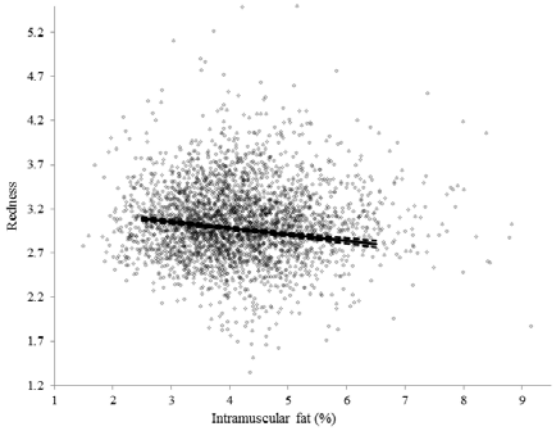

Figure 2. Effect of intramuscular fat content (%) on redness. Lines represent least square means ±SE. Markers represent individual animal residuals from the least squared means.

Increasing intramuscular fat content from 2.5 to 6.5% was associated with a 0.29 unit reduction ($P<0.05$) in redness (Fig. 2). The effects of isocitrate dehydrogenase activity and intramuscular fat on redness did not change when both were included in the model concurrently.

Increasing sire PEMD estimates across the range from -2.2 to 4.5 was associated with a 0.36 unit increase ($P<0.05$) in redness (Fig. 3). This effect was reduced to a 0.18 unit increase in redness when isocitrate dehydrogenase activity was included in the model concurrently.

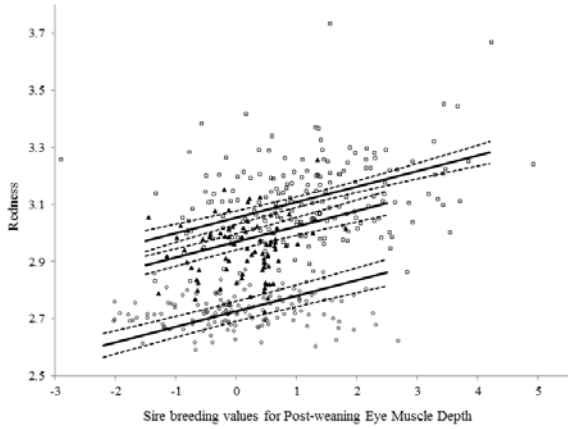

Figure 3. Effect of sire breeding values for PEMD on redness. Lines represent least square means ±SE for each sire type. Icons represent each sire's estimate from the base model plus the sire type least square mean for: □, Terminal sires; ×, Maternal sires; ○, Merino sires.

In line with the hypothesis, increasing isocitrate dehydrogenase activity and intramuscular fat were associated with a reduction in redness. Further investigation is required to determine if the reduction in redness in more oxidative muscles was due to an increased rate of browning caused by greater mitochondrial production of free radicals that promote metmyoglobin formation [1]. In the case of intramuscular fat, although our hypothesis was supported, the likely cause of the association is less clear. The negative impact of high intramuscular fat on redness does not appear to simply reflect its correlation with greater muscle oxidative capacity [5], as when both intramuscular fat and isocitrate dehydrogenase were analysed simultaneously their effects on redness remained the same. This indicates that the impacts of intramuscular fat and isocitrate dehydrogenase on meat redness function independently. In this case increased intramuscular fat may correlate with increased lipid peroxidation which has also been shown to promote myoglobin oxidation [7] and thus meat browning.

Also in line with our hypothesis, the progeny of high PEMD sires had redder loin meat than progeny from low PEMD sires. This positive impact on meat colour may be associated with reduced oxidative capacity in high PEMD sires [5]. In support of this the magnitude of the sire PEMD effect on redness was reduced when isocitrate dehydrogenase activity was included into the model simultaneously. Thus reduced muscle oxidative capacity, likely in-part caused by altered myofibre differentiation may underpin this association.

- CONCLUSION

Selection of sires based on muscularity may have a positive impact on the colour of lamb meat during retail display. However the associations found between muscle oxidative capacity, intramuscular fat and retail meat redness in this study demonstrate the need for careful monitoring of retail colour if the Australian lamb industry attempts to elevate either iron content (linked to oxidative capacity) or intramuscular fat for improved consumer appeal.

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