RETAIL LAMB BROWNING IS POORLY PREDICTED USING MEAT PH$_{24}$ AND COLOUR MEASURED AT THE START OF DISPLAY

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The rapid browning of wrapped lamb on retail display deters consumers and reduces meat value. A means of predicting the rate of browning is needed for retailers to maximise the display time of premium red product. 4405 mixed breed lambs produced over 5 years at 5 sites across Australia were slaughtered at ~22kg carcass weight. The loin muscle was sampled at 24 hours post mortem and measured for pH (pH_{24}) and meat colour. Colour samples were aged for 5 days before being re-sliced, bloomed, overwrapped and placed under simulated retail display for 72 hours. Meat surface colour (R630/R580) was measured 24 hourly during display using a Hunterlab spectrophotometer. Data were analysed in multivariate and mixed linear models to test the associations between meat colour at different display times. Simple and partial correlation coefficients between initial and subsequent measures were ≤ 0.2 despite incorporation of pH_{24}, demonstrating that meat colour at the start of display is not a useful predictor of meat browning at the end display. Correlations between 24, 48 and 72 hour measures were high (> 0.8) regardless of pH_{24}, suggesting that meat colour measured from 24 hours of display can provide an accurate prediction of subsequent colour.

Key Words – Color stability, myoglobin, redness.

I. INTRODUCTION

The colour of lamb meat on retail display is critical to consumer appeal [1]. Consumers expect lamb meat to have a bright cherry red colour, which they associate with meat freshness and quality. When lamb meat is sliced and overwrapped for retail display the surface of the meat rapidly develops a brown discolouration. This unattractive colour forces retailers to discount lamb meat after only around 2 days of display to ensure rapid product turnover prior to the appearance of browning. Alternatively, a shelf life of up to 8 days can be achieved with high O_2 modified atmosphere packaging [2], though this packaging is known to reduce the sensory appeal of the lamb meat [3].

Substantial variation exists between different animals for the rate of browning in lamb meat [4,5]. Meat initially gains a bright red colour with blooming or oxygenation, as myoglobin pigments are oxygenated to form red oxymyoglobin. With oxygen depletion over time, myoglobin pigments are oxidised to form the brown pigment metmyoglobin [1]. A number of factors impact the rate and extent of myoglobin pigment oxygenation, oxidation and thus the rate of meat browning [1,4,5]. Certain factors such as temperature and oxygen exposure are well established and are tightly controlled by retailers to minimise the rate of lamb meat browning on display [6]. However other muscle factors such as meat pH, which has a strong influence on the rate of lamb meat browning on display [4,5], is not known to or able to be controlled by retailers.

Meat browning may be measured using light reflectance to estimate the red to brown colour ratio of a meat surface (R630/R580). These ratios progressively reduce as lamb meat browns over retail display, previous work demonstrating that R630/R580 values below 3.3 units will lead to consumer rejection of the meat based on its colour [7].

Quantifying the pH of lamb meat in addition to measuring meat colour at the start of retail display may provide enough information for retailers to predict the rate that meat will brown over retail display. Retailers could then predict when the threshold for colour acceptability may be reached and thus at what time point of display that particular lamb meat should be discounted or downgraded. We hypothesised that pH_{24} and surface R630/R580 at the start of retail display will allow the prediction R630/R580 at the end of a 72 hour simulated retail display period for lamb loin meat.

II. MATERIALS AND METHODS

4405 lambs were produced via artificial insemination at 5 sites across Australia between 2007 and 2011. The lambs were the progeny of Terminal, Maternal or Merino sires and of Merino or Border-Leicester Merino dams and were a mix of sexes. The lambs were raised on extensive grazing pastures with supplementary feed provided when required. The lambs were consigned to slaughter groups based on their live weight for a target carcass weight of approximately 22 kg. Each grouping of lambs was slaughtered on the same day at one of four commercial abattoirs.

The loin muscle was dissected from each carcass 24 hours post mortem. Muscle pH (pH_{24}) was measured via the insertion of a TPS WP-80 probe into the centre of the loin muscle adjacent to the 12th rib, at an average muscle temperature of 3.1 °C (±1.7). A portion (> 5cm of loin length) of muscle was vacuum-packed, boxed and aged in a dark chiller at approximately 3°C for 5 days. These samples were then freshly sliced perpendicular to the long axis of the muscle, overwrapped with 15μm oxygen-permeable polyvinal chloride on black Styrofoam trays and exposed to simulated retail display for 72 hours. For this period the ambient air temperature was maintained at 2°C and light intensity was 1000 lux.

Colour was measured using a Hunter Lab spectrophotometer XE plus, with an aperture of 3.18cm, a D65 light source and 10° observer. Colour measures commenced 30 minutes post-slicing, at 0, 24, 48 and 72 hours of display. The colour was calculated as the ratio of reflectance of light at 630 nm and 580 nm (R630/R580); representing the "redness" of the meat surface [8]. Values were the average of two readings taken at 90° angles on the horizontal plane, at each time point.

Correlations between R630/R580 values at different time points during retail display were analysed in SAS, with simple correlations estimated using the "Proc Corr" command, and partial correlations estimated using a multivariate analysis, with fixed effects for site, year, slaughter group within site by year, sire type and sex and dam breed within sire type. Additionally, R630/R580 values at 72 hours were analysed using a linear mixed effects model with the same fixed effects as described above, as well as random terms for sire and dam by year to form a base model. Then each of the earlier R630/R580 time point measures were included one at a time as covariates, along with their squared term and any interactions with fixed effects, to assess their association with R630/R580 at 72 hours display.

III. RESULTS AND DISCUSSION

Values for R630/R580 at 0 hours were weakly correlated with subsequent time points, and correlation coefficients decreasing as time on retail display increased (Table 1, Fig.1). In the current Australian lamb value chain, information about breed, sex, and site are unlikely to be available at retail, meaning that the simple correlations are likely to be more relevant than the partial correlations. Even if this information was available the accuracy of the prediction would still be low.

Table 1 Simple (upper, above the diagonal) and partial (lower, below the diagonal) correlation coefficients between R630/R580 measures at each time point of simulated retail display

R630/R580	0 hr	24 hr	48 hr	72 hr
0 hr	-	0.20	0.18	0.10
24 hr	0.40	-	0.82	0.81
48 hr	0.41	0.83	-	0.85
72 hr	0.32	0.80	0.87	-

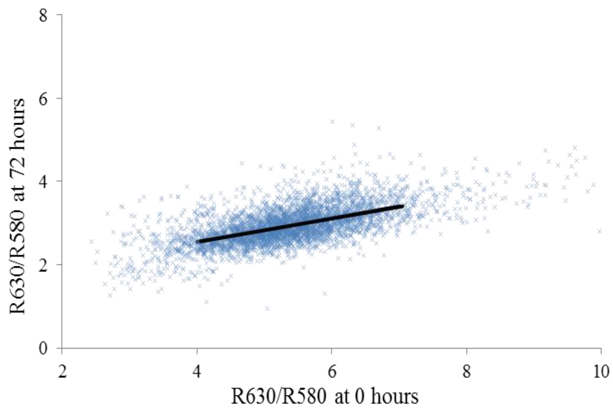

Figure 1. The correlation between 0 and 72 hours for R630/R580. The line represents predicted means and individual points are the residuals values (difference of raw value from the predicted means).

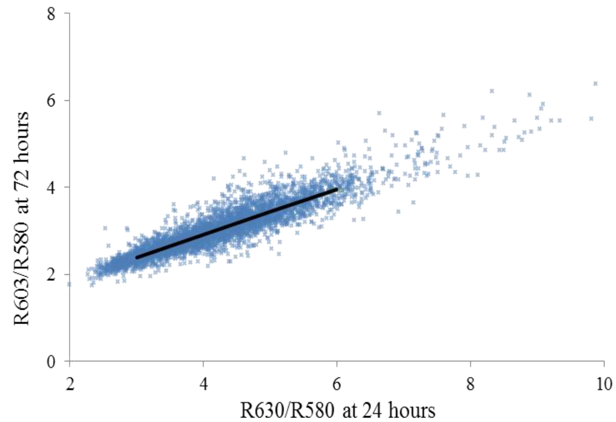

Figure 2. The correlation between 24 and 72 hours for R630/R580. The line represents predicted means and individual points are the residuals values (difference of raw value from the predicted means).

The prediction did not markedly improve by incorporating loin pH_{24} into the model, contrary to our hypothesis. While pH_{24} was significant (P<0.05), there was only a small increase in the variance explained (from 0.58 to 0.62) when pH_{24} and its interactions with fixed effects were incorporated. Therefore we can conclude that using loin pH_{24} measures in addition to surface R630/R580 measures at the start of retail display will not provide an accurate prediction of meat browning over the subsequent 3 days of retail display.

By contrast, meat R630/R580 measured at 24 hours of display was highly correlated with R630/R580 measured at 48 and 72 hours (Table 1, Fig. 2). The similarity between simple and partial correlation coefficients of meat R630/R580 measured at 24, 48 and 72 hours of display indicates that correcting for factors such as site of production, sex and breed had little effect. Hence, knowledge of these production factors is not required to improve the prediction of lamb loin browning at the end of display using R630/R580.

Meat browning is well recognised to be a complex trait that is impacted upon by a range of interrelated factors, many of which remain incompletely understood [1,5]. While pH_{24} and freshly oxygenated meat colour are both associated with lamb meat browning over retail display [4,5], these results suggest that these two factors do not account for enough variation in meat browning between individual animals to provide a useful prediction of the rate of meat browning over retail display.

The substantial improvement in the ability to predict meat browning based on colour measured at 24 hours into display rather than after blooming suggests that the factors determining an animal's meat browning are not manifesting their effects until some point between initial meat blooming and the proceeding 24 hours. These factors are likely to be numerous, given the range of genetic, processing and muscle factors that, in addition to meat pH, have been shown to influence the rate of lamb meat browning [1,4,5]. Additionally these results demonstrate that meat surface colour measured at 24 hours of retail display onwards could be of value in the development of a retail colour breeding value for lamb.

IV. CONCLUSION

Colour measured immediately after blooming at the start of retail display does not provide an accurate prediction of meat colour at the end of display, even with inclusion of meat pH_{24} in the model. However meat colour measured from 24 hours into display can provide an accurate prediction of meat browning after 2 to 3 days of display. Thus colour assessments made at 24 hours of display may enable retailers to identify with some confidence the meat to be discounted to avoid browning. Additionally meat colour measured from 24 hours of display could prove valuable in the development of a retail colour breeding value for lamb meat.

ACKNOWLEDGEMENTS

These authors gratefully acknowledge the financial support of the Cooperative Research Council for Sheep Industry Innovation and wish to thank the large number of people across Australia who assisted with site supervision, sample collection and measurement.

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