INFLUENCE OF MYOFIBRIL ORIENTATION ON LAMB COLOUR MEASUREMENT AND COLOUR STABILITY

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Abstract – This study aimed to test the effect of surface myofibril orientation upon colorimetric results. Thirty *semimembranosus* (SM) muscles removed from individual lambs were used to measure CIE reflectance values (*L, *a**, *b**) and wavelength ratio of 630nm and 580nm (R630/580) using by 2 Hunter Lab Mini Scanners (25 mm and 5 mm aperture) and 1 Minolta Chroma Meter. Measurements were taken both across and along myofibrils from each sample upon freshly exposed and bloomed surfaces. Mean *L** was lower when measurements were taken across the myofibrils (*P* < 0.001). Both *a** and *b** average values were higher when measured across myofibrils, with the difference significantly (*P* = 0.001) greater for bloomed surfaces. R630/580 was higher when measured across the myofibrils (*P* = 0.04) and no significant interaction between myofibril orientation and instrument was observed. These results show a necessity to account for myofibril orientation during colorimetric analysis of lamb meat.**

Key Words – Lamb meat, Colour stability, Muscle fibre orientation

I. INTRODUCTION

Lamb meat discolouration is unacceptable to many consumers and can attract heavily discounted prices. Consequently, the accurate and objective measurement of lamb meat colour and colour stability is vital to ensure quality and economic returns are maximised [1]. Meat colour is a function of metmyoglobin and oxymyoglobin levels [2] as the former is strongly associated with meat brownness and the latter with increased redness and heightened desirability [3]. Time on commercial display is known to influence these concentrations, with meat metmyoglobin concentration shown to intensify with display time [4] or ageing [2, 5].

The development of colorimetric instrumentation has significantly contributed to the objective analysis of meat colour. These instruments generally apply an Illuminant to the surface of a meat sample and record the wavelength of reflected light, opposed to light either absorbed or scattered by the meat surface. These measurements are reported as CIE colour space coordinates, or reflectance values; *L** (lightness or brightness), *a** (red/greenness), and *b** (yellow/blueness). Reflectance values can also be reported at incremental wavelengths, depending on colorimeter, and used to calculate the wavelength ratio of 630 nm and 580 nm (R630/580). This ratio provides a useful indication of metmyoglobin formation and hence overall consumer acceptability of a meat product [3]. Therefore, R630/580 has been used in the development of consumer quality thresholds aimed at guiding producers and retailers towards delivering quality meat products [6].

Sterrenburg [7] found fibre orientation affected light reflectance properties in fibrous translucent material, such as pork meat and teflon. Lamb meat is a translucent substrate [8] comprised predominantly of unidirectional muscle fibres (myofibrils) which present different fibre orientation dependent upon muscle cut face. Given research investigating meat colour and colour stability relies upon colorimetric instrumentation providing uniform, nonbiased and compatible measurements [9], this study investigated the effect of myofibril orientation on lamb meat colorimetric assessment.

MATERIALS AND METHODS

At 24 h post-mortem, the *semimembranosus* (SM) muscles were removed from 30 randomly selected lamb carcases slaughtered as a single group at a commercial abattoir. These were aged prior to analysis in individual, gas impermeable and vacuum sealed plastic bags at 3-4°C.

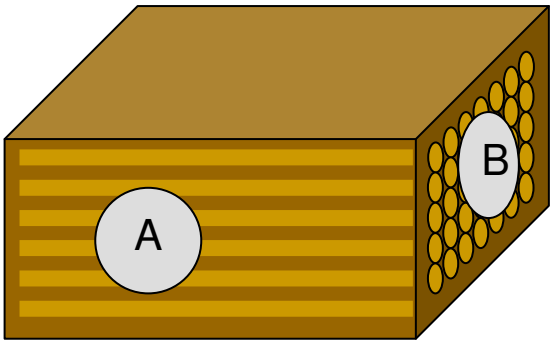

Figure 1. A stylised representation of myofibril orientation at measurement surfaces (A) along and (B) across the myofibrils.

At analysis, each SM had both parallel and perpendicular sections removed to expose the muscle surface (see Figure 1). Colorimetric measurements were taken on each exposed surface immediately and again following a 60 minute blooming period. These were made both across and along myofibrils (see Figure 1) using three colorimeters: 1) Hunter Lab Miniscan Model 45/0-L with an aperture size of 25 mm (Reston, VA, USA) calibrated using black and white tiles and Illuminant D-65 (X = 80.4, Y = 85.3, Z = 91.5), with 10 degree standard observer; 2) Hunter Lab Miniscan Model 45/0-S with an aperture size of 5 mm (Reston, VA, USA) calibrated using black and white tiles and Illuminant D-65 (X = 80.4, Y = 85.3, Z = 91.5), with 10 degree standard observer; and 3) Minolta CR-400 Chroma Meter (Minolta Camera Co., Osaka, Japan) calibrated with a standard white tiles plate (Y = 92.8, X = 0.3160, Y = 0.3323) under D-65 Illuminant. Measurements were made on each sample at each stage (freshly exposed surfaces and after blooming) by each instrument (in duplicate for each Hunter Lab mini scan and in triplicate for the Minolta), first along the fibre and then, immediately following, across the fibre.

To analyse each trait (L^*, a^*, b^* and R630/580) a separate linear mixed model analysis was performed. Model fixed effects included were for time, instrument, orientation, stage (freshly exposed versus 60 minutes blooming), interactions between time and stage and interactions between time, instrument and stage with orientation. Random effects were effects for animal (A) and interaction effects for time x instrument (TI), TI x instrument, TI x stage, A x TI, A x TI x instrument and A x TI x stage. The random error was allowed to differ in variation for Hunter Lab Miniscan and Minolta Colorimeter instruments as the measurements are recorded differently by these colorimeters. Models were fitted using the package *asreml* [10] under R [11].

II. RESULTS AND DISCUSSION

Myofibril orientation was shown to significantly affect average results for L^* ($P < 0.001$), a^*, b^* ($P < 0.001$) and R630/580 ($P = 0.04$). Results are summarised in Figures 2 and 3. Measurements taken across myofibrils had higher average a^*, b^* and R630/580 values and lower L^* values compared with those measured along myofibrils. For a^* ($P < 0.001$) and b^* ($P < 0.001$) values, the differences between across and along measurements are significantly larger for bloomed samples compared with freshly exposed samples ($P = 0.02$ and $P < 0.001$, respectively). Sterrenburg [7] also found these reflectance values to be influenced by fibre direction, finding L^* and a^* measurements were highest when measured on a surface with fibres having a perpendicular orientation. This deviation from the findings of this report is thought to stem from substrate differences, as Sterrenburg [7] analysed Teflon tiles rather than meat samples as per this study. Another source of variation may have been edge-loss effect; being light presumed absorbed when in fact it is projected outside the colorimeter sampling window [12].

Apart from the significant interaction effect associated with orientation and stage on a^* and

*b**, stage also influenced average *L**, with significantly larger results for freshly exposed samples than for samples allowed to bloom for 60 minutes ($P = 0.005$), Average R630/580 values did not differ significantly with stage ($P > 0.05$).

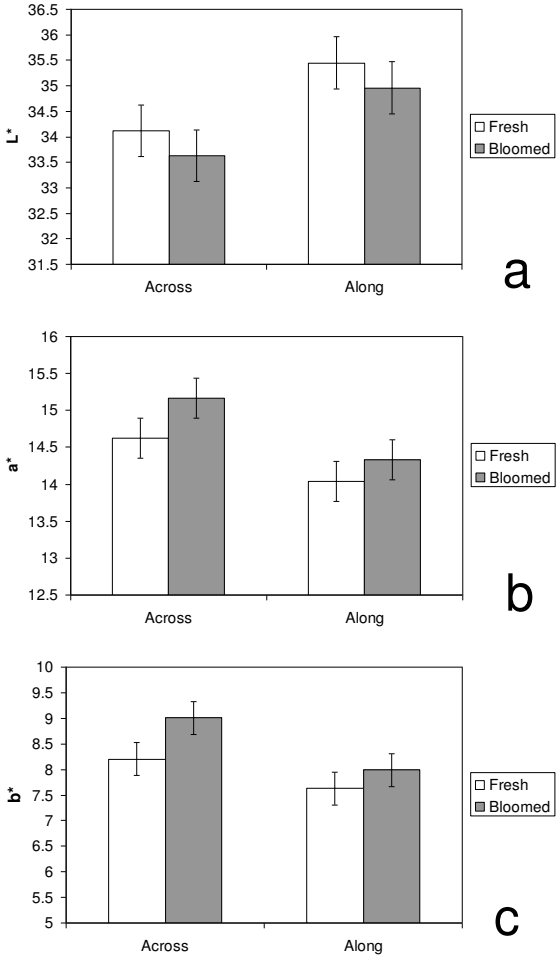

Figure 2. Plots of the mean and standard error for a) *L**, b) *a** and c) *b** reflectance values when colorimetric measurements were taken across or along the m. *semimembranosus* myofibrils on either a fresh cut surface or after it was allowed to bloom.

There was an effect of stage on average *L** ($P < 0.005$) and *b** ($P < 0.001$) values. Blooming permits deoxymyoglobin to be exposed to oxygen which transforms deoxymyoglobin into oxymyoglobin [13]. This shift in concentration is dependent on temperature, time, oxygen penetration into meat surface and competition for available oxygen [14], and ultimately results in a change in meat surface colour. The observed response of L* to bloom in the current study is far from standard, and further research into understanding its underlying biochemistry and trends is required. Nonetheless, in terms of consumer acceptability, L* has been found to have only a minor contribution, with b* and R630/580 the key determinants [3].

Furthermore, the observed interaction between stage and myofibril orientation on *a** and *b** values ($P < 0.001$) suggests oxymyoglobin formation from deoxymyoglobin and the resultant colour change varies dependent on myofibril directionality.

R630/580 was higher when measurements were made across myofibrils rather than along myofibrils ($P < 0.041$; Figure 3). For lamb meat, R630/580 has been used to indicate consumer acceptability of lamb meat in terms of colour [1, 15]. This result is supported by previous research findings showing that perpendicular fibres have greater light reflectance than those of parallel orientation between wavelengths of 400 nm and 700 nm [7], the range R630/580 is calculated within. This suggests colorimetric analysis in the determination of thresholds should include considerations of muscle surface myofibril orientation.

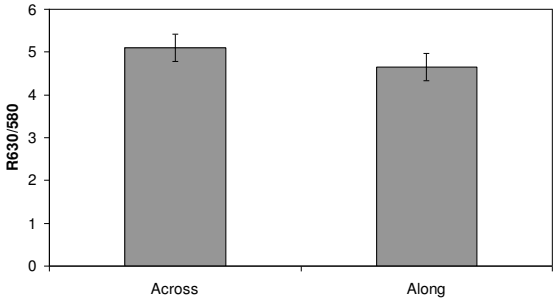

Figure 3. A plot of the mean and standard error for the reflectance ratio of 630 nm and 580 nm (R630/580) wavelengths when colorimetric measurements were taken across or along the m. *semimembranosus* myofibrils.

Significant differences ($P < 0.05$) were identified in this study in the three instruments for measuring *L**, *a** and *b**, but no significant interaction effects were identified between instrument and the other factors in this study, including myofibril orientation. This suggests

observed orientation effects on colorimetric measurement are not restricted to the colour meter or instrument used, within the scope of this study.

CONCLUSION

It appears that the accurate colorimetric analysis of lamb meat depends on myofibril orientation at the site of measurement, as measurements taken across the muscle fibres generally are higher than those taken along these fibres, except for *L** values. Blooming was also confirmed as best practise prior to colorimetric analysis so as to obtain measurements representative of stabilised surface colour. From these observations, it is recommended that myofibril orientation is considered during future research investigating lamb meat colour and colour stability. However, additional research into the effect of myofibril orientation would aid in validating this recommendation.

ACKNOWLEDGEMENTS

The authors wish to thank Matt Kerr and Stephanie Fowler for their contribution during sample collection and analysis. The author Alvarenga is grateful for a Scholarship No. 0360/13-9 from the CAPES Foundation, Ministry of Education of Brazil. The cooperation of Gundagai Meat Processors is also acknowledged. This study was funded by the NSW Department of Primary Industries.

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