LAMB COLOUR STABILITY MEASUREMENTS ARE SUBJECT TO ILLUMINANT AND VIEWING ANGLE SELECTION

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Abstract – This study investigated the effect of illuminant and viewing angle parameter selection on the colorimetric analysis of lamb meat colour stability across display time and after different ageing periods. A calibrated HunterLab colorimeter was used to assess lamb m. *longissimus lumborum* at three ageing periods (5, 12, 40 d) placed under simulated retail display (1.6°C and 851 lux lighting average) and measured at intervals (0, 24, 48, 72 h) using each combination of illuminants (A, D65) and viewing angles (2°, 10°). Using a linear mixed model analysis, the illuminant x viewing angle x ageing period x display time four-way interaction was found to significantly affect all measured CIE values (L*, a*, b*). This outcome highlights the need for illuminant and viewing angle parameters to be reported in all future colorimetric studies investigating the appearance or colour of lamb.

Key Words – Lamb, Colour stability, Illuminant, Observation angle, CIE measurement

I. INTRODUCTION

Lamb meat colour is fundamental to consumer evaluation of quality and intrinsic value. It has been well established that display time within a retail context has a detrimental influence on lamb meat colour and, this can be exaggerated by prolonged ageing [1]. It should be noted, however, that animal diet and actual muscle antioxidant content (e.g. vitamin E) can act to improve lamb meat resilience against discolouration caused by display times and ageing periods [2]. This occurs via alterations to the myoglobin oxidation reactions which ultimately determine lamb meat colour and appearance. For instance, when lamb meat has a high deoxymyoglobin (DMb) content it will result in a purplish surface appearance and as DMb oxidises to oxymyoglobin (OMb) this causes a bright red coloured appearance. Prolonged exposure to oxygen will result in OMb becoming metmyoglobin (MMb) which is associated with brownish discolouration and decreased consumer acceptability [3, 4].

Colorimetric instruments (e.g. HunterLab) or colorimeters can provide the opportunity for lamb meat colour to be measured objectively. These instruments routinely apply light to a meat sample and record the light wavelengths reflected and not otherwise absorbed or scattered upon contact with the measured surface. Colorimeters report measurements as CIE colour space coordinates, being; L* (lightness or brightness summation), a* (redness), and b* (yellowness) [4]. The light used by colorimeters is referred to as illuminants, which are sources of visible light with standardised spectral distribution profiles. These can be manipulated to suit the measured surface as illuminant A (2857 K) represents light typical of incandescent or tungsten-filament lighting whereas illuminant D65 (6504 K) represents daylight [4]. The angle at which illuminants are applied to a measured surface can also be adjusted, and this is referred to as viewing or observation angle.

Findings from a publication survey of colorimetric research (1998-2007) found 48.7% failed to report illuminant selection and 65.7% did not report the viewing angle employed [5]. This could have significant implications upon data amalgamation or research compatibility with variations in colorimeter settings known to vary experimental observations. For example, recent research demonstrated the significant influence of appropriate aperture size selection on colorimetric measurements for lamb [6]. Therefore, this study aimed to investigate the effect of illuminant and viewing angle selection on lamb meat colour stability during display, as affected by ageing period and measured as CIE values using a HunterLab colorimeter.

II. MATERIALS AND METHODS

At 24 h *post-mortem*, a single m. *longissimus lumborum* (LL) was sampled from Dorper lambs (n = 62) which were slaughtered as a single group at a commercial abattoir. All LL were sectioned into three equal samples which were vacuum packaged and randomly allocated ageing periods (5, 12, 40 d) according to location and so that each LL was represented in each period. Ageing occurred under refrigeration (1.6°C average). Following their prescribed ageing period, a guide was used to cut the LL samples to sections of a uniform 3 cm thickness. It was ensured that the myofibres on the measurement surface were perpendicular to the colour meter [7]. These sections were then individually placed on black foam trays and overwrapped with PVC food film wrap (15 µm) and permitted to bloom for 45 min before colorimetric analysis.

Colorimetric measurements were taken in duplicate and over four display time intervals (0, 24, 48, 72 h) between which all samples were displayed under simulated retail lighting (851 lux average) and refrigeration (1.6°C average). A HunterLab colorimeter (Miniscan Model 45/0-L: Reston, VA, USA) with a 25 mm aperture was calibrated (X = 80.4, Y = 85.3, Z = 91.5). This was set so that each combination of each illuminant (A, D65) and viewing angle (2°, 10°) was used to measure each LL sample. The recorded CIE values (L*, a*, b*) were then tabulated for analysis.

Data were analysed using a linear mixed model fitted using the GENSTAT statistics package [8]. As individual terms where dropped from the full fixed model, the fixed effects included were interaction effects for illuminant (I) x display time (T) x ageing period (A) x viewing angle (V). Animal was included as a random effect. The level of significance was set as $P < 0.01$.

III. RESULTS AND DISCUSSION

A significant four way interaction between illuminant, viewing angle, ageing period and display time was observed all CIE values – L* ($P < 0.009$), a* ($P < 0.001$), and b* ($P < 0.001$).

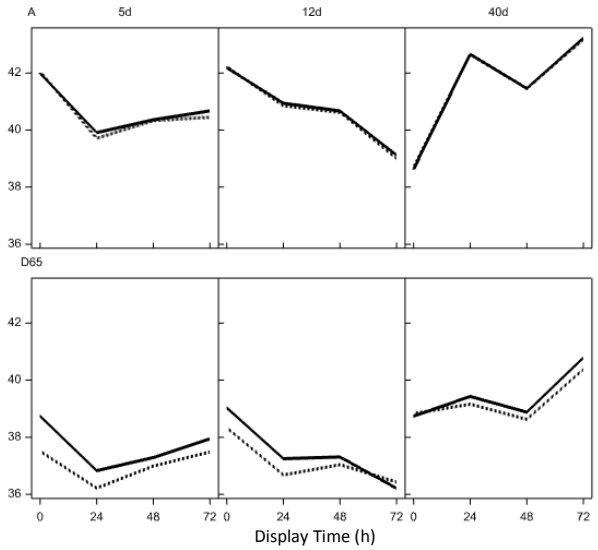

Figure 1. A trellis plot of L* (y-axis) with illuminant (A, D65) and ageing period (5d, 12 d, 40 d) fitted as group effects and viewing angle with 2° (solid line) and 10° (dashed line) as individual frame effects.

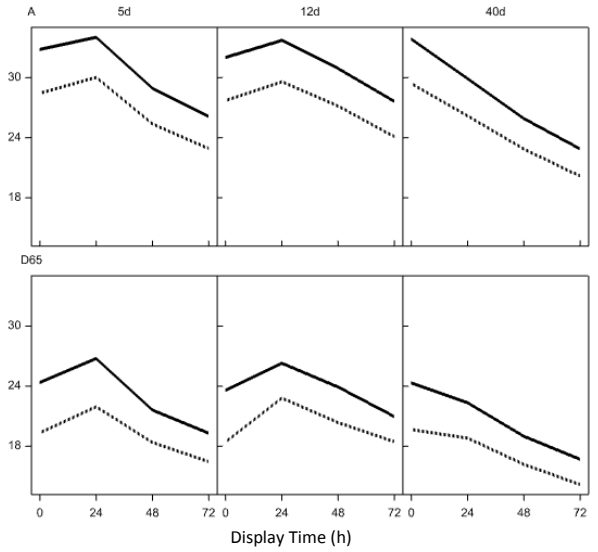

Figure 2. A trellis plot of a* (y-axis) with illuminant (A, D65) and ageing period (5d, 12 d, 40 d) fitted as group effects and viewing angle with 2° (solid line) and 10° (dashed line) as individual frame effects.

Figure 1 shows that L* values are highest when measured using illuminant A. Both illuminants, however, follow similar trends across all ageing periods and display times. This could result from protein degradation and release of free water that

occurs during display and ageing which, in turn, enhances the scatter of any light applied by a colorimeter and ultimately lightness measurements [9]. For D65, L* was higher when 2° viewing angle was set, but its difference to 10° was observed to decrease with increasing display time. 2° viewing angle utilises a smaller fraction of the available measurement surface to measure CIE values than 10° [4]. Therefore, this observed converging trend for 2° and 10° viewing angles suggests that lamb meat adopts an increasingly homogenous L* across display times (0-72 h).

Lamb a* values were highest across display times and ageing periods when illuminant A and 2° viewing angle parameters were used (Figure 2). The basis of this observation is the emphasis that illuminant A places upon red spectral wavelengths which is not reciprocated by D65 [4], and this implication on a* being the CIE measure of relative redness. It is interesting to consider this observation within the context that a* values have been identified as valuable to indicate lamb colour acceptability - with Khliji et al. [10] establishing an a* threshold of 21.7 using D65 illuminant and 10° viewing angle. Hence, it would prove valuable to undertake a companion analysis investigating consumer acceptance in relation to a* using illuminant A and 2° viewing angle, which this study demonstrates has greatest variation over display time. Indeed this would be necessary to allow consumer thresholds to be established as those based on illuminant D65 would no longer apply. Until this is undertaken the use of illuminant A would not be recommended as subsequent data from experiments could not be interpreted from a consumer perspective.

For both illuminants and viewing angles, a* declined as display time increased, with the exception of a peak observed at 24 h display time. This peak could represent complete oxidation of DMb and OMb content achieving saturation to result in the bright red (a*) appearance [3]. Furthermore, the decline following this peak is characteristic of OMb transition to MMb and its increasingly brownish or discoloured appearance.

Figure 3 shows that 10° resulted in higher b* values and more variation across display times when compared with 2° viewing angle. When D65 illuminant was used, this b* variation between viewing angles was observed to increase with display time. This suggests illuminant D65 is a better discriminator for b* spectral wavelength (e.g. yellow/green). All ageing periods exhibited a similar b* peak at 24 h display time which was similar to a*. This is thought to result from the same influence of myoglobin oxidation reactions, especially as b* values are not influenced by lamb meat pigment or haem content as found with a* values [3]. Overall, b* values declined as ageing periods increased.

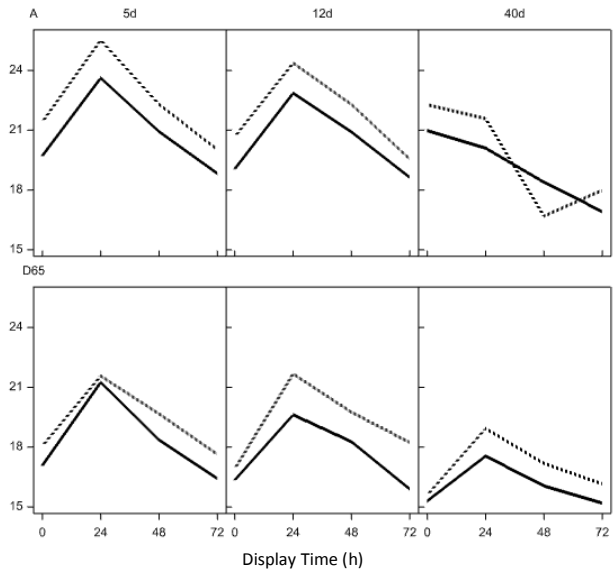

Figure 3. A trellis plot of b* (y-axis) with illuminant (A, D65) and ageing period (5d, 12 d, 40 d) fitted as group effects and viewing angle with 2° (solid line) and 10° (dashed line) as individual frame effects

CONCLUSION

This study demonstrated that CIE values reported using a HunterLab colorimeter depend upon the illuminant and viewing angle parameters selected. From this, it may be concluded that all future colorimetric studies investigating lamb meat must report illuminant and viewing angle settings. This will facilitate better comparisons and enable amalgamations

between projects and research collaborators. This study also highlights a need for additional research investigating consumer acceptance of lamb meat in association with colorimetric values measured using other illuminants and viewing angle combinations than those based on illuminant D65 and 10° viewing angle.

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