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The importance of chill rate when characterising colour change of lamb meat during retail display

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ABSTRACT

An experiment was conducted to compare the effect of two chilling rates (Con and Fast) on colour change of lamb meat during simulated retail display. Measurements were made on 3 muscles; LD (*m. longisimuss dorsi*), SM (*m semimembranosus*) and ST (*m. semitendinous*). Meat samples from 32 Merino crossbred lambs were vacuum packed and stored for 5 days at 2 °C, then cut and overwrapped in polyvinyl chloride film on black polystyrene trays, stored in a display cabinet at 4 °C with lights on and measured twice daily for 4 days, using a Hunterlab minilab 45/20 L D65, aperture 10°. Sarcomere length was shorter, shear force higher and colour change greater in meat from the Fast treatment compared to the Con treatment. Colour differences between treatments were likely due to oxygenation (bloom) as well as oxidation effects. Chill rate is important when characterising colour change during display and should be considered in measurement protocols.

1. Introduction

The surface of meat changes in hue of colour from red to brown during retail display, due to the formation of metmyoglobin (Faustman, 1990). Colour is an important visual cue denoting freshness and quality to consumers who prefer to purchase meat that is red rather than brown in colour. Findings that colour stability is likely to be heritable (King et al., 2010), has created an interest in creating a colour stability trait that could be used for animal breeding purposes (Mortimer et al., 2010). Spectrophotometer measurement has the advantage of being cheap and easy to do when compared to chemical analyses.

However, the technical specifications of the instruments used to measure colour can alter the magnitude of colour estimates (Yancey & Kropf, 2008) and a need to standardise colour measurement techniques was recently highlighted by Tapp, Yancey, and Apple (2011). Furthermore, the potential for processing conditions to affect colour has been demonstrated (Hildrum, Nilsen, Bekken, & Naes, 2000; Ledward, 1985). To add further complication, different authors have applied the term colour stability to different colour parameters, meat processing and display scenarios. These range from a change in colour after freezing and thawing (Farouk & Lovatt, 2000) to a change in colour during simulated retail display when either exposed to (Jacob, D'Antuono, Smith, Pethick, & Warner, 2007), or not exposed to light (Johnson, McLean, Bain, Young, & Campbell, 2008).

Standardising a definition and measurement protocol for colour stability would allow closer comparison between studies and would be useful for specific purposes such as calculating animal breeding values. Without standardisation, the various methods might represent different components of the relevant biochemical pathways, associated with meat colour and colour change during display (Faustman, 1990). Oxygen consumption due to mitochondria remaining active post mortem influences the depth from the surface of the oxymyoglobin layer, hence blooming time and the depth from the surface at which metmyoglobin forms (Bendall, 1972a). Oxygen consumption also generates free radicals that favour lipid per-oxidation (Bendall, 1972a; Tang et al., 2005), which recently was linked to myoglobin oxidation (Faustman, Mancini, Sun, & Suman, 2010). Antioxidants particularly vitamin E reduce the rates of lipid and myoglobin oxidation. The enzyme metmyoglobin reductase can also reduce metmyoglobin concentration once formed (Faustman, Chan, Schaefer, & Havens, 1998).

In a commercial scenario, factors causal to colour change during retail display operate at different parts of the lamb meat supply chain yet potentially still interact with one another. For example, colour may be associated with rigor temperature when meat is fresh but not after an extended ageing period (Bendall, 1972a; Rosenvold & Wiklund, 2011). The requirement for vitamin E in animal diets (Faustman et al., 1998) depends on the meat ageing period (Jose, Pethick, Gardner, & Jacob, 2008) and packaging system. Factors that operate in one part of a supply chain, such as chilling regime, could potentially confound comparisons of factors in another part of a supply chain, such as animal genotype.

This experiment compared colour change in lamb meat from 3 muscles; *m. longissimus dorsi* (LD), *m. semimembranosus* (SM) and *m. semitendinous* (ST) during simulated retail display, using two different chilling rates, conventional (Con) and fast (Fast).

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2. Method

2.1. Experimental design

A chiller at a commercial abattoir was used for the Con treatment, and a prototype chiller designed to achieve a very fast chilling temperature time profile of 0 °C in 5 h (Sheridan, 1990), was used for the Fast treatment.

The design consisted of a comparison between two post slaughter chilling treatments; conventional (Con) and fast (Fast) and consisted of 8 replicates of 4 carcases, consisting of 2 carcases per treatment, selected from 8 different consignments of cross bred merino lambs at a commercial abattoir, all from different vendors. Three replicates were conducted on one day and then another 5 replicates on the day following. The lambs were 5–8 months of age and the hot carcase weight was 20.7 ± 0.60 kg (mean ± SEM) at the time of slaughter. Lambs (n = 32) within a replicate were stratified according to carcase weight to low (19.2 ± 0.65 kg) and high (22.2 ± 0.88 kg) categories then assigned randomly to each treatment within these categories.

2.2. Slaughter details

Lambs from both treatments were electrically stimulated immediately post dressing, about 25 min post stunning, using a portable medium voltage electrical stimulation unit supplied by Applied Sorting Technologies, 5 Kim Close, Bulleen, Victoria, 3105. Each carcase was stimulated individually by applying one electrode to the right front leg and the other electrode to the rear left leg. The setting used was a frequency of 15 Hz, current 1A, and pulse width of 2.5 μs; stimulation was applied for a period of 40 s. Carcases were placed in the chilling treatments immediately after electrical stunning was completed. Con carcases were chilled in a commercial chiller for 24 h (mean air temperature 6.8 ± 0.83 °C), and Fast carcases were placed in the prototype chiller for 3 h (mean air temperature −10.2 ± 0.28 °C), then a commercial chiller for 21 h (mean air temperature 1.9 ± 0.11 °C) thereafter.

2.3. Measurements

Carcases from both treatments were weighed post dressing (HSCW), then 3 h and 24 h after the commencement of chilling. Muscle pH was measured using a TPS W-80 metre (http://www.tps.com.au) attached to a Mettler Toledo LoT406-M6-DXK-S7/25 glass probe electrode and calibrated with standard buffers. Acidity (pH) was measured 0.4 and 0.5 h post slaughter to validate the effectiveness of electrical stimulation that occurred in between these times. Acidity (pH) and temperature of the short loin were also monitored during cooling to compare temperatures at rigor, although the time intervals were slightly different between treatments due to practical difficulties associated with measuring the Fast carcases. Con carcases were measured at 3.4, 6.5, 10.1, 13.2, and 21.3 h and the Fast carcases at 6.9, 18.15 and 19.7 h post slaughter. Low temperature of carcasses in the Fast treatment made prediction of temperature when the pH reached 6 difficult, so a prediction of the pH when the temperature reached 18 °C was used as an alternative. Ultimate pH (pHu) was measured at 6 days post slaughter at the time samples were processed for other meat quality measurements.

Muscle temperature was measured in all carcases at an interval of 1 min for 24 h post slaughter. Muscle temperatures were monitored using Hobo U12-006 4 station external data loggers attached to TMC6-HC 100 mm stainless steel probes. The probes were placed in the loin and hind leg of each carcase with 4 probes and one logger per carcase. For the hind leg the probes were placed parallel to the surface at a depth of 5 mm (surface) and orthogonal to the surface at a depth of 100 mm in the SM, about 10 cm distal to the anus (deep). For the LD the probes were placed at the level of the thoracolumbar junction, parallel to the surface at a depth of 5 mm (surface) and on an acute angle such that the tip was located at a depth of 50 mm approximately. Ambient air temperature was measured every 15 min for each Fast replicate (n = 8) and with 1 logger continuously on each of the 2 days (n = 2) for the Con treatment.

Samples from 3 muscles (LD, SM and ST), were collected one day after slaughter for measurement of shear force, sarcomere length, drip loss and colour stability. At the time of collection they were sliced into appropriate sizes as detailed later, weighed and packed in a plastic vacuum bag.

Shear force samples were cut into 65 g blocks and frozen on day 1 and day 6 after slaughter accordingly. Shear force was measured with a Lloyd (www.lloyd-instruments.co.uk.) TAPlus Texture Analyser (1 kN), using the method described in Pearce (2008). Samples were thawed, cooked in a water bath at 70 °C for 30 min, cut into strips and sheared with an inverted V shaped blade passed through muscle orthogonal to the direction of muscle fibres. Sarcomere length samples were frozen one day after slaughter then measured with a laser diffraction technique described by Bouton, Harris, Ratcliff, and Roberts (1978). Drip loss was measured one day after slaughter by suspending 40 g (approximate) samples in a plastic bag for 24 h at 2 °C then reweighed. Drip loss was expressed as a percentage of the weight change between the initial and final weighing.

Samples for colour measurement were stored at 2 °C for 6 days after slaughter then re-sliced to provide a fresh surface for measurement. Samples were allowed to bloom for 30 min at 2 °C before wrapping with polyvinyl chloride cling wrap (Resinite "DHW" Meat AEP, 3 μ thickness, oxygen transmission rate of 2300–3000 cm^3/100 sq in/24 h) on a black polystyrene foam tray and exposed to simulated retail display for 4 days in a cool room with air temperature kept in the range of −2 to 6 °C. During this time the samples were exposed constantly to an overhead light source provided by 58 W Nelson Fluorescent Meat Display BRB Tubes of 1520 mm in length. This light source was suspended above the table at a sufficient height to provide a light intensity of 1000 lx at the table level. Light intensity was measured with a Dick Smith Electronics Light Meter Q1367.

Colour measurements were conducted in the cool room used for display and samples were left wrapped during measurement. At each reading the measurement was replicated after rotating the spectrophotometer 90° in the horizontal plane. A Hunter Lab Mini Scan (tm) XE Plus (Cat. No. 6352, model No. 45/0-L, reading head diameter 37 mm) was used to measure light reflectance. The light source was set at "D65" with aperture set to 10°. The instrument was calibrated on a black glass then a white enamel tile as directed by the manufacturer's specifications.

Oxy/met was calculated by dividing the percentage of light reflectance at 630 nm by the percentage of light reflectance at 580 nm (Hunt et al., 1991). Luminescence (L*), red green (a*), and blue yellow (b*) colour measurements were made with the same Hunterlab Mini Scan XE Plus instrument using the colour programme. Psychometric hue angle (h) and psychometric chroma (C) were calculated using the equations; Psychometric chroma $C = (a^2 + b^2)^{0.5}$, Psychometric hue $h = \tan^{-1}(b/a)$ (Hunt et al., 1991).

2.4. Statistical analyses

Genstat version 12 was used for all statistical analyses (http://www.vsni.co.uk). Analysis of variance was used to compare treatments (Con, Fast) for carcase weight, shear force, sarcomere length, pH at the time when temperature was 18 °C, and drip loss; with blocking for replicate within kill day. The pH at 18 °C was predicted using the method described in the Sheep CRC operational protocol (Pearce, 2008). For carcase weight the effects of time, treatment (Con, Fast) and the interactions between time and treatment were compared with blocking for replicate within kill day and initial weight as a covariate.