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Effect of ageing prior to freezing on colour stability of ovine longissimus muscle

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ABSTRACT

The effect of different ageing periods (0, 2 and 3 weeks at −1.5 °C) of lamb loins (n = 24) prior to freezing (9, 7 and 6 weeks at −18 °C, respectively) compared to the aged-only (never frozen) lamb for 9 weeks postmortem on colour stability during display was assessed under high-oxygen modified atmosphere (HiOx-MAP; 80% O_2) and oxygen permeable overwrap packaging conditions. The aged/frozen loins and aged-only loins in HiOx-MAP had similar ($P>0.05$) surface redness, colour intensity, and discolouration. Further, no significant difference found in shear force between the loins aged 3 weeks/frozen 6 weeks and the aged-only loins. However, more lipid oxidation ($P<0.05$) was found in the aged-only compared to the aged/frozen loins in HiOx-MAP throughout display. These results suggest that ageing loins prior to freezing would provide equivalent tenderness and colour stability, and better lipid oxidation stability compared to the aged-only loins under HiOx-MAP.

1. Introduction

Prolonging the bright-cherry red colour of fresh meat during retail display is critical to retail meat markets because consumers' meat purchasing decisions significantly rely on the overall appearance of the product. Shoppers' discrimination increases with the accumulation of the oxidized form of myoglobin (metmyoglobin; MMb) on the meat surface (Hood & Riordan, 1973), and consumers will reject meat purchase when 40% of the total myoglobin pigment is in the MMb form on its surface (Kropf, Hunt, & Piske, 1986). There are many intrinsic/extrinsic factors influencing the rate of MMb formation on meat during retail display (Giddings, 1977). Among those factors, the storage conditions including temperature and duration are among the most vital factors affecting the level of MMb accumulation in meat (Ledward, 1985). Moreover, previously frozen-thawed meat exhibited a slower rate of oxygenation — conversion from deoxymyoglobin (DMb) to oxymyoglobin (OMb), and more rapid discolouration than fresh meat cuts during storage (Ben Abdallah, Marchello, & Ahmad, 1999). Lanari, Bevilacqua, and Zaritzky (1990) also found that frozen meat at −25 °C had higher MMb accumulation compared to unfrozen refrigerated beef loins stored at 4 °C.

New Zealand is the world's largest lamb exporter, accounting for 40% of global exports by volume in 2008 (MIA, 2009). Traditionally, New Zealand lamb was exported as a frozen product. However, improvements in hygienic processing, packaging and chilling technologies have allowed New Zealand meat processors to supply chilled unfrozen lamb cuts to overseas markets. Currently, chilled lamb products account for approximately 20% of total New Zealand lamb exports by volume, but they make up 35% of exports by value (MIA, 2009). The chilled prime cuts fetch higher in-market prices than their frozen counterparts because the former is considered a higher quality product having more reliable tenderness, less drip loss and longer retail colour display life. However, recent studies found that the tenderness and drip loss differences between chilled and frozen meat can be narrowed if the meat is aged sufficiently prior to freezing (Farouk, Wiklund, Stuart, & Dobbie, 2009a; Wiklund, Farouk, Stuart, & Dobbie, 2009). Further, the colour of frozen-thawed beef and venison meat can actually be improved by ageing the meat (≥ 3 weeks for beef and 1–2 weeks for venison) prior to freezing when compared to meat frozen at 2 days *post mortem* (Farouk et al., 2009a). In spite of this, there was no published information on tenderness, colour and lipid oxidation stability of lamb meat aged in different periods prior to freezing storage. Therefore, the objectives of the present study were to 1) determine the effect of different ageing periods (0, 2 and 3 weeks) prior to freezing (9, 7 and 6 weeks of frozen storage respectively) on instrumental tenderness, colour, and lipid oxidation stability of lamb loins compared to aged-only never frozen lamb loins (9 weeks) and 2) to compare the influence of different retail packaging conditions — high oxygen modified atmosphere (HiOx-MAP; 80% O_2/20% CO_2) and oxygen permeable overwrap polyvinyl chloride film (PVC) on lamb meat colour stability.

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2. Materials and methods

2.1. Raw materials and sampling procedure

Twenty-four lambs were slaughtered at a commercial abattoir. At 24 h *post mortem*, loins (*M. longissimus dorsi*) from both sides of the long loin saddles (New Zealand Meat Specification Code# 3341) were removed (yielding 48 loins in total = 24 lambs × 2 sides), vacuum-packaged, placed on ice, and transported to the AgResearch Ruakura campus. The loins were randomly allocated to four treatments in groups of 12 paired loins. The four treatments combined different ageing (−1.5 ± 0.2 °C) and freezing (−18 ± 0.2 °C) periods in a total storage period of 9 weeks: 1) frozen 9 weeks; 2) aged 2 weeks and frozen 7 weeks; 3) aged 3 weeks and frozen 6 weeks; and 4) aged 9 weeks (never frozen). One 6-cm thick chop for shear force measurement was cut from the anterior portion of each loin, vacuum packaged, and stored for 9 weeks according to the assigned combination of the four chilling/freezing periods. Then, the remaining loins from each treatment were vacuum packaged and stored for 9 weeks. After the storage, the frozen loins were thawed for 2 days at −1.5 °C prior to the repackaging for retail display. Within each ageing/freezing storage treatment, each loin was cut into six 3-cm thick chops, in which five chops were randomly assigned to high-oxygen modified atmosphere packaging (HiOx-MAP; 80% O_2/20% CO_2) for colour measurements on days 0, 3, 5, 7 and 8, and one chop was for oxygen permeable polyvinyl chloride overwrap film (PVC) for repeated colour measurements during 8 days of retail display. The loin chops were placed in polystyrene food grade trays (Plix FST75, 19 cm × 14 cm × 1.2 cm; Auckland, New Zealand). For HiOx-MAP, each tray was put in a shrinkable bag (BB7L, 30 by 39 cm/an oxygen-transmission rate of 50 cm^3 O_2/m^2/24 h at 23 °C; Cryovac Sealed Air Corporation, Hamilton, New Zealand), and packaged to a high-oxygen modified atmosphere (HiOx-MAP; 80% O_2/20% CO_2, Certified Standard within ± 2%, BOC GASES; Hamilton, New Zealand). HiOx-MAP was accomplished by using a Securepak 10 Controlled Atmosphere Packaging Machine (Securefresh Pacific, Auckland, New Zealand) by applying vacuum, then flushing the package with the gas mixture, and sealing. The gas to meat ratio for the MAP was approximately 2.5:1. For PVC, trays were wrapped with oxygen-permeable polyvinyl chloride film (23,000 $cm^3/O_2/m^2$/24 h at 23 °C). Then, the loin chops were displayed for 8 days at 2 °C under continuous fluorescent natural white light (1350 lx, CRI = 82, Colour temperature = 4000 K; Osram, Auckland, New Zealand).

2.2. pH

The pH of the loins was measured at 24 h *post mortem* and after 9 weeks of storage using a calibrated pH probe (Testo 205 pH meter; Lenzkirch, Germany) inserted directly into the meat. Three different random locations for each loin were measured and averaged for statistical analyses. The calibration of pH electrode was performed with standardized buffers (pH 4.0 and 7.0) prior to each measurement.

2.3. Shear force

The shear force of the loin was measured from each 9-week of ageing/freezing treatment. The loin chop previously packaged in a bag was cooked in a water bath set at 99 °C to an internal temperature of 75 °C (measured by thermocouples) and then immediately placed in ice-water slurry. Once cooled, 10 mm × 10 mm cross section samples (ten replicates for each loin) were cut out from the cooked loin chops and sheared with the MIRINZ Tenderometer (Macfarlane & Marer, 1966). The peak shear force (kg F) was determined.

2.4. Colour measurement

Instrumental surface colour (CIE $L^*a^*b^*$) of loin chops packaged in either HiOx-MAP or PVC during 8 days of retail display was evaluated using a HunterLab MiniScan XE Plus Colour Meter (Illuminant D65, 2.5 cm diameter aperture, 10° standard observer; Hunter Associates Laboratory, Inc., Reston, VA). Calibration was performed by using standard black and white tiles prior to the colour measurement. CIE L^* a^* b^* values were used to calculate saturation index $[(a^{*2} + b^{*2})^{1/2}]$ and hue angle $[(b^*/a^*)^{\tan -1}]$ (AMSA, 1991). Colour was measured at days 0, 3, 5, 7 and 8. Initial display colour at day 0 was measured after blooming for 2 h at 2 °C immediately after 9 weeks of vacuum storage prior to retail packaging into either MAP or PVC. Three different locations for each chop were scanned and averaged for statistical analyses.

2.5. Lipid oxidation

The extent of lipid oxidation of loin chops in HiOx-MAP from three treatments (frozen 9 weeks, aged 3 weeks/frozen 6 weeks, and aged 9 weeks) at the initial (day 0), middle (day 5), and end (day 8) of display period was determined by using the method described by Bergamo, Fedele, Balestrieri, Abrescia, and Ferrara (1998). The aged 2 weeks/frozen 7 weeks treatment was excluded from lipid oxidation measurements due to a limited capability to conduct the assay. In brief, each chop was diced and mixed. Then, approximately 4.5 g of sample were taken and were homogenized with 4.75 ml of distilled water and 0.25 ml of ethanolic butylated hydroxy toluene. The homogenized sample was centrifuged (5 min, 10,000 rpm, radius = 11.5 cm; centrifuge 5810R, Eppendorf, Westbury, NY, USA). The 500 μl of supernatant was mixed with 500 μl of 10% TCA and centrifuged (5 min, 10,000 rpm, radius = 11.5 cm) to remove proteins. Then, 300 μl of supernatant was transferred into 1.5 ml crew cap vials and 700 μl of thiobarbituric acid (TBA) reagent was added. The vials were incubated for 30 min at 90 °C and allowed to cool at room temperature (approximately 22 °C) before injection on the HPLC. The absorption found using HPLC was converted to mg malonaldehyde/kg meat and reported as thiobarbituric acid-reactive substances (TBARS). TBARS level was found using known concentrations of malonaldehyde (MDA) as standard curves.

2.6. Data analyses

The design was a balanced incomplete block design with two of the four storage treatments allocated to both sides from an animal in a saturated arrangement. Within a loin, each sub-sample for different packaging and display time (HiOx-MAP only) was allocated using a Latin Square to account for a location effect along the loin. The data were analyzed using the REML directive of GenStat (12th Edition, 2010; GenStat for Windows, version 12.2.0.3717., VSN International, Oxford) with animal and loin within animal as the random effects, and the treatments, location and sides being the fixed effects. Treatment effects were determined using Wald statistics. Least squares means for all traits of interest were separated (F test, $P<0.05$) by using least significant differences.

3. Results and discussion

3.1. pH

There was no significant difference in initial pH values of the loins at 24 h *post mortem* prior to the aged/frozen storage (Table 1). After 9 weeks of storage, an increase ($P<0.05$) in pH was found for all treatments, where the frozen-only loin had a lower ($P<0.05$) increase in pH (0.08 units) compared to the aged/frozen or aged-only loins (average 0.18 units). Although there were differences ($P<0.05$) in pH