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Effect of different aging temperatures prior to freezing on meat quality attributes of frozen/thawed lamb loins

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ABSTRACT

The objective of this study was to determine the effect of different aging temperatures prior to freezing on quality attributes of frozen/thawed lamb loins. The loins (*M. longissimus lumborum*; $n = 32$) were randomly allocated to one of the four different aging/freezing treatments: aged only (−1.5 °C for 14 days) and aged (−1.5 °C for 14 days, 3 °C for 8 days, or 7 °C for 8 days) then frozen/thawed loins. The loins aged at elevated temperatures (3 °C or 7 °C) for 8 days had equivalent shear force, protein degradation and purge loss values compared to the loins aged at −1.5 °C for 14 days ($P > 0.05$). However, significantly higher drip loss and less color stability were observed in the loins with increasing aging temperatures compared to the loins aged at −1.5 °C. These results suggest that application of elevated aging temperatures could shorten required aging periods prior to freezing, while not adversely affecting tenderness and purge loss of frozen/thawed meat.

1. Introduction

Freezing has been practiced for a long period of time in the meat industry as one of the most effective methods for prolonging shelf-life of meat products (Kiani & Sun, 2011). Although freezing has a merit in terms of preservation, a deterioration of meat quality upon thawing is often observed, primarily due to cell disruption and destruction of muscle fibers caused by extracellular cryo-damage (Sebranek, 1982). It has, however, been reported that quality defects of the frozen/thawed meat could be minimized by aging meat prior to freezing (Farouk, Wiklund, Stuart, & Dobbie, 2009; Kim, Liesse, Kemp, & Balan, 2015; Kim, Frandsen, & Rosenvold, 2011). Several studies have shown that application of aging prior to freezing can provide better or equivalent meat quality attributes such as tenderness, water-holding capacity (less purge/drip loss), and/or color stability of beef, lamb and venison compared to aged-only (never frozen) counterparts (Farouk & Wiklund, 2013; Kim et al., 2015, 2011; Wiklund et al., 2009).

The aging process improves tenderness and/or water-holding capacity (WHC) through the degradation of the cytoskeletal myofibrillar proteins by endogenous proteolytic enzymes and subsequent alteration of the meat ultrastructure (Huff-Lonergan & Lonergan, 2005; Olson, Parrish, & Stromer, 1976). Elevating aging temperatures induces more degradation of cytoskeletal myofibrillar proteins, since the proteolytic enzyme activity is enhanced with an increase in aging temperature (Bechtel & Parrish, 1983; Dransfileld, 1994). In fact, a positive relationship between μ-calpain activity and the increase of aging temperature has been reported (Camou, Marchello, Thompson, Mares, & Goll, 2007). Camou et al. (2007) found that μ-calpain was more active at higher chilling temperatures in five bovine muscles (*longissimus lumborum*, *longissimus thoracis*, *psoas major*, *semimembranosus* and *triceps brachii*) under the same pH condition. Thus, it would be reasonable to hypothesize that by placing the meat at a slightly higher aging temperature (than a typical aging temperature (−1.5 °C) for the aged/frozen meat processing in New Zealand), the required aging times to achieve the minimum threshold of tenderness will be reduced. This will, in turn, result in additional cost savings for meat processors by accelerating the aging process prior to freezing.

Although the positive impact of elevated aging temperatures on meat tenderness development *per se* can be expected (Dransfileld, 1994), little to no research has been undertaken that determines how this affects other important meat quality characteristics, such as WHC and meat display color of frozen/thawed meat. Furthermore, a potential adverse impact of the elevated aging temperature prior to freezing on shelf-life of thawed meat would still need to be evaluated, since storage temperature is one of the most critical factors affecting microbial growth and subsequent meat shelf-life (Borch, Kant-Muermans, & Blixt, 1996; Giannuzzi, Pinotti, & Zaritzky, 1998). Therefore, the objective of the present study was to evaluate the effect of various aging

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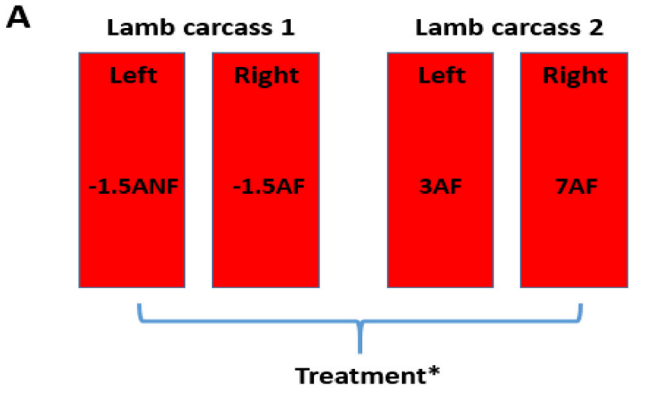
temperatures (−1.5, 3 and 7 °C) with different aging times prior to freezing on meat quality characteristics and shelf-life of aged/frozen/thawed lamb loins.

2. Materials and methods

2.1. Raw materials and processing

At 24 h *postmortem*, both loins (*M. longissimus lumborum*) from 16 lamb carcasses were purchased (yielding 32 loins in total and $pH_{24\ h} < 5.8$), vacuum packaged, placed on ice and transported to the Meat Science Laboratory at AgResearch Ruakura. The loins were assigned to one of the four different aging/freezing conditions as (ANF = aged/never frozen; AF = aged/frozen); 1) aged at −1.5 °C for 14 days (never frozen, −1.5ANF), 2) aged at 3 °C for 8 days then frozen/thawed (3AF), 3) aged at 7 °C for 8 days then frozen/thawed (7AF), 4) aged at −1.5 °C for 14 days then frozen/thawed (−1.5AF) in a saturated arrangement (eight loins per treatment) as shown in Fig. 1. After each aging treatment, the loins assigned for AF were placed in a −18 ± 1 °C freezer (air velocity 1.3 m/s) for 1 week and then thawed at 3 ± 1 °C in a chiller (air velocity 0.25 m/s) overnight. The operating temperatures were monitored using Tinytrag data logger (Gemini Data Loggers Ltd., KoolTrack Inc., Chichester, WS, UK) during aging/freezing/thawing process. After thawing (or chilling only storage for the ANF control), four cuts from each loin were made for evaluating meat quality attributes (purge, drip and cook loss, shear force, and color stability) and Western-blot assays. The pH, aerobic plate count and *Escherichia coli* analyses of loin samples were conducted at 24 h postmortem and after each assigned aging/freezing/thawing treatment.



Treatment*	Ageing	Freezing (1 wk)
1) -1.5ANF	at -1.5°C for 14 days	No freezing
2) -1.5AF	at -1.5°C for 14 days	Frozen/thawed
3) 3AF	at 3°C for 8 days	Frozen/thawed
4) 7AF	at 7°C for 8 days	Frozen/thawed

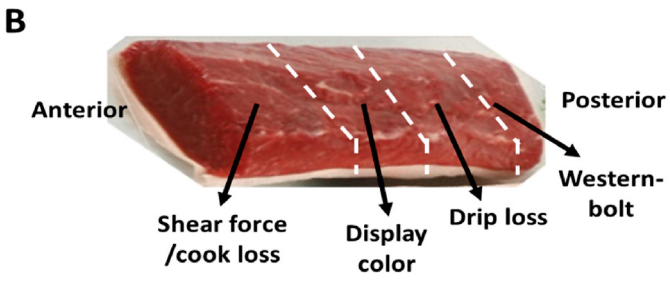


Fig. 1. The schematic figures illustrating the experimental design of the study (A) and subsample allocations (B) of each loin for trait measurements after assigned aging (ANF) or aging/freezing/thawing (AF). The four aging/freezing treatments were allocated to pairs of loins (*M. longissimus lumborum*) from 16 lamb carcasses (a total of 32 loins) in a saturated arrangement as a balanced incomplete block design, where each carcass was used as a block.

2.2. pH

The pH was measured using a calibrated Hanna 99163 pH meter with a FC232D combined pH/temperature probe (Hanna Instruments, Smithfield, RI, USA). The probe was directly inserted into both sides of each loin sample at 24 h *postmortem* and after the assigned aging/freezing storage periods.

2.3. Aerobic Plate Count (APC) and Escherichia coli (E. coli) analyses

To measure APC and *E. coli*, additional separate loin samples for each treatment were used to prevent any confounding cross contamination during the handling process of purge (thaw) loss data collection. The sampling was processed by swabbing a 12.6 cm^2 area of the surface of the lamb loins before or after storage. The APC and *E. coli* analyses were fulfilled using dry rehydratable film (3 M petrifilm aerobic plate count and *E. coli*) and measured by following the procedure of the AOAC proficiency testing program each 990.12 and 991.14 (AOAC, 2005).

2.4. Purge (thaw) and drip loss

Purge loss of the loin samples was measured by recording the initial weight of the loins prior to vacuum packaging. Then, after their assigned aging and/or freezing/thawing, the loins were dried with paper towels and reweighed. The purge (or thaw) loss (%) was calculated from the weight difference between before and after aging/freezing/thawing of the weight of the original sample.

Drip loss was measured by taking a cube portion of each loin sample (about 45 g; dimension = 6 × 3 × 2.5 cm) without any visible fat and connective tissue (Honikel, 1998). The cube was placed in a plastic net and then suspended by a hook in a container. After 48 h of suspension at 3 ± 1 °C, the loin was reweighed. The drip loss was calculated from the weight difference (%) between before and after suspension of meat samples. The combined loss (%) was also calculated by summing each purge and drip loss together.

2.5. Cook loss and shear force

Cook loss was measured by cooking loin cuts (approximately 65 g) in a plastic bag immersed in a water bath set at 99 °C up to an internal temperature of 75 °C using a Digi-Sense scanning temperature logger (Eutech Instruments Pte Ltd., Singapore) fitted with t-type thermocouples positioned at the center of the samples. Once the samples reached 75 °C verified, they were immediately cooled down to 10 °C in ice-water slurry. The weight of the cut was measured before and after cooking. After cooking, each cut surface was blotted with paper towels and reweighed for the loss in weight. The cooking loss was calculated using weight loss as a percentage of the uncooked cut weight. Shear force was measured as described by Chrystall and Devine (1991) and MacFarlane and Marer (1966). The 10 mm × 10 mm cross section meat samples (ten replicates from each sample) were prepared from cooked meat, and shear force (kgF) measured using a MIRINZ Tenderometer (MIRINZ Inc., Hamilton, New Zealand).

2.6. Western-blot

Whole muscle protein was extracted from each sample after the assigned aging/freezing storage periods to quantify the band intensity of desmin, troponin-T and small heat shock protein 27 (sHSP27) by following the procedure described by Lonergan, Huff-Lonergan, Rowe, Kuhlers, and Jungst (2001). After trimming out subcutaneous fat and