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Evaluation of combined effects of ageing period and freezing rate on quality attributes of beef loins

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ABSTRACT

The objective of our study was to evaluate the combined effects of ageing period and different freezing rates on meat quality attributes of beef loins. Pairs of loins (*M. longissimus* at 1 day *post mortem*) from 12 carcasses were divided into four equal portions and randomly assigned to four ageing/freezing treatments (aged only, frozen only, and 3 or 4 weeks ageing at −1.5 °C then frozen). Two freezing methods (fast freezing by calcium chloride immersion or slow freezing by air freezer at −18 °C) were applied to the loin sections. Fast freezing had no effect on shear force ($P > 0.05$), but significantly improved the water-holding capacity of the aged/frozen loins by reducing purge and drip losses. Ageing-then-freezing significantly improved shear force values of loins compared to both the aged only and frozen only loins. These observations suggest that fast freezing will add more value to the aged/frozen/thawed meat by minimising the amount of water-loss due to the freezing/thawing process.

1. Introduction

Freezing is one of the most widely practiced, effective and efficient methods for food preservation. Freezing has been extensively used in the meat industry, as it can maintain a reasonably acceptable level of meat quality for months and even years (Mateo-Oyague & Perez-Chabela, 2004). The freezing process has substantial impacts on the quality attributes of the frozen/thawed meat products. In particular, the rate of freezing plays a crucial role in determining the size and location (or distribution) of ice crystals within the frozen meat tissue (Bevilacqua & Zaritzky, 1980; Bevilacqua, Zaritzky, & Calvelo, 1979), which subsequently influences the quality of the frozen/thawed meat (Leygonie, Britz, & Hoffman, 2012a). It has been generally agreed that slow freezing rates cause the formation of extracellular/large ice crystals within muscle resulting in considerable damage in muscle proteins and cell membranes, consequently diminishing meat quality characteristics (particularly showing unacceptably high moisture loss as purge and/or drip) (Grujić, Petrović, Pikula, & Amidžić, 1993; Hergenreder et al., 2013; Leygonie et al., 2012a; Martino, Otero, Sanz, & Zaritzky, 1998; Petrović, Grujić, & Petrović, 1993). Conversely, fast freezing results in the formation of numerous fine ice crystals, which are uniformly distributed mostly at intracellular levels within muscle (Mateo-Oyague & Perez-Chabela, 2004). Thus, the extent of quality deterioration caused by freezing is relatively less for the fast frozen meat compared to the slow frozen counterpart.

Although the influence of freezing rate on ice crystal formation *per se* is well established, research outcomes of its direct impact on meat quality have not been consistent. While some of the studies showed improved frozen/thawed meat quality attributes (particularly minimised purge and/or drip loss) due to fast freezing rates (Grujić et al., 1993; Ngapo, Babare, Reynolds, & Mawson, 1999a; Petrović et al., 1993; Sacks, Casey, Boshof, & van Zyl, 1993), others did not (Añón & Calvelo, 1980; Hergenreder et al., 2013; Muela, Sañudo, Campo, Medel, & Beltrán, 2010; Ngapo, Babare, Reynolds, & Mawson, 1999b). This inconsistency could be attributed to several critical aspects, such as 1) the subjective definitions of "fast" and "slow" freezing rates, as not all the studies actually measured the freezing rate or the freezing velocity — the time that elapsed from −1.5 °C (beginning of freezing) to −7 °C, where 80% of water in meat tissue is being frozen (Bevilacqua et al., 1979), 2) the different freezing methods used (*e.g.* cryogenic, air blast, freezing tunnel, nitrogen chamber and/or high-pressure-assisted freezing), and 3) *post mortem* ageing time prior to freezing, as substantial changes/improvement in meat tenderness and water-holding capacity occur during ageing through myofibrillar protein degradation (Huff-Lonergan & Lonergan, 2005).

Although numerous studies determined the effects of ageing, freezing, or thawing on meat quality attributes, the combined impacts of ageing and freezing on meat quality characteristics have not been extensively studied. In fact, several recent studies reported that the difference in meat quality, such as tenderness, colour and water-holding capacity, between chilled (never frozen) and frozen/thawed meat can

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be greatly reduced by sufficiently ageing the meat prior to freezing (Farouk, Wiklund, Stuart, & Dobbie, 2009a,b; Kim, Frandsen, & Rosenvold, 2011; Kim, Luc, & Rosenvold, 2013; Wiklund et al., 2009). Therefore, it can be hypothesised that by applying fast freezing (through cryogenic immersion freezing) to aged beef loins, the positive effect of ageing-then-freezing on meat quality attributes will be enhanced by minimising the freezing-related cell/muscle tissue damage. The objective of the current study was to determine the effects of ageing period and freezing rate on meat quality attributes of beef loins.

2. Materials and methods

2.1. Raw materials and processing

Both loins (*M. longissimus lumborum*) from 12 steers (around 2 years old; average carcass weight 300 kg ± 16 kg s.d.) were obtained from a local meat processing plant at 24 h *post mortem*, vacuum packaged, placed on ice, and transported to AgResearch Ruakura campus. On the same day, once the pH was measured, each loin was cut in half to obtain 4 loin sections and randomly assigned to four different ageing (at −1.5 °C)/freezing (at −18 °C) combinations (Fig. 1); 1) ageing for 4 weeks (A4; aged only, never-frozen control), 2) ageing for 4 weeks and then frozen for 2 weeks (A4F2), 3) ageing for 3 weeks and then frozen for 2 weeks (A3F2) and 4) frozen at 1 day *post mortem* and stored for 2 weeks (F2; non-aged control). Prior to freezing, the loin sections assigned for freezing, were halved (average 0.98 kg per section; approximately 7 cm × 16 cm × 8 cm (height × width × length)), vacuum packaged and assigned to either fast or slow freezing treatments.

2.2. Freezing process

The samples assigned to fast freezing were placed in a calcium chloride immersion tank, while the samples assigned to slow freezing were placed in cartons within a conventional air freezer (air velocity 1.3 m/s; operating temperature at −18 °C). The freezing temperature for both fast and slow conditions was monitored using an Agilent HP 75000 Series C Data Acquisition & Control unit (Agilent Technologies Ltd, Englewood, CO, USA), which was fitted with T-type thermocouples mounted in sets of 4 on thin nylon rods — 3 placed within 5 mm of each other to ensure a centre reading temperature, and a 4th inserted just under the sample surface to monitor the surface temperature set and set to record data at 1 min intervals. All thermocouples were checked for calibration at 0 °C in an ice reference prior to use and the difference from zero added/deducted prior to further data analysis. The immersion tank was a 250 l insulated tank fitted with a heat exchanger. The tank heat exchanger was attached to a pump and in turn to an in-house designed refrigeration unit consisting of a Kirby Polar Pack condenser unit (Model PP575SLM-2, manufactured by Heatcraft Australia Pty Ltd, NSW Australia) fitted with a titanium plate heat exchanger (Type M6-MWFG, Alfa Laval NZ Ltd) and PID controller (Model E5CN, OMRON Electronics Inc., Schaumburg, IL, USA). Calcium chloride solution was pumped through the cooling system and also used as the working fluid in the immersion tank, where it was operated at −17 to −18 °C prior to immersion. On reaching the target temperature (−18 °C), the fast frozen loins were then moved to the air freezer (in which the slow frozen loins were frozen) for a further storage period of 2 weeks. Following storage, the frozen loins were thawed overnight at 3 °C in a chiller (air velocity 0.25 m/s) prior to being removed from the vacuum package. After the assigned ageing and/or freezing period, each loin was analysed for pH, water-holding capacity (purge, drip and cook loss), shear force, colour stability and proteolysis.

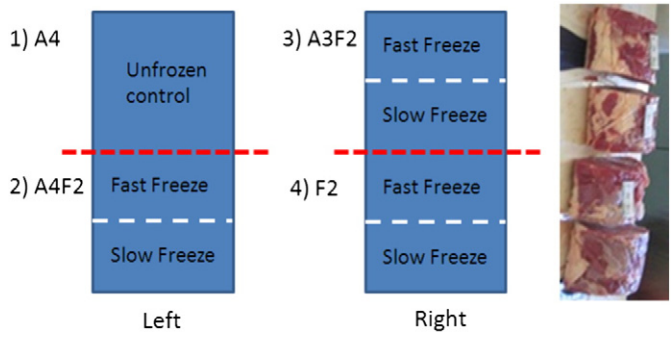

Fig. 1. Schematic figures illustrating the treatment allocation (aged (−1.5 °C)/frozen (−18 °C) treatments[1] and freezing rates[2] (fast and slow)) within both loins (left/right) from a carcass. [1]Treatments: 1) A4 — ageing for 4 weeks, 2) A4F2 — aged 4 weeks/frozen 2 weeks, 3) A3F2 — aged 3 weeks/frozen 2 weeks, and 4) F2 — frozen at 1 day *post mortem* (non-aged control). All frozen loins were thawed overnight at 3 °C prior to being removed from the vacuum package for further analyses. [2]Freezing rate: the beef samples assigned to fast freezing were placed in a calcium chloride immersion tank operated at −17 to −18 °C, while the samples assigned to slow freezing were placed in a conventional air freezer (−18 °C).

2.3. pH

The pH of the loin samples at 1 day *post mortem* and after aged/frozen storage was measured in duplicate by inserting a pH probe (Testo 205 pH meter with a combined temperature and pH insertion probe, Lenzkirch, Germany) directly into the meat.

2.4. Purge and drip loss

The initial weight and after storage weight of each loin section were weighed to obtain the purge loss values. After the assigned storage periods, the loin sections were taken out from the vacuum packages, blotted dry on paper tissues and reweighed to calculate purge loss as the difference between initial weight and final weight.

Drip loss was obtained after each ageing/freezing storage following the procedure of Honikel (1998) with a few modifications. A sample (about 50 g) of meat with any visible fat and connective tissue trimmed out was weighed and then placed in a net and hung by a hook within a closed container. After suspending the samples in the container for 48 h at 4 °C, the sample was blotted dry and reweighed to calculate the percentage drip loss.

2.5. Cook loss and shear force

The loin sample (about 60 g) assigned for the shear force measurement was placed in a plastic bag and cooked in a water bath (set at 99 °C) to an internal temperature of 75 °C (monitored by a Digi-Sense scanning temperature logger with a thermocouple (T-type) placed into the centre of each sample, Eutech Instruments Pte. Ltd., Singapore) and then immediately placed in ice-water slurry. The initial weight and final cooking weight of each loin sample were measured to obtain the cooking loss expressed as a percentage of the original sample weight. For shear force measurement, once the cooked meat in a bag was cooled to below 10 °C, ten replicates of 10 mm × 10 mm cross section samples for each sample were cut out parallel to the fibre direction and sheared with the MIRINZ Tenderometer perpendicular to the fibre direction (Chrystall & Devine, 1991; MacFarlane & Marer, 1966). The average peak shear force (kgF) of ten replicates was calculated.

2.6. Colour stability

A steak (2.4 cm thick) cut from each loin section was placed in a polystyrene food grade tray (Plix FST75, 19 cm × 14 cm × 1.2 cm; Auckland, New Zealand) and wrapped with oxygen-permeable polyvinyl chloride film (23,000 $cm^3/O_2/m^2$/24 h at 23 °C). Then, the steaks were displayed for 7 days at 4 °C under continuous fluorescent natural white light (1350 lx, CRI = 82, colour temperature = 4000 K; Osram, Auckland, New Zealand). On days 1, 4 and 7 of simulated retail display,