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High pressure processing improves the tenderness and quality of hot-boned beef

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ABSTRACT

Strip loins from different grades of cattle were subjected to two levels of high pressure processing (HPP) within 1 h of slaughter at a commercial meat processing plant and chilled for 1 day before freezing. The physical and eating quality characteristics of *longissimus thoracis* (strip loin) steaks from HPP were compared to meat that was chill aged for 1 or 28 days. HPP produced meat after 1 day with 60% lower shear force and higher sensory eating quality scores than 1 day chill aged meat. Extended chill storage for 28 days produced steaks of similar tenderness to HPP meat. HPP also increased the ultimate pH and decreased the cooking loss. Chilled storage of the *gluteus medius* from prime cattle for 28 days significantly improved the shear force by 18%, whilst HPP improved both the shear force by 43% and the sensory eating quality scores. HPP can produce high eating quality eye of rump medallions within 1 day of slaughter.

1. Introduction

High Pressure Processing (HPP) has been utilised by the food industry to extend the shelf life of retail products. Pressures from 400–600 MPpa have been shown to neutralise bacterial activity and pasteurise food (Smelt, 1998). Current HPP machines can batch process large volumes of product and have been used extensively with fresh vegetables, fruit juices and processed food products including meat (Mújica-Paz, Valdez-Fragoso, Samson, Welti-Chanes, & Torres, 2011).

Early work on HPP of meat focussed on improving tenderness (Bouton, Ford, Harris, Macfarlane, & O'Shea, 1977; MacFarlane, 1973) which is recognised as the most important consumer eating quality characteristic. Tenderness is the key determinant of whether consumers are repeat buyers or willing to pay a premium price for products with guaranteed low shear force values (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). However only eight out of forty beef muscles were tender in a meta-analytical study (Sullivan & Calkins, 2011). In addition, many of the animals processed for beef products are from the dairy industry which does not select stock for their meat quality. Cull cows made up 45% of the cattle slaughtered in the 2014/15 season in New Zealand (Beef and Lamb New Zealand, 2016). The remaining animals were 37% prime (steers and heifers) and 18% bulls.

High pressure processing is a clean technology that can tenderise post-*rigor* meat but requires high pressures and high temperatures (Bouton et al., 1977). Unfortunately, under these processing conditions, myoglobin, which is the major determinant of meat colour, is denatured (Carlez, Veciana-Nogues, & Cheftel, 1995). This gives the fresh meat a cooked appearance which does not visually appeal to consumers. Therefore, HPP has not been commercially adopted for tenderising fresh post-*rigor* meat for the retail market although Sikes and Tume (2014) have used 200 MPa and temperatures above 60 °C to develop a heat-only cooked steak product.

MacFarlane (1973) reported in an early HPP paper that pre-*rigor* muscles exposed to pressures below 138 MPa in laboratory equipment produced substantial improvements in meat tenderness. The improvement in tenderness of pre-*rigor* beef with pressures around 100 MPa was confirmed by Kennick, Elgasim, Holmes, and Meyer (1980). In a recent review Ma and Ledward (2013) stated there were potential benefits from high pressure processing pre-*rigor* red meat providing consumers accepted the final retail product. However, to date, it has not been economic to use HPP on pre-*rigor* meat from whole carcasses and the supply of pre-*rigor* meat has also been limited as most meat processors prefer to cold bone post-*rigor* meat. HPP has, therefore, not been applied commercially to fresh meat.

HPP may disrupt structural components of muscles and affect other meat properties in addition to tenderness. For example, pressure induced disruption of myofibrils and protein denaturation has been related to increased water holding capacity in processed meats (Sun & Holley, 2010). HPP also alters the rate and extent of *post mortem* pH fall (MacFarlane, 1973; MacFarlane, McKenzie, & Turner, 1982).

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This pH effect depends on the pressure and temperature used in the HPP treatment. A patent application to use HPP to improve beef quality (Smit, Lea, Summerfield, & Cannon, 2010) indicated that the improvement in quality was linked to the inhibition of glycolysis.

The current research compared the effect of pre-*rigor* HPP on the physical characteristics and eating quality of *longissimus thoracis* and *gluteus medius* from different sex classes of beef. A local meat processor routinely hot bones beef carcasses within 1 h of slaughter and produces a range of pre-*rigor* meat cuts. A commercial HPP machine was installed in one of their plants and the effect of applying different levels of HPP to hot-boned pre-*rigor* strip loins and the eye of rump was compared to prolonged chill ageing for producing high quality prime, cow and bull meat products.

2. Materials and methods

2.1. Processing conditions and quality evaluation

Twelve prime (mean carcass weight 287 kg), six bulls (mean carcass weight 330 kg), and six cows (mean carcass weight 198 kg) were randomly selected at a beef export plant from different producers on the same day, slaughtered and hot-boned by standard industry procedures. A 55 L Hiperbaric HPP machine was installed in the boning room to minimise the time between removal of the strip loins from the carcasses and HPP treatment. All muscles were in the pre-*rigo*r state and vacuum packed prior to receiving high pressure treatment which occurred within 60 min of slaughter. Preliminary experiments with the HPP machine identified suitable operating parameters.

At 50 min post-slaughter the two *longissimus thoracis* (LT) or strip loins were removed from the carcasses and divided into two halves which were individually vacuum packed. These portions were randomly assigned to four different treatments. One portion from each loin was HPP treated for 3 min at 175 MPa (HPP175), another for 2 min at 250 MPa (HPP250) and the remaining two left untreated as controls for 1 day (C1) and 28 days chill ageing (C28). The first three portions (C1, HPP175 and HPP250) were subsequently chilled to – 1 °C, held chilled for 1 day and then frozen at −20 °C. The final portion (C28) was chilled to −1 °C and held chilled for a total of 28 days before freezing at −20 °C. A set of 25 mm steaks was removed from each of the frozen strip loins for shear force measurements and another set of 25 mm steaks for sensory evaluation. The steaks were vacuum packed, randomly labelled and stored at −40 °C.

The rump was also removed from the carcasses of six prime animals randomly selected from the twelve prime animals already identified at 50 min post-slaughter. The eye of rump, *gluteus medius* (GM), was separated and divided into three equal portions. One portion was HPP treated at 175 MPa for 3 min (HPP175) and the remaining two (C1 and C28) left untreated as controls. All portions were chilled to – 1 °C, C1 and HPP175 were held chilled for 1 day and then frozen at −20 °C. C28 was chilled for a total of 28 days before freezing at −20 °C.

The pH of each LT sample was measured at 24 h post slaughter using a Hanna HI9125 pH meter and Ionode spear-tip probe. The LT samples were then weighed (for cook loss calculation), and cooked in a 100 °C water bath to an internal temperature of 75 °C. Samples were immediately cooled to below 4 °C before tenderness assessment. After overnight chilling, samples were dried with a paper towel and reweighed to enable weight loss during cooking to be calculated. Samples were sheared using a G2 Tenderometer (Carne Technologies, New Zealand) that measures the force required to shear through 10 × 10 mm samples at right angles to the fibre direction.

2.2. Sensory evaluation

Frozen *longissimus* steaks from seven prime, six bulls and five cows from the animals already selected were allowed to thaw in a 4 °C refrigerator overnight and then to reach room temperature prior to cooking. The steaks were grilled on a double sided Silex grill, set at 180 °C, until an internal temperature of 65 °C was reached, typically within 6 min, as indicated by a temperature probe inserted into the centre of each steak. The steak was removed, covered in tin foil, rested for 5 min, and was considered to be medium grilled. Eight 25 × 25 mm squares were removed from each grilled steak. Each square, whilst still warm, was allocated randomly to a member of an untrained panel of 96 consumers. Each panellist received 4 different steaks at each sitting in a room designed specifically for the sensory evaluation of food products. Each steak was scored on a continuous scale from 0 to 100 on its tenderness, juiciness, flavour and overall eating acceptability. The scores were inserted into a formula to generate an overall consumer eating score (MQ4) as described by Watson, Gee, Polkinghorne, and Porter (2008) and utilised in a beef grading system (Polkinghorne, Watson, Thompson, & Pethick, 2008).

Each frozen eye of the rump was allowed to thaw in a 4 °C chiller overnight and then to reach room temperature prior to cooking in an oven (Bakbar Turbofan 32Max) set at 190 °C. Up to eight eye of rumps were cooked simultaneously with commercial temperature probes (Cooper Atkins Roasting Thermometer 323) inserted into each rump which was then covered with tin foil. Each rump was roasted to an internal temperature of 65 °C, typically within 60 min, rested for 8 min and then delivered to the sensory room. The roast was considered medium cooked. Each roasted rump was cut into 25 mm thick rump medallions from which eight 25 × 25 mm squares were removed. Each square, whilst still warm, was allocated randomly to a member of an untrained panel of 96 consumers, who sensory evaluated the product as described for the strip loins.

Samples of the rump medallions were analysed for tenderness using a MIRINZ tenderometer (Bickerstaffe, Bekhit, Robertson, Roberts, & Geesink, 2001).

2.3. Statistical analysis

All of the above variables were statistically analysed using the analysis of variance appropriate for a split plot design, with animals at the highest level of the statistical hierarchy (“main plots”) and steaks at the lowest level of the hierarchy (“sub plots”). Stock type (prime, bull, cow) was a “main plot” treatment factor, and treatment (C1, C28, HPP175 and, if present, HPP250) was a “sub plot” treatment factor.

3. Results and discussion

3.1. Effect of HPP on physical qualities of longissimus thoracis

Consumers have identified tenderness as the primary eating quality factor (Dikeman, 1987; Platter et al., 2003). The effect of HPP and 28 day ageing on the tenderness of hot-boned strip loins from all stock are shown in Fig. 1 and Table 1(b). The results illustrate that 28 day chill ageing significantly improved ($p < 0.001$) meat tenderness by 57%, from 12.68 to 5.45 kgF. This was consistent with earlier reports that substantial improvements in tenderness occur after 14 to 24 days of chill ageing (Juarez et al., 2012; Morton, Bickerstaffe, Kent, Dransfield, & Keeley, 1999; Shackelford, Wheeler, & Koohmaraie, 1997; Shanks, Wulf, & Maddock, 2002; Smith, Culp, & Carpenter, 1978). A similar improvement in tenderness of 63% to 4.69 kgF was obtained by HPP175 treatment of the meat followed by 1 day chill ageing. There were no significant differences between the tenderness of steaks produced by the two HPP treatments, but the HPP250 treated steaks at 4.07 kgF were significantly more tender than those chill aged for 28 days ($p < 0.05$). HPP of beef pre-*rigor longissimus thoracis* muscles at 103Mpa was previously observed to improve tenderness (Kennick et al., 1980; MacFarlane, 1973). This is the first study to confirm those results under commercial conditions (Ma & Ledward, 2013; Simonin, Duranton, & de Lamballerie, 2012).

The *longissimus* from bulls was of overall lower quality with the bull