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Influence of HPP conditions on selected beef quality attributes and their stability during chilled storage

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ABSTRACT

The aim of this work was to determine the effects of combined pressure and temperature treatments on beef quality attributes after processing and during chilled storage. Beef M. *pectoralis profundus* samples were pressurised at 400 and 600 MPa at 35, 45 and 55 °C and compared with non-treated (NT) and oven cooked samples. High pressure processing (HPP) at higher temperatures (55 °C) resulted in lower Warner Bratzler Shear Force (WBSF) and cook loss values than processing at 35 °C. Thiobarbituric acid reactive substances (TBARS) values of pressurised samples were lower than cooked samples after processing and throughout refrigerated storage. An increase ($p<0.001$) in the omega 6/omega 3 (n6/n3) fatty acid ratio was found when pressure–temperature treatments were compared to raw samples, however, oven cooked samples presented the highest n6/n3 ratio among all of the treatments examined. The reported results show that HPP alters meat quality to a lesser extent than conventional cooking, thereby minimising the processing impact.

1. Introduction

The growing demand by consumers for more natural, minimally processed convenient food products that are safe, has stimulated food industry interest in high pressure processing (HPP) (Wilson, Dabrowski, Stringer, Moezelaar, & Brocklehurst, 2008). HPP offers a commercially viable alternative to heat and, used in combination with temperature, also appears to be a promising approach for producing shelf stable foods (Balasubramaniam & Farkas, 2008). Previous studies have shown that in addition to being more effective at preventing microbial growth, a combination of HPP and high temperatures is more effective for tenderisation of meat than HPP alone (Ma & Ledward, 2004; Macfarlane, McKenzie, & Turner, 1980; Zamri, Ledward, & Frazier, 2006).

However, pressurisation at high temperatures could have a detrimental effect on other quality attributes. High pressure can modify the structure and function of meat proteins. These changes affect the textural and physiochemical properties of the muscle. Depending on the meat protein system, the pressure, the temperature, and the duration of the pressure treatment, meat can be either tenderised or toughened (Jung, Ghoul, & de Lamballerie-Anton, 2000; Xiang Dong & Richard, 2010). Lipid oxidation is an important meat quality parameter which is affected by HPP. High pressure causes the lipid component of meat to become susceptible to attack by molecular oxygen resulting in lipid oxidation and could also induce alteration of fatty acid composition of meat. Some authors have reported increased levels of lipid oxidation in pressurised meat (Cheah & Ledward, 1996; Ma, Ledward, Zamri, Frazier, & Zhou, 2007).

In an attempt to find the ideal processing conditions the combined effect of high pressure (400–600 MPa) and temperature (35–55 °C) on a range of quality attributes of a low value beef muscle M. *pectoralis profundus* was analysed immediately after processing. The shelf life (colour, lipid oxidation, fatty acid and microbial analysis) of each of these treatments was also analysed. The approach used in this investigation used non-treated and conventionally cooked meat as controls in order to have reference values to compare with pressure–temperature induced changes on meat quality. Thus providing information on pressure–temperature induced changes on meat quality traits compared to heat induced changes.

2. Materials and methods

2.1. Sample preparation

Post-rigor beef *pectoralis profundus* muscles were obtained from a local distribution plant. The animals were fed with concentrated cereal based feed that primarily comprised wheat and barley. Briefly, carcasses from 3 crossbred heifers slaughtered at 22 months of age were hung by the achilles tendon within 1 h of slaughter at 0 °C for 2 days. Muscles were excised, individually vacuum packed and stored at 4 °C until sampling. The head and the tail (posterior and anterior) of each muscle were discarded to minimise variability within a muscle. Muscles were cut across the fibre into steaks (2.5 cm thick). From each muscle a 350 g portion was assigned to each treatment. These

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meat portions were randomly assigned and vacuum packed in polyamide polyethylene bags using a vacuum packaging machine, J-V006W (Jaw Feng Machinery Ltd., Chia Yi County, Taiwan).

2.2. High pressure processing and oven cooking

Vacuum packed samples were treated for 20 min at 400 and 600 MPa, at 35, 45 and 55 °C in a high pressure vessel (100 mm internal diameter, 254 mm internal height, Pressure Engineered System, Temse, Belgium) filled with a mixture of water and rust inhibitor (Dowcal N, 60% v/v in distilled water). Time taken to reach the target pressure was approximately (60–100 s) and depressurisation took 10 s. Temperature in the sample chamber was monitored during processing. Compressive heating during pressurisation led to a temperature variation of ±4 °C. Conventional cooking was performed in a moisture oven; the chamber was set at 72 °C until a core temperature of 70 °C was reached. Non-treated (NT) samples and oven cooked samples were used as controls. Each treatment was carried out in triplicate (i.e. meat from an individual animal equates to one replicate). Sampling for all quality measurements was done the day after treatment (day 1). Additional samples were also taken for colour (after 15 and 30 days of storage) and TBARS, FAA and microbial analysis (after 7, 15, 30 days of storage).

2.3. Cook loss and Warner Bratzler Shear Force (WBSF)

Steaks of 2.5 cm in thickness were cooked in plastic bags in a water bath at 72 °C, until an internal temperature of 70 °C was achieved (AMSA, 1995). A temperature probe, HI 9061 (Hanna Foodcare Digital Thermometer, Bedfordshire, England) placed in the geometric centre of a steak was used to monitor temperature. Samples were allowed to cool and excess moisture was removed with tissue paper. The weight of each sample was recorded before and after cooking. Cook loss was expressed as the percentage of the weight difference after cooking.

WBSF was carried out on the cooked samples according to Wheeler, Shackelford, and Koohmaraie (1996). An Instron Universal testing machine Model 5543 (Instron Ltd., High Wycombe, UK) and Instron Series IX Automated Material Testing System software for windows (Instron Ltd., High Wycombe, UK) were used. Seven cores from each sample were assessed.

2.4. pH measurements

The pH of non-treated and processed samples was measured using a glass probe pH electrode, EC-2010-11 (Refex sensors Ltd., Westport, Co. Mayo, Ireland) by direct insertion into the meat. The average of three measurements was taken for each sample.

2.5. Colour measurements

Samples were exposed to air at room temperature for 10 min prior to analysis. Colour measurements were taken from the cut surface following sampling according to the procedure of Stewart, Zipser, and Watts (1965) using the CIE L*a*b* system with a dual beam xenon flash spectrophotometer (HunterLab Ultra Scan XE, Hunter Associates Laboratories, Inc., Reston, VA). CIE L* (lightness), a* (redness), b* (yellowness) values were recorded. The UltraScan XE was standardised before analysis using black and white tiles. The illuminant (D65, 10°) consisted of an 8° viewing angle and a 10 mm port size. The average of three measurements was taken for each sample.

2.6. Measurement of lipid oxidation

Thiobarbituric acid reactive substances (TBARS) values were measured as an index of lipid oxidation according to Siu and Draper (1978). The TBARS number is expressed as mg of malondialdehyde (MDA) per kilogram of sample. Two independent extracts from each sample were carried out. Three replicates of each treatment were analysed.

2.7. Intramuscular fat content (IMF) content

Samples were homogenised in a Robot Coupe blender (R301 Ultra, Robot Coupe SA). The IMF content of samples was determined using the Smart Trac5 rapid moisture/fat analyser (Smart Trac 5 Model 907875, CEM Corporation, NC, USA) following the manufacturer's instructions. Samples were analysed in duplicate. Results were then expressed as % IMF.

2.8. Fatty acid analysis

Total lipids were extracted using the method of Folch, Lees, and Stanley (1957). Fatty acid methyl esters (FAME) were prepared according to Slover and Lanza (1979). The FAME were analysed by gas chromatography (Varian Star CX3400 GC with a flame ionization detector, Varian Ltd., Walton-on-Thames, UK) and separated using a FAME column (100 m × 0.25 mm i.d., 0.2 μm film thickness, Chrompack, London). The injector and detector ports were set at 270 °C and 300 °C, respectively. The oven temperature program was initially set at 40 °C for the first 2 min, and then employed a variable temperature ramp up to 220 °C where it remained for 3 min followed by an increase up to 240 °C, where it remained for 10 min. The carrier gas was hydrogen and the flow rate of 1.6 ml/min was measured at the initial temperature. Fatty acid methyl esters were identified by comparison of retention times with standards (Sigma Chemical Co. Ltd., Poole, UK). Fatty acids were quantified using tricosanoic acid methyl ester (C23:0), added prior to saponification, as an internal standard. Column response and linearity were checked using a mixture of fatty acids (C16:0, C18:0, C18:1n9, C18:2n6, relative to internal standard C23:0, Sigma Chemical Co. Ltd., Poole, UK).

2.9. Microbiological analysis

Meat samples (10 g) were added to 90 ml of maximum recovery diluent (Oxoid, Basingstoke, England) and homogenised. After appropriate dilutions total viable counts (TVC) were enumerated by pour plating on plate count agar (Oxoid) and incubated at 30 °C for 72 h. Lactic acid bacteria (LAB) were enumerated by plating on MRS agar (Oxoid) and incubated at 37 °C for 24 h; Enterobacteriaceae were enumerated by plating on Violet Red Bile Glucose agar (Merck) and incubated at 30 °C for 24 h. The presence of *Listeria*, *Salmonella* and *Campylobacter* were investigated according to ISO 11290-1:1996, ISO 6579:2002 and ISO 10272-1:2006, respectively. All counts were expressed as log colony forming units per gram of meat (Log 10 CFU/g meat).

2.10. Statistical analysis

Data was analysed using the general linear model (GLM) procedure from the statistical analysis system (SAS) package (SAS 9.1 version, SAS Institute Inc., Cary, NC, USA) with animal as a random effect. Two different models were applied. The first model included treatment as a fixed effect, and was used to assess the effect of processing (NT, HPP and oven cooked) on meat quality parameters. The second model only considered pressurised samples, and was used to assess the effect of the pressurisation conditions applied (pressure and temperature levels) on meat quality traits. Interactions between temperature and pressure were excluded from the second model, and the main effects of pressure and temperature levels on meat quality were assessed. Differences were assessed using the Tukey test. The level of significance was set at $p<0.05$.