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Application of high pressure processing to improve the functional properties of pale, soft, and exudative (PSE)-like turkey meat

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ABSTRACT

Improvement of functional and rheological properties of turkey breast meat proteins with different ultimate pHs at 24 h post-mortem (pH_{24}) was attempted using high pressure processing (up to 200 MPa for 5 min at 4 °C). Pressures of 50 and 100 MPa were found to increase the water holding capacity of low pH meat. At these pressures, higher protein surface hydrophobicity and greater exposure of sulfhydryl groups were evident. These elements may have contributed to improved water retention properties of the treated protein. The formation of a better gel network was also evident at 50 and 100 MPa as revealed by the dynamic viscoelastic behavior. Application of high pressure significantly ($P<0.05$) increased total protein solubility in both low and normal pH meats. Aggregation of myofibrillar proteins increased in low pH meat at higher pressure (200 MPa) as revealed by SDS-PAGE profile.

Industrial relevance: A major concern in the poultry industry is reduced meat functionality, such as low water holding capacity (WHC) in low pH poultry meat leading to reduced yield causing economic loss in the production of further processed products. An alternative technology to reduce salt and improve water retention properties is by the application of high pressure processing (HPP) to produce healthier food products.

1. Introduction

Global turkey production has been growing steadily worldwide over the past few decades. Traditionally the poultry industry market was primarily on whole birds and cut-up products. More recently, processors have adapted to changing trends as consumers increase their demand for more convenient, ready to eat products (Poultry Marketplace, 2010). Increasing occurrence of a pale, soft, exudative (PSE)-like meat condition in turkeys, similar to the one observed in pigs, has become a major concern in the poultry industry since it affects important meat quality attributes involved in the production of value-added products. In pigs, the combination of rapid post-mortem pH decline and high carcass temperature causes protein denaturation in the muscle, which leads to reduced protein functionality, such as decreased water holding capacity (WHC) (Santos, Roseiro, Goncalves, & Melo, 1994). The condition in poultry seems to be more related to the extent of post-mortem acidification (i.e. low pH at 24 h) rather than fast post-mortem pH decline after slaughter (Fraqueza, Cardoso, Ferreira, & Barreto, 2006). It has also been shown that in broilers, low post-mortem muscle pH led to decreased WHC and weaker gel formation (Zhang & Barbut, 2005). Thus, reduced protein functionality in low pH poultry meat may have serious consequences. It leads to an estimated economic loss of more than U.S. $200,000,000 per year in the turkey industry in further processed products (Owens, Alvarado, & Sams, 2009). The suitability of PSE meat can be increased for the production of these products by varying processing conditions such as marination with salt or phosphates using tumblers or injectors to increase the juiciness (Barbut, 2009). However, the addition of these ingredients may pose a problem for consumers due to health consciousness and a demand for additive-free products.

High pressure processing (HPP) is currently being used by the meat industry as a post-processing technology to extend shelf life and improve the safety of ready to eat meat products (Jofré, Garriga, & Aymerich, 2008). High pressure (up to 1000 MPa) can affect protein conformation and may lead to protein denaturation, aggregation or gelation, depending on factors, such as the protein system, applied pressure and temperature, and the duration of the pressure treatment (Messens, VanCamp, & Huyghebaert, 1997). High pressure processing can also be used as a means to improve the functional properties of muscle proteins (Macfarlane, 1974). An important aspect in meat processing is the solubility of the proteins as it is related to many of their functional properties. Studies reported that low pressure treatment at 150 MPa and 200 MPa increased the protein solubility of sheep myofibrillar proteins (Macfarlane, 1974) and chicken myofibrils (Iwasaki, Noshiroya, Saitoh, Okano, & Yamamoto, 2006), respectively. Partial replacement of additives such as NaCl and polyphosphates is possible using high pressure processing, since it

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has a similar effect on myofibrillar proteins as the additives. A recent study conducted by Sikes, Tobin, and Tume (2009) reported a large increase in myofibrillar protein solubility and improvement in water retention of cooked products and textural properties of low-salt beef sausage batters with the application of high pressure up to 400 MPa. Hence, it has been shown that high pressure processing is effective in improving the functional properties of proteins, while allowing low salt levels to be used in food processing of various meat products.

Previous studies have shown that lower muscle pH is associated with lower water holding capacity, as evident in pale turkey meat (Barbut, 1993; Fraqueza et al., 2006). High pressure processing may induce changes in low pH turkey breast meat proteins to positively influence water holding capacity. We hypothesize that high pressure processing used at low pressure levels (50–200 MPa) for short time as a pre-treatment before thermal processing, can improve the water retention potential of meat proteins. In fact, pre-treatment using high pressure processing (50–300 MPa) before cooking has been shown to improve gel forming ability in fish surimi (Hsu & Jao, 2007). To our knowledge, no studies have been reported on improving protein functionality of PSE-like turkey breast meat with the application of high pressure processing. Hence, the aim of this work was to study the effects of high pressure processing on turkey breast meat with low and normal pH at 24 h post-mortem and its relationship with pressure induced changes on protein functionality.

2. Materials and methods

2.1. Sample selection

Turkeys were slaughtered at 106 day of age and the average flock weight was 11.1 kg. A total number of 35 skinless, boneless breast fillets from Hybrid Tom turkeys were initially selected from a local processing plant (Lilydale Inc., Edmonton, Alberta, Canada) at 24 h post-mortem. They consisted of 26 pale and 9 normal fillets. Selection was made using color measurement based on lightness (L*) values as reported by Zhang and Barbut (2005). The samples were labeled and placed individually in plastic bags, packed on ice and transported to the laboratory. L* values and ultimate pH at 24 h post-mortem (pH_{24}) were measured again on all 35 breast samples in the laboratory. Eight breast samples were further selected within each class (pale and normal), according to their pH_{24}. In this experiment, two classes of meat with different pHs were selected because ultimate pH has been indicated as a valid tool to differentiate protein functionality. In summary, the color and pH characteristics are reported in Table 1. The average L* and pH values of the samples were within the following range: pale ($L^*>52$, $pH\leq5.7$) and normal ($46<L^*<52$, $pH\geq6.0$) and referred to as low and normal pH meats, respectively. Each fillet was labeled according to the class and was minced individually in a Kitchen-Aid food processor (Model KFP 7500B, KitchenAid, St. Joseph, MI, USA) for 2 min. The food processor was pre-chilled and operated in a cold room (4 °C) to prevent the temperature of the samples exceeding 10 °C throughout the mixing process. The samples within each class were then mixed homogeneously to obtain two batters of low and normal pH meats. The average pH values of low and normal pH meat batters were 5.75 ± 0.06 and 6.01 ± 0.03, respectively. All the analyses were carried out in frozen meat samples that were vacuum packaged in polyethylene bags and stored at −30 °C for 3 weeks and thawed overnight at 4 °C.

Table 1
Physical properties of low and normal pH meats*.

Measurement	Class of meat	
	Low pH meat	Normal pH meat
L* (24 h)	52.1 ± 0.9^a	46.4 ± 0.8^b
a* (24 h)	2.9 ± 0.3^b	5.3 ± 0.8^a
b* (24 h)	0.84 ± 0.90^a	-0.22 ± 0.77^b
pH_{24}	5.68 ± 0.09^b	6.08 ± 0.10^a

Means within each row with no common superscript differ significantly ($P<0.05$). L* = lightness; a* = redness; b* = yellowness; and pH_{24} = ultimate pH at 24 h post-mortem.

* Results are presented as means ± standard deviations (n = 8).

2.2. Color measurements

The colorimeter, Minolta CR-400 (Konica Minolta Sensing Americas, Inc., Ramsey, NJ 07446) was calibrated using a standard white ceramic tile. Color was measured on the internal side of turkey breasts in an area free of obvious color defects to get a uniform color reading with illuminant D65 as the light source. L*, a* and b* refer to lightness, redness, and yellowness, respectively.

2.3. pH measurements

Approximately 5 g of minced turkey breast meat was homogenized with 45 mL of distilled water and the pH of the homogenate was determined using a pH meter (UB-10, Ultra Basic pH meter, Denver Instrument, Bohemia, NY, USA).

2.4. Meat batter formulation for high pressure processing

The formulation of batters used in this study was chosen based on a preliminary study conducted in our laboratory. Batters were prepared with NaCl (0.5% w/w) and varying concentrations of water (10, 20 and 30%) and subjected to high pressure at 100 and 200 MPa. Results showed that high pressure at 100 MPa increased protein solubility and improved water holding capacity of batters with 10% water compared to all other batters with no pressure treatment (control) and pressure treatment at 100 and 200 MPa. Thus, the optimal batter formulation for this study was determined to contain 10% water. Raw meat batters were prepared by comminuting minced turkey meat (89.5%) with water (10%) and NaCl (0.5%) using a motor and pestle. During preparation, the batter was maintained at a temperature of less than 10 °C. The batters were then filled into cryovials (12.0 mm-diameter and 24.0 mm-height) of 2 mL capacity for high pressure treatments.

2.5. High pressure processing

Pressure treatments were performed using a U111 high pressure multivessel apparatus (UNIPRESS Equipment Division, Warsaw, Poland), which has a maximum pressure limit of 800 MPa and is capable of operating with temperature between 0 °C and 120 °C. The apparatus has four pressure chambers to hold samples, each with a maximum sample envelope dimension of 12.4 mm-diameter and 60.0 mm-height. The pressure medium used in the sample chambers was propylene glycol. The apparatus is thermostated by a heat exchanger connected to an external circulator. The temperature was maintained by a thermostating circulator bath (Lauda Proline RP 855 Low Temperature Thermostat, GMBH & Co. Lauda-Konigshofen, Germany). The apparatus has one high pressure transducer between the intensifier and the vessels, which monitored the pressure profile during treatment cycles. The batters were subjected to 50, 100, 150 and 200 MPa at 4 °C and were held for 5 min. The time required to reach pressure was 20, 30, 38, and 43 s for 50, 100, 150, and 200 MPa, respectively. All samples were then kept at 4 °C for analyses.

2.6. Protein solubility

Sarcoplasmic and total protein solubilities were determined according to the method as described by Van Laack, Liu, Smith, and Loveday (2000) with modifications. For sarcoplasmic protein solubility, 2 g of meat was homogenized with 40 mL 0.03 M phosphate buffer (pH