



ORIGINAL SCIENTIFIC PAPER

The effect of high pressure treatment on the quality of chicken breast meat

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Abstract

In the present work, the effect of high pressure processing (HPP) (0, 100, 200 and 300 MPa) and different treatment time (5 and 10 minutes) on the moisture uptake, cooking yield, colour and texture, as well as microbial population of chicken breast fillets was investigated. The application of high hydrostatic pressure resulted in a modification of quality parameters of chicken breast meat. By increasing pressure and time of the treatment the moisture uptake was reduced: samples treated with 300 MPa for 10 min had the lowest moisture uptake values. Cooking yield was not affected by HPP treatments. Increased pressure affected the colour by increasing L^* , a^* and b^* values (only HPP treatment of 100 MPa in duration of 5 and 10 minutes did not affect colour of chicken breast meat). Lower pressures (100 and 200 MPa) tenderized, whereas elevated pressure (300 MPa) increased hardness in chicken breast fillets. Higher level of pressure (300 MPa) reduced bacteria count by about 3.0 – 5.3 log (CFU/g), depending on the microorganism and duration of the process.

Keywords: high pressure processing, chicken breast meat, muscle colour, meat quality, meat safety

Introduction

High pressure processing (HPP) is considered a novel food technology that has gained popularity in the last two decades. HPP is most widely used for its ability to significantly reduce food borne illness causing pathogens (Carlez et al, 1993; Hayman et al, 2004). Besides food safety, research has indicated that HPP may offer other benefits to meat properties. Recently, use of high pressure in combination with lower temperature is attracting food scientists to consider new applications of this technology. Kimura et al (1994) stated that advantages of high pressure processing on foods include a lack of effect on flavour, colour and vitamins. High-pressure processing may also affect some other important product qualities, such as changes in the colour and texture of foods, which might influence their consumers' acceptability. Functional properties of muscle proteins could be improved by high pressure treatment. This may be due to the increase in moisture-protein or protein-protein interactions (Hong et al, 2005). Improvement of water-binding properties of meat due to high pressure processing shows its importance in meat processing where this is one of the key characteristics required (Hong et al, 2005). However, this may further affect the colour of such products which may have a negative impact on their appeal. Hence it is interesting to know how high pressure processing influences the colour of chicken breast meat. In fresh meat, the application of low pressure levels can be used to improve the functional and rheological properties of meat. High pressure in the food industry is typically used in the range of 200 to 800 MPa (de Lamballerie-Anton et al, 2002). Food products that are subjected to high pressure processing are usually packed under vacuum in a flexible package and put in a pressurized container. Previous investigations have indicated that pressurization level (MPa), time, and pressurization liquid temperature provide great variability in changes that meat properties undergo (Souza et al, 2011). In order to determine how to obtain the ideal changes in meat properties, HPP conditions must be further investigated. High pressure treatment is

an effective technology in reducing bacterial spoilage and extending shelf-life of chicken breast fillet, especially when used high pressures, however it may have a negative impact on some quality characteristics (Kruk et al, 2011). So, the purpose of this study was to investigate the effects of high hydrostatic pressure processing conditions (with low pressures of 100, 200 and 300 MPa) on the physical properties and microbial population of non-treated and HPP-treated white meat products, using chicken breasts as a testing meat. The results would provide information to understand the relationship between the changes of the physical properties of non-treated and HPP-treated meat, such as moisture uptake, cooking yield, colour, and texture properties subjected to different HPP conditions (pressure and treatment time) at 4 °C as well as microbial growth.

Materials and methods

Sample Preparation

Commercially available chicken breast fillets were purchased from the local market (Vindija, Varaždin) and transported to the laboratory under chilled conditions. All samples were from the same producer and chickens were raised under same conditions. Upon arrival, whole chicken breast fillets were individually vacuum-packaged in polyamide polyethylene bags (Dora-Pak d.o.o., Croatia) and stored at 4°C and processed within 24 hours.

High Pressure Treatment

The samples were subjected to high pressure treatments of 100, 200 and 300 MPa for 5 and 10 minutes in a high pressure vessel (Stansted Fluid Power Ltd., Stansted, UK). The HPP unit is equipped with a built in thermocouple to control temperature of compression fluid (propylene glycol: water = 3:1). The initial temperature of the packaged samples was equilibrated to 4 °C. Non treated samples were kept as a control. After treatment, the samples were stored at 4°C until the measurements were performed.

Colour Instrumental Measurement

Breast meat surface colour was measured using a Minolta CM-700d (Osaka, Japan) spectrophotometer equipped with illuminant D65 10° standard observer, 8 mm aperture, with open cone. Prior to analysis, the spectrophotometer was calibrated to the white plate (White Calibration Cap CM-A177). The L* (lightness), a* (redness), and b* (yellowness) colour was measured (CIE, Commission Internationale de l'Eclairage, 1976). Before analysis spectrophotometer was calibrated with White Calibration Cap CM-A177.

Moisture Uptake and Cooking Yield

Moisture Uptake and Cooking Yield were determined by the method of Van Laack et al (2000). 6 g homogenised breast meat was weighed into a 50 mL plastic test tube. After addition of 10 mL 3.5% NaCl solution, the tube was capped and shaken vigorously for 15 s. The suspensions were incubated at 25 °C for 30 min and were centrifuged (15 min, 3,000 × g). Subsequently, the supernatant was discarded, the tube was thoroughly drained, weight of tube and pellet was assessed, and moisture uptake was calculated as follows:

$$[(\text{weight pellet} + \text{tube}) - \text{weight tube} - 6.00] / 6.00 \times 100 = \text{moisture uptake (\%)}$$

After weighing, the tubes were recapped loosely and incubated for 20 min at 80 °C. Following this cooking, the juices were poured off, the tubes were thoroughly drained and weighed, and cooking yield was calculated as follows:

$$[(\text{weight pellet} + \text{tube}) - \text{weight tube}] / 6.00 \times 100 = \text{cooking yield (\%)}$$

Texture Profile Analysis

Texture (hardness, chewiness, elasticity and shear force) was measured by using an TA. HD plus Texture Analyzer (Stable Micro Systems, UK) equipped with a blade knife. Freshly prepared meat samples were cut into pieces (diameter 3.0 cm, height 2.0 cm), and the measurement speed was set at 1.00 mm/s and a load cell of 30 kg. Texture analysis was automatically performed by the texture expert software (version 4.0.12.0. Stable Micro Systems Ltd.), and following parameters were recorded: hardness (N), elasticity (mm), chewiness (mJ) and shear force (Ncm²). Analyses were carried out at room temperature (21–23 °C) on five samples of chicken breast fillets per treatment.

Microbial Analysis

Salmonella sp. 3064, *Escherichia coli* 3014, and *Listeria monocytogenes* ATTC 23074 were obtained from the Collection of Microorganisms of the Laboratory of General Microbiology and Food Microbiology, Faculty of Food Technology and Biotechnology, University of Zagreb (Zagreb, Croatia). They were stored at –70 °C in the Nutrition broth (Biolife, Milano, Italy) with 30% (v/v) glycerol. To prepare inoculum, the bacteria were cultivated at 37 °C for 24 h in a Nutrition broth.

Pathogens Inoculation

Chicken breast filletes (10 g) were surface-sterilized with 70 % (v/v) ethanol, air dried and inoculated with 0.1 mL of pathogen bacterial suspension containing 10⁶ – 10⁷ CFU/mL. After inoculations chicken breast filletes were vacuum-packaged in polyamide polyethylene bags and stored at 4 °C .

Microbiological Counts

After high pressure treatment 10 grams of each sample was homogenised in 90 mL of sterile 0.88% NaCl solution for 3 min using a Stomaher Lab Blender (Labox 33, Metal, Zagreb, Croatia) and serially diluted before plating (pure plate and spread plate methods) on selective media. Methods for the enumeration of bacteria were performed according to the ISO standards as follows: Aerobic mesophilic bacteria HRN EN ISO 4833-1:2013; *Salmonella* sp. HRN ISO 6579:2002; *E. coli* HRN ISO 16649-2:2001 and *L. monocytogenes* HRN EN ISO 11290-2:2008. The results of microbial growth are expressed as the logarithm of colony forming units (log CFU/g).

Statistical Analysis

One-way ANOVA was carried out using SPSS program Win 9.0 software (SPSS Inc., Chicago, IL, USA). Treatment (pressure) was the only design effect in this trial and was tested as a fixed level factor. Differences between means were assessed using Tukey's test, the significance being assigned at P<0.05.

Results and discussion

The effect of high pressure on meat colour, moisture uptake and cooking yield

The colour of fresh meat is one the most important evaluation parameters consumers use when purchasing. Chicken meat colour is variable, and dependent on factors such as diet, slaughter methods and storage conditions (Del Olmo et al, 2010). Effect of HPP treatment parameters (pressure and time) on colour of chicken breast meat is shown in Table 1. HPP treatment influenced the three colour parameters determined on chicken breast fillets, which showed a significant difference (P<0.05) between HP treated and control fillets. L* value increases with increasing pressure regardless of the time of the treatment. Pressure of 100 MPa in duration of 5 and 10 minutes did not affect L* value (52.32 to 52.60) when comparing it with the control samples (49.76). When fillets were subjected to treatment of 200 MPa L* value increased (63.88



to 64.50) while samples treated with 300 MPa had the lightest colour (the highest L* values in the range from 74.80 to 76.93). Similar, pressure of 300 MPa resulted in increment of a* value while pressure of 100 and 200 MPa lowered a* value. In the case of b* parameter, which had an initial value of 7.27, high-pressure of 100 MPa did not affect this value and was in range from 6.13 to 7.44 while pressure of 200 and 300 MPa (regardless of the time of treatment) resulted in significantly higher values, which ranged from 11.79 to 12.74 and from 13.69 to 14.48, respectively. Based on obtained results for colour measurement it can be concluded that HPP treatment of 100 MPa in duration of 5 and 10 minutes did not affect colour of chicken breast meat.

In some research, the use of HPP has decreased meat colour score (Carlez et al, 1993; Jung et al, 2003). It is generally regarded that pressure levels greater than 200 MPa result in the denaturation of sarcoplasmic and myofibrillar proteins resulting in meat colour changes (Carlez et al, 1995; Jung et al, 2003). When pressure was greater than 150 MPa L* values increased (appearing lighter) and a* decreased (less red) (Carlez et al, 1993). Carlez et al (1995) found results similar to their earlier research, but further concluded that pressure at or above 200 MPa causes a „whitening“ effect to the meat. An increase in lightness

(L*), for pressures above 200 MPa, is the most often reported modification of raw meat colour. The increase in L* results in a whitening effect and has been observed in chicken meat treated at 400 to 500 MPa at 5 to 10 °C, in pork meat treated at 200 to 400 MPa at 20 °C, and in beef meat treated at 200 to 600 MPa at 10 °C (Simonin et al, 2012). This whitening effect has been related to either (i) protein coagulation with a resulting loss of solubility of sarcoplasmic and/or myofibrillar proteins that affect structure and surface properties; or (ii) globin denaturation and heme group displacement or release (Simonin et al, 2012). In general, HPP colour induced-changes vary according to the myoglobin content and are more dramatic for fresh red meat than for white meat and cured meat products. Undesired changes can be limited by optimizing the process parameters of HPP treatment such as pressure, time, temperature, curing, oxygen removal and the increased pH (Bajović, 2010). When looking for a reduction of the colour changes induced by HPP, one should keep in mind that measures to protect the colour quality and stability can result in changed microbial inactivation kinetics and thus safety and shelf-life of the final product.

Table 1. Effect of HPP treatment parameters (pressure and time) on colour, moisture uptake and cooking yield of chicken breast meat.

Time (min)	Control ¹	5			10			SEM ²
		100	200	300	100	200	300	
L*	49.76 ^a	52.32 ^a	63.88 ^b	74.80 ^c	52.60 ^a	64.50 ^b	76.93 ^c	1.526
a*	0.13 ^{abc}	-1.34 ^a	-0.66 ^a	2.87 ^c	-0.33 ^{ab}	1.01 ^{abc}	2.05 ^{bc}	0.140
b*	7.27 ^a	7.44 ^a	11.79 ^b	13.69 ^b	6.13 ^a	12.74 ^b	14.48 ^b	0.493
moisture uptake (%)	27.21 ^{cd}	31.21 ^d	22.38 ^{bc}	19.85 ^{ab}	24.92 ^{cde}	24.99 ^{bc}	15.59 ^a	0.724
cooking yield (%)	91.63	95.96	90.25	83.86	95.21	86.82	81.05	0.803

¹ Control is the sample without HPP treatment

² SEM standard errors of the mean

^{a,b,c,d} Means within a row without a common superscript differ significantly ($P < 0.05$)

Monitoring the changes of water holding capacity is essential for controlling the quality of meat products. Lean muscles consist of approximately 75% water of which majority is held within the structure of the muscle and muscle cells. Therefore, any treatment affecting structural changes in the muscle can cause the release of water entrapped within the muscle structures. HPP has been shown to influence the structure and function of muscle proteins (Kruk et al, 2011). With increased pressure muscle fibres become finer and more compact (Kim et al, 2007). The ability of meat to retain water is an important quality attribute both commercially and also in terms of consumer acceptance. No significant effect ($P > 0.05$) on cooking yield was observed between control (non-treated samples) and the other treatments (Table 1). This is in accordance with the literature where HPP treated meat between 200 and 300 MPa appear to indicate that, there is no general trend for protein denaturation and cook loss (Cheftel and Culioli, 1997) since cooking loss percentages have been reported to be increased (McArdle et al, 2010), decreased (Souza et al, 2011) or not significantly affected (Kruk et al, 2011). Moisture uptake showed statistic significant differences ($P < 0.05$) and samples treated with 300 MPa for 10 min had the lowest moisture uptake values. Pressure of 100 MPa in duration of 5 and 10

minutes did not affect moisture uptake while treatment of 200 MPa had a bit lower values than non-treated samples. Cooking yield was not affected by HPP treatment. Results of moisture uptake showed statistic significant differences ($P < 0.05$). Research of Kruk et al (2011) showed that chicken breast fillets and the pressure of 300 MPa caused a significant increase of moisture content; however, the cooking loss was not significantly different than the control. Only a higher pressure of 450 and 600 MPa significantly increased cooking loss by 6.4 and 19.7%, respectively.

The effect of high pressure on texture of chicken breast meat

The textural profiles were assessed as hardness, chewiness, elasticity and shear force. Except for the elasticity, all other parameters have shown significant difference ($P < 0.05$) between control and treated samples. Pressure of 100 MPa in duration of 5 minutes had the lowest

hardness (67.89 N). Low pressures (100 and 200 MPa) tenderized, whereas elevated pressure (300 MPa) increased hardness in chicken breast fillets (Table 2). The HPP effects on meat hardness are dependent on rigor stage, pressure, temperature and their combination. In general, low pressures (<200 MPa) can tenderize pre-rigor meat, whereas tenderization post-rigor with HPP can only be achieved by higher temperatures (Sun and Holley, 2010). Hardness is an important texture attribute to consumers and dictates the commercial value of meats (Kruk et al, 2014). Many researchers reported that the texture profile of meat, especially hardness, increased significantly with an increase of pressure. Chewiness was decreased by pressure of 100 MPa in duration of 5 minutes while in duration of 10 minutes had values similar to control. By increasing pressure and time of the treatment chewiness increases so the samples treated with 300 MPa in duration of 10 minutes had the highest values (80092.90 mJ). Our texture analysis results are in agreement with other studies. Villacis et al (2008) reported that when turkey breast muscles were treated with pressure above 150 MPa, product hardness, gumminess, and chewiness values increased with increasing

pressure. Cohesiveness also increased with the pressure holding time for all pressures. Master et al (2000) showed that hardness of fish increased as a result of high pressure processing at 200 and 400 MPa. A similar effect of increased pressure on hardness was observed in beef muscle (Ma and Ledward, 2004) and chicken breast meat (Kruk et al, 2011). Kruk et al (2011) showed that hardness increased significantly at 450 MPa and was not different from 600 MPa pressure. A similar trend was observed for chewiness. Cohesiveness significantly increased at 300 MPa and was not different from 450 to 600 MPa, whereas gumminess significantly increased at 450 and 600 MPa compared to controls, but was not different from 300 MPa pressure treatments (Kruk et al, 2011). On the other hand, Suzuki et al (1990) reported that pressures of 150 MPa or higher achieved tenderization effect on beef by fragmentation of myofibrillar proteins and reduction of gap filament integrity. Samples treated with pressure of 100 (103.33; 120.15 Ncm⁻²) and 200 (116.22; 110.91 Ncm⁻²) MPa had lower while samples treated with 300 MPa had higher (145.77; 126.29 Ncm⁻²) values for shear force than control (121.37 Ncm⁻²) (Table 2).

Table 2. Effect of HPP treatment parameters (pressure and time) on texture of chicken breast meat.

Time (min)	5			10			SEM ²	
HPP (MPa)	Control ¹	100	200	300	100	200	300	
Hardness (N)	88.85 ^{bc}	67.89 ^a	84.08 ^{ab}	103.12 ^c	86.84 ^{bc}	93.27 ^{bc}	99.77 ^{bc}	1.658
Elasticity (mm)	33.98	28.92	28.27	43.28	30.94	37.04	35.55	0.751
Chewiness (mJ)	62661.60 ^b	51456.99 ^a	65537.12 ^c	75836.55 ^e	64252.21 ^{bc}	70187.22 ^d	80092.90 ^f	1342.166
Shear force (Ncm ⁻²)	121.37 ^{ab}	103.33 ^a	116.22 ^{ab}	145.77 ^b	120.15 ^{ab}	110.91 ^{ab}	126.29 ^{ab}	1.915

¹ Control is the sample without HPP treatment

² SEM standard errors of the mean

^{a,b,c,d,e,f} Means within a row without a common superscript differ significantly ($P < 0.05$)

The effect of high pressure on pathogen survival

Effect of high processing at 4°C on microbial populations (log CFU/g) of chicken breast fillet is shown in Table 3. The application of 100 and 200 MPa reduced the number of aerobic mesophilic bacteria and pathogens for about 2 to 3 log units depending on the duration of the process of 5 and 10 minutes (Table 3).

Table 3. Effect of high processing at 4°C on microbial populations (log CFU/g) of chicken breast fillet.

Samples	log CFU/g						SEM ⁵	
	Initial number	100 MPa		200 MPa		300 MPa		
		5min	10min	5min	10min	5min	10min	
Meat ¹	5.30 ^f	3.62 ^c	3.45 ^c	3.11 ^d	2.34 ^c	1.84 ^b	1.15 ^a	0.194
Meat+L.m. ²	6.43 ^e	4.38 ^d	4.15 ^d	4.18 ^d	3.83 ^c	3.54 ^b	3.00 ^a	0.155
Meat+E.c. ³	7.54 ^e	4.86 ^d	4.76 ^{cd}	4.79 ^d	4.63 ^c	3.81 ^b	3.48 ^a	0.187
Meat+S ⁴	7.46 ^f	4.91 ^c	4.81 ^{de}	4.72 ^d	4.45 ^c	3.43 ^b	2.08 ^a	0.234

¹Meat = sample without patogen bacteria

²Meat+L.m. = meat + *Listeria monocytogenes*

³Meat+E.c. =meat + *Escherichia coli*

⁴Meat+S = meat + *Salmonella sp.*

⁵SEM standard errors of the mean

^{a,b,c,d,e} Means within a row without a common superscript differ significantly ($P < 0.05$)



Increasing pressure between 100 and 400 MPa efficiently reduced strains of *Salmonella* while increasing pressure between 400 and 700 MPa caused significant reductions of bacterial strains to almost undetectable levels (Gola et al, 2000; Malicki et al, 2005). In this study considerably reducing the number of pathogenic bacteria was obtained by applying increasing pressure of 300 MPa in duration of 5 and 10 minutes, and there were 45 and 53% for *L. monocytogenes*, 50 and 54% for *E. coli* and 54 and 72% for *Salmonella* sp. Results of this study shows that higher level of pressure causes inactivation of microorganisms which is in agreement with results of many authors who had proven that microbial inactivation are based on the protein denaturation which results in enzyme inactivation and membrane damage (Barbosa-Canovas et al, 1995; Cheftel and Culioli, 1997; Kruk et al, 2011; Bajović et al, 2012; Rodríguez-Calleja et al, 2012). In this study, *L. monocytogenes* and *E. coli* showed a similar pressure resistance while the most susceptible pathogen proved *Salmonella* spp., because the number was reduced by about 5 log units (Table 3). Obtained results from this and other studies indicate that the inactivation depends on a number of factors related to the Gram type, physiological state and strain particularities (Jofré et al, 2010). Some authors have shown that bacterial

resistance to high pressure is highly variable even among strains of the same species (Liu et al, 2012).

Conclusions

The application of high hydrostatic pressure resulted in a modification of quality parameters of chicken breast meat. Increased pressure and time of the treatment resulted by lowering moisture uptake values. No significant effect ($P>0.05$) on cooking yield was observed between control (non-treated samples) and the other treatments. Increasing pressure affected the colour by increasing L^* , a^* and b^* values (only HPP treatment of 100 MPa did not affect colour of chicken breast meat). Except for the elasticity, all other textural parameters (hardness, chewiness and shear force) have shown statistically significant difference ($P<0.05$) between control and treated samples. Low pressures (100 and 200 MPa) tenderized, whereas elevated pressure (300 MPa) increased hardness in chicken breast fillets. Increased pressure and time of the treatment resulted in higher chewiness of treated samples. Applied pressure levels of 300 MPa lead to an inactivation of 2.8 – 5.3 log units for the *L. monocytogenes* ATTC 23074, *E. coli* 3014 and *Salmonella* sp. 3064.

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