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HIGH PRESSURE EFFECT ON THE SENSORY AND PHYSICAL ATTRIBUTES OF PORK

Sanita Sazonova, **Ruta Galoburda**, **Ilze Gramatina**, **Evita Straumite**
Latvia University of Life Sciences and Technologies, Latvia
sanita.sazonova@llu.lv

Abstract
High-pressure processing (HPP) is typically used for the microorganism inactivation, which provides safety and prolonged shelf life of meat and meat products. However, for consumers along with safety, it is important to have good sensory properties, which is a combination of tender and juicy meat with an intense meat flavour. These attributes may change because of the high pressure processing; therefore, the aim of the study was to evaluate the effect of HPP on sensory and physical attributes of pork upon processing at 300 and 600 MPa at room temperature for 1 and 15 min. After HPP the processed pork samples were cooked within the package in a water bath. Colour of cooked pork did not differ among samples. Moisture content of samples decreased with the increased processing time. Sensory evaluation revealed that HPP treatment did not influence the colour and flavour of cooked pork irrespective of treatment parameters applied in the current study. The panellists indicated that increased pressure made pork samples drier and tougher, thus changing such sensory attributes as juiciness and chewiness, which are important for meat palatability. The correlation found between chewiness determined by sensory analysis and toughness determined by Warner-Bratzler shear device suggested this instrumental method as a better tool when compared to the instrumental texture profile analysis (TPA).
Key words: meat, HPP, sensory attributes, texture, colour.

Introduction

Recently, high pressure processing (HPP) gains popularity as an alternative to thermal processing to inactivate microorganisms (Amaro-Blanco *et al.*, 2018). The main objective of HPP is to achieve the decontamination of foods while preserving their sensory properties (Rivalain, Roquain, & Demazeau, 2010). Pressure levels applied for the pasteurization of meats and meat products, range in an area of 300 – 600 MPa for a short processing time, from seconds to several minutes at room temperature. HPP application results in an instantaneous and uniform transmission of the pressure throughout the product and is independent of the product size and geometry (Ramirez-Suarez & Morrissey, 2006). However, depending on the pressure applied, HPP affects quality parameters like texture and colour typically associated with fresh meat – the meat becomes more gel-like structured and paler (Sazonova, Galoburda, & Gramatina, 2017a).

Robbins et al. (2003) in their survey found that colour, price, visible fats and cuttings were the most important factors that underpinned the purchase of beef steaks, but the tenderness, taste and succulence were more prominent in eating satisfaction. A good eating quality is a combination of tender and juicy meat and an intense meat flavour. Consumer research has shown that meat flavour is a very important factor for the consumers (Aaslyng & Meinert, 2017). Meat juiciness strongly depends on water holding capacity of the product. Muscle comprises approximately 75% water, and the addition of water to meat, and the hydration of the meat after processing or cooking, is closely related to taste, tenderness, colour, and juiciness (Warner, 2017).

Consumers are the final step in the meat supply chain, and consumer expectations of quality and tenderness are important to satisfy their needs and influence re-purchase decisions. High pressure processing can be applied at various meat processing stages. These non-thermal innovative technologies can be used at different levels of success to create physical disturbances in muscle structure, enhance proteolysis and aging, as well as denaturation and solubilisation of muscle proteins, resulting in a change in texture and succulence (Warner, 2017).

There are few studies on texture of cooked meat ready for consumption, with no consistent information about the differences between raw and cooked meat. For meat texture evaluation, both sensory and instrumental methods are used. Among instrumental methods the most popular is Warner Bratzler shear force, which measures the maximum force for sample shearing and texture profile analysis (TPA), which is based on the imitation of mastication or chewing process with a double compression cycle (Chen & Opara, 2013). If on one hand the texture of raw meat influences consumers' decision at the time of purchase, texture of the cooked product is important due to the effects on sensory perception during consumption. Probably, pressurization of a previously cooked or cured product cannot change texture parameters, since proteins have already been denatured, and thus, are not influenced by pressure (Oliveira *et al.*, 2017).

The aim of this work was to evaluate the effect of high pressure processing on sensory and physical attributes of pork cooked after processing at 300 and 600 MPa at room temperature for 1 and 15 min at each pressure.

Materials and Methods

Raw materials

Chilled pork obtained from *Musculus longissimus lumborum* (Latvia) has been purchased from the meat processing company Nakotne (unpackaged; stored in chilled condition at temperature 3 ± 1 °C; maximal storage time 24 h). No breed, age, sex or premortal handling was recorded.

Preparation of meat samples

1. The obtained chilled pork was cut in 2.5 ± 0.2 cm thick slices across the muscle fibre.
2. Slices were divided into portions with the weight of 150.0 ± 0.2 g each, packed in the vacuum pouches made from polyamide/polyethylene film (film thickness 60 ± 3 μm).
3. Stored in the refrigerator at 4 ± 2 °C till experiments were completed on the same day.
4. Samples of meat were treated in a high-pressure processor ISO-Lab S-FL-100-250-09-W (Stansted Fluid Power Ltd., UK) with a pressure chamber of 2 L and a maximum operating pressure of 900 MPa. The pressure transmitting medium was a mix of propylene glycol with water (1:2 v/v) at room temperature. Vacuum-packed samples were randomly assigned to one of the treatment pressures (300 and 600 MPa), while the untreated sample served as the control. The HP treatment for vacuum-packed samples at each pressure level was applied for three meat samples for durations of 1 and 15 minutes. Pressure and time were chosen based on the previous studies and literature summaries, which showed that under the pressure of 300 MPa, the microorganisms were not inactivated, but the increase of the pressure above 600 MPa did not give better inactivation rates (Sazonova *et al.*, 2017a).
5. After HPP and before sensory evaluation, the processed pork samples were cooked within the package in a water bath *AppliTek 21AT (HetoLabEquipment, Denmark)* at 85 ± 2 °C while reaching internal sample temperature of 75 °C and subsequent cooking for 10 min.

Sensory evaluation of HPP pork samples

The sensory evaluation of pork samples cooked after HPP treatment was conducted according to the sensory standard method ISO 4121:2003. To determine the intensity of aroma, colour, juiciness and chewiness, a five point line scale (for colour 1 – light, 5 – dark; for flavour 1 –weak, 5 – intense; for juiciness 1 – dry, 5 – juicy; for chewiness 1 – tough, 5 – soft) was used. Meat samples were evaluated by 30 panellists comprising students and staff of the Faculty of Food Technology, Latvia University of Life Sciences and Technologies. Together with the samples, panellists received evaluation sheets indicating the sequence of samples and the instructions for the assessment.

Texture measurement

For instrumental measurement of cooked HPP processed pork texture two most popular methods were selected: Warner-Bratzler shearing and Texture profile analysis (TPA). In both cases a texture analyser TA.HD.Plus was used and data were generated by Exponent software (Stable Microsystems Ltd., UK).

In the shear test, meat toughness was determined using the Warner-Bratzler shear device, which consists of a blade and a slotted platform. The meat sample was cut in strips of 2 cm width and placed under shearing blade, which at a speed of 1 mm s^{-1}, parallel to the meat fibre, sheared the test portion in half. For each sample of meat, 10 measurements were completed.

For texture profile analysis (TPA), according to the procedure of Trespalacios and Pla (2007), an aluminium cylindrical probe (SMP P/50, flat bottom, diameter 50 mm) at ambient temperature (22 ± 2 °C) was used. Square samples (20 × 20 mm) were axially compressed to 40% of their original height using a double compression cycle test. The trigger force used for the test was 0.049 N, with a pre-test speed of 1 mm s^{-1}, test speed 5 mm s^{-1}, post-test speed 5 mm s^{-1}. A time of 5 s was allowed to elapse between the two compression cycles. Therefore, attributes of gumminess and chewiness were selected for further evaluation (Zheng *et al.*, 2015).

Determination of moisture and colour

Moisture of pork meat samples was determined in triplicate according to a standard method LVS ISO 1442:1997. Meat colour was analysed using colorimeter *Color Tec PCM/PSM* (Accuracy Microsensors, USA), evaluating colour in CIE L* a* b* system. Two meat samples per type of treatment were analysed, measuring colour at least in 10 different places on each sample surface.

Statistical analysis

Experimental results are presented as mean ± standard deviation. Single factor analysis of variance (ANOVA) was used to compare the means. For data analysis, confidence level was 95% (a=0.05). The factors have been evaluated as significant, if p-value < $\alpha_{0.05}$. For analysis of sensory data along with two way ANOVA, Tukey's test was applied.

Results and Discussion

Colour, flavour, juiciness and chewiness of cooked HPP pork were quantified with sensory analysis, while texture attributes were measured also by instrumental methods. Sensory evaluation resulted in the determination of the intensity of the sensory

Table 1

Intensity of sensory attributes of cooked high pressure treated pork

Sample	Colour[1]	Flavour[1]	Juiciness[1]	Chewiness[1]
Control	2.07 a	2.90 a	2.67 b	3.27 b
300 MPa/1min	2.37 a	2.70 a	2.83 b	3.47 b
300 MPa/15min	2.07 a	2.70 a	3.10 b	3.53 b
600 MPa/1min	2.23 a	2.70 a	2.33 ab	1.83 a
600 MPa/15min	2.37 a	2.67 a	1.70 a	1.33 a

[1]Evaluated by a 5-point line scale (1 – light, weak, dry, tough; 5 – dark, intense, juicy, soft).
Different letters in the same column indicate significant differences among treatments ($p<0.05$).

properties (Table 1), which were selected of their importance in meat palatability evaluation according to the consumer studies conducted by several research groups (Bak *et al.*, 2012; Reed *et al.*, 2017).

Summing up the obtained results, we can conclude that there was no significant difference in colour ($p=0.307$) and aroma ($p=0.864$) among the samples, but there were significant differences among the samples in their juiciness ($p=0.003$) and chewiness ($p=0.000$), which was more influenced by the processing pressure rather than the time.

Colour

It has been established that high pressure may induce quite significant and obvious changes in the colour of the raw meat (Hughes *et al.*, 2014). Our earlier studies also indicated that colour of pork after meat treatment at 50 – 100 MPa does not cause visible changes in a colour intensity parameter L* (Sazonova, Galoburda, & Gramatina, 2017b). However, higher pressure induced an increase in lightness of the samples. The L* value increased for all samples treated at 100 – 500 MPa ($p<0.05$), but it was not significantly affected by treatment time (1 – 15 minutes). Overall, a high pressure treatment caused significant changes in the colour of fresh meat and thus complicated the commercialization of HPP fresh meat, since from the consumer point of view, the lack of fresh meat of the typical colours (Bajovic *et al.*, 2012).

The colour of samples coked after HPP no longer showed significant differences in colour as indicated by sensory panellists in the current study. The colour scores ranged from 2.07 to 2.37, being close to light colour. The differences of raw HPP pork colour were eliminated by heat treatment, as a result changing meat colour from pink to light brown colour due to myoglobin denaturation (Hughes *et al.*, 2014) (Hughes *et al.*, 2014). Thus, colour changes in the high pressure processing step are not relevant if a product is further processed. After the heat treatment, the final products had a uniform colour, typical of cooked meat. Colour value component L* was on average 71.47; a*=-1.1; b*=14.42. Also, an instrumental measurement of the colour of the target did not show significant differences ($p=6.964$).

Flavour

The panellists evaluated the intensity of meat flavour, which plays an important role in the acceptance and preferences of consumers. No significant differences were established among the evaluated samples. The flavour of all the samples on the 5-point scale was estimated to be within the range 2.67 – 2.90, which is in the middle “neither weak, nor intense”. Prepared meat has its flavour and taste derived from volatile aroma constituents, which results from thermally induced reactions between aroma precursors such as water soluble components (amino acids, peptides, carbohydrates, nucleotides, etc,) and lipids (Robbins *et al.*, 2003). One can conclude that the samples have got the flavour during heat treatment, not because of high pressure treatment. It has been reported that the aroma is combined with other sensory properties, such as softness and juiciness, is considered as the most important criterion for acceptability, which affects the consumer’s decision on the use of these products in the diet (Robbins *et al.*, 2003).

Juiciness

Sensory evaluation results showed that the pork samples that have undergone treatment at 600 MPa were scored as drier (1.70 – 2.33), comparing to the control sample or the samples treated at 300 MPa. The sensory results had a moderate correlation ($r=0.619$) with the results of instrumental measurements, which indicated lower moisture content (Figure 1) in both samples treated for longer time (15 min compared to 1 min) irrespective of applied pressure. This indicates that juiciness, unlike other evaluated parameters, is a subjective characteristic of meat, which is determined by the consumer or trained assessor.

Meat typically contains about 75% water. However, its content is changed depending on applied type of treatment and it is closely related to the taste

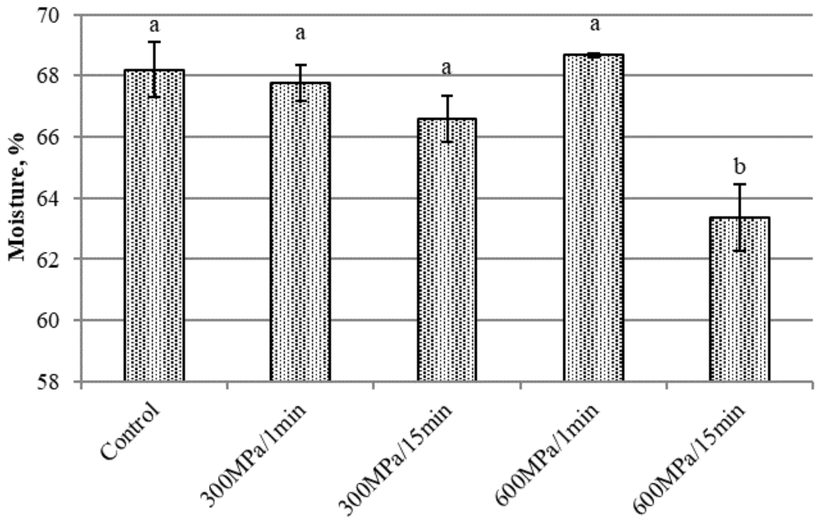

Figure 1. Moisture content of the studied HPP pork samples after cooking.

of the meat, colour, softness and juiciness. After measuring the moisture content, we conclude that as the treatment time increases, the moisture content of the sample decreases (Figure 1). The calculations showed significant differences only for the cooked sample, which was processed at 600 MPa at 15 min (p=0.007), which is in agreement with sensory evaluation about juiciness which was assessed at a five-point scale with 1.70 being closer to dry. During heat treatment, the muscles lose water, but the proteins become less flexible and tougher. While using longer heating times, some proteins such as sarcoplasm and collagen make jelly and can hold water (Warner, 2017). HPP can denature some sarcoplasmic proteins, and this can have a negative effect on water holding capacity and increase in drip losses leading to changes of water content of the meat (Marcos *et al.*, 2010). Short range surface forces seem to dominate theories of water–protein interactions, and the theoretical foundations of bulk water-holding are still lacking (Puolanne & Halonen, 2010).

Texture

Sensory evaluation results showed that between the sensory properties of the samples – juiciness and chewiness had a strong correlation (0.943). The samples treated at 600 MPa according to the sensory evaluation were less juicy, having scores for 1 min sample 2.33, but 15 min – 1.70. Also, the chewiness of these samples was estimated to be tougher – 1.83 and

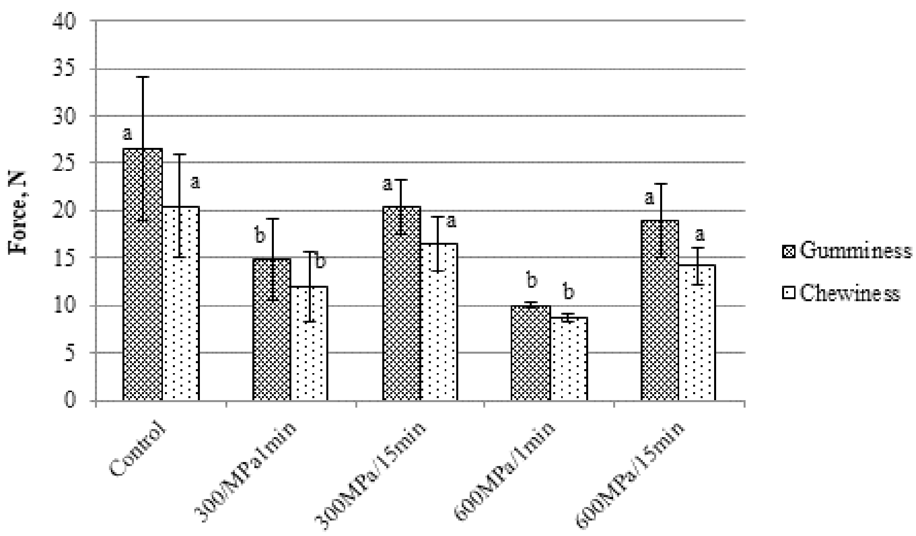

Figure 2. Gumminess and chewiness of cooked HPP pork samples using the TPA method.
Different letters (a – b) for the same property (gumminess or chewiness) indicate significant differences among samples (p<0.05).

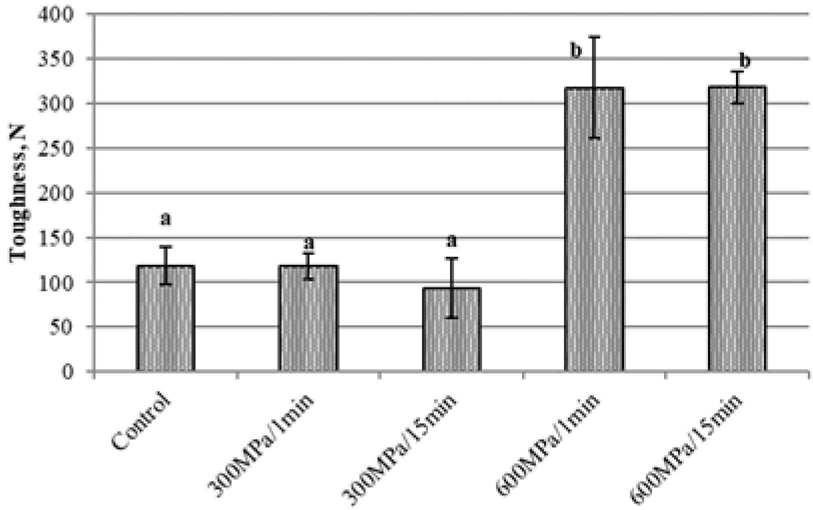

Figure 3. Toughness of the studied pork samples after cooking as measured by Warner-Bratzler shear device.

1.33, respectively. These results indicate that less juicy samples are harder to chew, and may have a harder texture. The sensory studies performed by Otremba et al. (2000) also indicated that, there is a strong positive correlation between the heat-treated meat consistency and the sense of juiciness - the release of water on the first or second bite, and moisture content capture – sensory juice evaluation after several chewing cycles. However, as found in the study, different muscle consistency and succulence may be different (Hughes *et al.*, 2014).

It should be noted that the data obtained in the sensory evaluation do not coincide with the results obtained by analysing the consistency of the samples using the instrumental method – compression force (Figure 2).

An increase in a processing time from 1 to 15 min, both at pressure 300 MPa and pressure 600 MPa the samples showed a significant difference between gumminess (p=0.043 and p=0.004), and chewiness (p=0.042 and p=0.001). In contrast, regardless of time and pressures applied, there is no significant difference between gumminess (p=0.60 and p=0.539), and chewiness (p=0.121 and p=0.198).

When measuring the texture of pork samples using Warner-Bratzler shear device a significant difference between the analysed samples (p=0.010) was observed, the higher the treatment pressure applied, the greater the force must be applied to cut the meat.

Accordingly, the toughness of the meat samples increased when higher pressure (600MPa) was applied irrespective of the treatment time. This method correlated with the sensory evaluation results, when texture of pork became tougher with increased pressure.

Conclusions

Sensory evaluation revealed that HPP treatment did not influence the colour and flavour of cooked pork meat irrespective of treatment parameters applied in the current study (300 and 600 MPa, 1 and 15 min). The panellists indicated that increased pressure made pork samples drier and tougher, thus changing such sensory attributes as juiciness and chewiness, which are important for meat palatability. The correlation found between chewiness determined by sensory analysis and toughness determined by Warner-Bratzler shear device suggests this instrumental method as more suitable tool for cooked meat evaluation when compared to instrumental texture profile analysis (TPA).

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