Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

1999
Volume 2
Issue 2
Series FOOD SCIENCE AND TECHNOLOGY

KORZENIOWSKI W., JANKOWSKA B., KWIATKOWSKA A. 1999. THE EFFECT OF HIGH PRESSURE ON SOME TECHNOLOGICAL PROPERTIES OF PORK **Electronic Journal of Polish Agricultural Universities**, Food Science and Technology, Volume 2, Issue 2.
Available Online http://www.ejpau.media.pl

THE EFFECT OF HIGH PRESSURE ON SOME TECHNOLOGICAL PROPERTIES OF PORK

Wladyslaw Korzeniowski, Barbara Jankowska, Aleksandra Kwiatkowska
Faculty of Food Science, The Chair of Meat Technology and Chemistry , The University of Agriculture and Technology, Olsztyn, Poland

ABSTRACT

Pork meat (m. longissimus dorsi) was treated with high pressure of 100, 200, 300 and 400 MPa. The pressure was applied for 10 minutes at room temperature. The concentration of hydrogen ions increased by 0.2 units within the pressure range of 300 and 500 MPa. The application of 300 and 400 MPa resulted in the increase of drip loss and contributed to the decrease in free water content compared to the control sample. All tested pressures caused a decrease in added water and thermal drip. The changes of these parameters strengthened with the increase of pressure applied. Pressures between 100 and 200 MPa slightly brightened the meat color but significant changes of this parameter began at 300 MPa. The greatest increase in color brightness and the largest share of the denatured myoglobin were observed following the application of 400 MPa.

Key words: HP - technology, pascalization, izostatic pressuring, activity of microorganism

INTRODUCTION

The technology of high pressure (HP - technology, pascalization, izostatic pressuring) is a non-heat technique used for food processing at pressure ranges between 100 and 1000 MPa. The first work in this field was done by Hite in 1899, who treated some food products with a pressure of 680 MPa (Mertens 1993). In Japan in 1990, high-pressure technology was implemented on industrial scale in fruit processing. Apart from this, the above technology was applied to expand the shelf time of squids and sashimi, as well as to shorten the length of raw ham ripening from two week to 3 hours (Drobisz-Kopydlowska, 1997).

High pressure affects microorganism activity and can delay or accelerate enzymatic processes, resulting in changes to food components due to configuration alternations (Tauschner 1995). It can be generally stated that the application of high pressures in low or moderate temperatures does not change the sensoric and nutritious value of food, however, it may influence the native protein and lipid configurations and the raw material technical properties (Hayakawa et al 1996, Tyszkiewicz 1997). Based in the above, studies on determining the influence of high pressure on selected parameters characterizing pork quality were undertaken.

MATERIALS AND METHODS

The experiment was carried out on a swine muscle (M.longissimus dorsi) originating from nine individuals of the same sex. The raw material was sampled from cooled carcasses, 24 hours following slaughtering 180-200 g (about 200 x 40 mm) samples were cut out along muscle fibers from each muscle. Each sample was weighted and placed in a polyamide foil. The samples were treated with the following pressures: 100, 200, 300, 400 MPa at the same temperature of 20 ^{o}C for 10 minutes in a high pressure chamber at the Central of High Pressure Research of the Polish Academy of Sciences in Warsaw. In the above experiments, water was used as the medium conveying pressure. The time of compression and decompression was 50 and 40 seconds respectively. The samples were then stored at the temperature of 4 ^{o}C for 24 hours and then underwent the following analyses.

After the removal of the polyamide foil, the resulted discharge was separated and the meat sample was weighed and the amount of the discharged liquid was calculated on the basis of the weight difference between the samples before and following pascalization. A pH-value was carries out with the use of PHM-80 pH-meter with a GK-2401 C combined glass electrode. Meat water capacity was determined in a centrifuge following meat sample homogenization with distilled water for 15 seconds at 10 000 rpm and centrifuging the homogenate for 6 minute at 400g. The ability to maintain native water was determined on the basis of the amount of discharge resulting from treating the prepared meat sample with the pressure of 6630.39 Pa (2 kg) for 3 minutes (Hamm 1972). Thermal drip was also determined after the prepared meat samples were heated at a temperature of 80 ^{o}C for 30 min (Kotter et al 1968). The color was determined sensorically and the color physical parameters were specified by: photometric brightness, the dominant wavelength and the colorimetric purity (with the use of the SPECOL spectrophotometre with a Rd/0 device calibrated against barium oxide. The total concentration of pigments and their denaturation degree was also determined. A cooled (0 ^{o}C), 0.04 M phosphate buffer at pH 6.8 was used to extract the pigments according to the Warris (1979) technique. The absorbency of the obtained solution was determined at the following wave: 525 and 700 nm. Based in this, the concentration of denatured and non-denatured myoglobin was calculated with the use of the following formulas:

The myoglobin concentration: /M/ = (E525 - E700) * 2.303 * the dilution co-efficient

% of denatured myoglobin = [1-(M in the pascalized sample/M in the control sample)]*100 (Trout 1989)

The results obtained were the average of the three samples from 9 meat samples which underwent statistical analysis with the use of Duncan's test.

RESULTS

The control samples featured a pH level of 5.61. Pressures of 100 and 200 MPa did not change the above parameter. However, the application of pressures of 300 and 400 MPa contributed to the increase of hydrogen ion concentration by around 0.2 units, to the level of 5.78 and 5.8 (table 1). The results obtained indicate that the pascalization of meat removed from a carcass following rigor mortis does not change the pH value or, in case of the application of the pressure of 200 MPa, may increase pH value. The above changes, however, are not as radical as the ones reported by other authors who pressurized meat removed from carcasses before rigor mortis. The pressure causes rapid glycolyses and a consequent violent decrease in pH value to the minimum level (Elkhalifa et al. 1984a, 1984b, Macfarlane 1973, Horgan 1980/81, However , Suzuki et al 1990) after applying a pressure between 200-300 MPa for 5 minutes, 72 hours following the cattle slaughter, reported a mild pH-value increase in muscle tissue by 0.2 units. The author correlates the pH-value increase with the configuration changes of petide chains. Similarly, other authors demonstrated that processed fish treated with pressure produced only a slight pH value increase (Kloczko and Chudoba 1997).

Table 1. The influence of high pressure on pork pH value

Parameter	control sample	Sample treated with the pressure (MPa)			
		100	200	300	400
pH value	5.61 ± 0.12^{AB}	5.61 ± 0.17^{CD}	5.78 ± 0.15^{E}	5.78 ± 0.14^{AC}	5.80 ± 0.13^{BDE}

1. All results are average $\pm$ standard deviation from 9 muscles
2. Values marked with the same letters differ significantly (pH=0.01)

The effect of pressure on muscle tissue water holding capacity were evaluated on the basis of the determination of the discharge, free water, added water bonding ability as well as thermal drip level. The results of the above analyses were included in Table 2.

Table 2. Hydration properties of pork treated with pressures of 100, 200, 300, 400 MPa for 10 minutes

Parameter	control sample	Sample treated with the pressure (MPa)			
		100	200	300	400
drip loss	4.2 ± 2.04^{AB}	6.96 ± 1.42^{AC}	7.06 ± 1.49^{BD}	5.04 1.56	4.26 ± 1.52^{E}
free water [%]	$22.41^{ABC} \pm 7.00$	23.69 ± 6.81^{DE}	26.97 7.69^{AF}	8.05 ± 4.08^{BDFG}	9.95 ± 3.74^{DG}
thermal drip [%]	31.19 ± 2.62^{AB}	29.76 ± 2.73^{CD}	30.15 ± 3.13^{EF}	26.94 ± 3.66^{ACE}	24.66 2.50^{BDE}
water holding capacity [%]	31.12 ± 13.14^{ABC}	28.37 ± 12.79^{DE}	21.28 5.15^{A}	20.00 ± 7.83^{BD}	19.03 5.92^{E}

1) as in table 1

The discharged amount constituted 4.22% of the tissue mass. Pressures of 100 and 200 MPa resulted in a discharge increase to the level of 6.96 to 7.06%. At a pressure of 300 MPa the discharge amount was smaller, while at 400 MPa it was the same as in the control sample. The amount of free water, which equaled 22.41% in the control sample, also changed according to the applied pressure. The amount of free water was larger by 1.28% in samples treated with 100 MPa and samples treated with 200 MPa increased by 4.56% compared with the control sample. Higher pressure also resulted in the reverse direction of changes, since the amount of free water under pressures of 300 and 400 MPa was lower than in the control sample and equaled only 8.05% and 9.95% respectively.

In case of the amount of thermal drip, the same tendency was observed regardless of pressure level. Each of the tested pressures resulted in a decrease in this parameter in comparison with the control sample. However, pressures of 100 and 200 MPa changed the discharge amount by 1.04-1.43% but for applied pressures of 300 and 400 MPa the discharge was 4.25-6.53% lower. Thus, the discharge resulting during the heating of samples which were treated with 300 and 400 MPa was significantly lower than in the control sample. The meat pressurized under these conditions featured the maintenance of native water ever following the heat treatment. According to the references, pressure may cause muscle fiber structure damage. It is mainly connected with actin and myosin filaments and cell organelle, however, changes in cell membrane structure, which progress with the increase of pressure, are not excluded (Elgasim and Kennick 1982, Suzuki et al 1990). The above may result in the observed discharge increase of meat juice following the treatment of pressures at the level of 100-200 MPa. However, in the case of 300 MPa the discharge is lower, and at 400 MPa it is comparable with the control sample, which indicates both better water maintenance by cell protein structures and, consequently, lower discharges as well as apparently greater cell membrane damage. This correlation is very clearly shown in the case of determining the amount of free water. Its amount at pressures 300-400 MPa is less than half of the samples not treated with pressure. This indicates a very strong native water bonding by fibrous muscle proteins. Literature notes indicated that high levels of pressure applied even at low temperatures result in the gelation of muscle proteins (Schöberl et al 1997, Bonderias et al 1997, Okamoto et al. 1990). Gels formed under pressure are smoother, more flexible and of stronger structure than gels obtained as the result of heat treatment, and feature very good water bonding ability (Cheftel and Culioli 1997). The existence of very good native water bonding ability, as found in our own studies, following the application of 300-400 MPa, indicates that such levels of pressure cause pork protein gelation and, consequently, better water bonding ability.

Further results illustrate the ability of broken-up muscle tissue to bond added water. It was established that all of the applied pressures resulted in a decrease in water bonding degree. The pressure of 100 MPa changed this feature slightly. Pressures of 200 and 300 MPa caused further decrease in water absorbability. The samples treated with 400 MPa featured the poorest ability to bond water.

The significant pressure effect on muscle protein hydrofilic properties was also shown. The achieved results are similar to the experimental results obtained by Macfarlane (1974) who worked on with sheep meat. This author demonstrated that pressures between 0.1-150 MPa cause slight changes in water absorption and pressures above 150 MPa result in a decrease in muscle tissue water absorption.

Following the sensoric determination of pork meat color, it was established the pressures such as 100 and 200 MPa cause only a slight meat brightness, from intense red to light red, whereas higher pressures resulted in significant meat color change, at 300 MPa to pale pink and at 400 MPa to white and gray color.

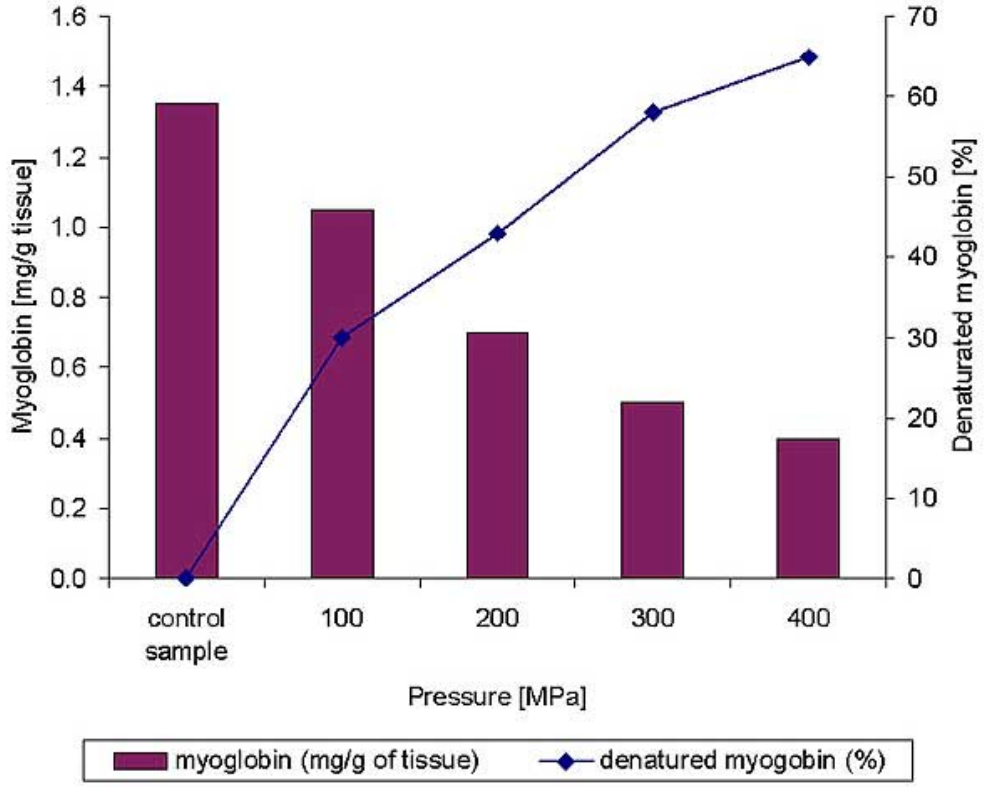
The meat color was also determined instrumentally through determining its photometric brightness, colorimetric purity and the dominant wavelength. The color brightness analysis showed its insignificant increase at pressures of 100-200 MPa. Clear changes in this parameter ware observed at higher pressures. Photometric brightness increased at 300 MPa up to the level of 56.12 and at 400 MPa up to 61.37 (the control sample was 32.26). The measurement of the dominant wavelength showed the following differences between the experimental samples and the control sample: in the pascalized samples at lower pressures, slightly higher values were observed, whereas at pressures between 300-400 MPa a shift of the dominant wavelength towards the shorter waves were noticed. This correlation was clearest under the application of 400 MPa. Also, values characterizing the colorimetric purity indicated an increasing tendency at pressures between 100-200 MPa, whereas pressures 300-400 MPa resulted in the reverse tendency (table 3).

Table 3. Physical parameters of pork color treated with the following pressures 100, 200, 300, 400 MPa for 10 minutes

Parameter	control sample	Sample treated with the pressure (MPa)			
		100	200	300	400
photometric brightness [%]	32.26 ± 5.82^{AB}	34.20 ± 5.06^{CD}	32.29 ± 5.59^{BF}	56.12 ± 8.23^{ACE}	61.37 ± 6.25^{BDF}
colometric purity [%]	0.787 ± 0.13	0.800 ± 0.21	0.992 ± 0.14^{A}	0.760 ± 0.13	0.645 ± 0.08^{A}
dominant wavelength [nm]	604.24 ± 8.11	604.61 ± 0.13	606.53 ± 8.12	602.22 ± 7.34	601.11 ± 7.33

The amount of myoglobin extracted from samples that were not treated with pressure averaged 1.36 mg/g of muscle tissue. It was observed that the higher the pressure applied, resulted in the smaller amount of extracted pigments. The smallest differences, compared to the control sample, were observed following the application of 100 MPa, and only half as much pigment was extracted following the application of 200 MPa. Almost three times less pigment was extracted following the application of 300 MPa, and even less pigment was isolated by applying 400 MPa. Poorer muscle pigments extracting ability from the tissue may result from many factors such as for instance microfibrous protein aggregation which make pigment extraction more difficult or pigment structural changes, including denaturation of myoglobin. The degree of muscle pigment denaturation in the samples treated with pressures between 100 and 400 MPa ranged from 28.31% to 66.33% (fig 1).

Figure 1. The influence of pressure of 100, 200, 300, 400 MPa on muscle pigments content



According to Carlez et al (1993), the color of the prepared beef changes, beginning at a pressure of 150 MPa (brightening with a red shade), whereas above 350 MPa the meat color changes into white and gray, similar to cooked meat color. In his other publications, also on prepared beef, the author suggests that the meat off-coloring results both from "whitening" and the disappearance of the red color (Carlez et al. 1995). Similarly, Suzuki et al (1990) draw the conclusion that the pressure of 300 MPa is responsible for the color changing into gray. Similar results were obtained by Shigehisha et al (1991) experimenting with pork homogenate. The color brightness increased between 100 and 200 MPa and reached the maximum value following the application of pressure between 300 and 400 MPa. Further color brightening was not observed until the application of 600 MPa.

The results discussed in this paper are thus similar to the above-mentioned ones. Color brightening was observed following pressurization between 100 and 200 MPa and the maximum brightness was obtained at 400 MPa. The observed myoglobin denaturation increase with the increase of the applied pressure indicates the important role of such pigment changes in the formation of pascalized meat color.

CONCLUSIONS

The results of this study on the evaluation of high pressure effect on some technological pork properties read to the following conclusions:

1. The hydration properties of pork muscle tissue may be changed by the application of high pressures. The range of such changes depends on the level of the applied pressure values.

2. The amount of free water, the water holding capacity and thermal drip are lowest at 400 MPa.
3. Significant changes of pork meat color begins at 300 MPa and the samples treated with the highest level of pressure of 400 MPa featured the highest photometric brightness.
4. The myoglobin denaturation degree increases along the increase of the applied pressure. The largest amount of the denatured pigment was found for 400 MPa.

REFERENCES

1. Bonderias A.J., Perez-Mateos M., Solas M.: Frozen storage of high-pressure and heat-induced gela of blue whiting (Micromestistius poutassou) muscle: rheological, chemical and ultrastructure studies. Z.Lebensm. Unters. Forsch. 1997, 205, 335-342.
2. Carlez A., Rosec J.P., Richard N., Cheftel J. C.: High pressure inactivation of Citrobacter freundi, Pseudomonas fluorescens and Listeria innocua in inoculated minced beef muscle. Lebensm. Wiss.u. Technol. 1993, 26, 357-363.
3. Carlez A., Venciana-Nogues T., Cheftel J.C.: Changes in color and myoglobin in minced beef meat due to pressure processing. Lebensm. Wiss.u. Technol. 1995, 28, 528-538.
4. Cheftel J.C., Culioli J.: Effects of high pressure on meat: a review Meat Sci. 1997, 46, 211-236.
5. Drobisz-Kopydlowska D.: XLII Miedzynarodowy Kongres Nauki o Miesie i Technologii w Lillehammer - Wplyw wysokich cisnien na zywnosc. Gosp. Miesna, 1997, 49, 32-33.
6. Elgasim F.A., Kennick W.H.: Effect of high hydrostatic pressure on meat microstructure. Food Microstructure 1982, 1, 75-82.
7. Elkhalifa E.A., Anglemier E.A., Kennick W.H., Elgasim E.A.: Effect of prerigor pressurisation on postmortem bovine muscle lactate dehydrogenase activity and glycogen degradation J.Food Sci. 1984, 49, 593-594.
8. Elkhalifa E.A., Anglemier E.A., Kennick W.H., Elgasim E.A.: Influence of prerigor pressuration on postmortem beef muscle creatine phosphokinase activity and degradation of creatine phosphate and adenosine triphosphate. J.Food Sci. 1984, 49, 595-597.
9. Hamm R.: Kolloidchemie des Fleisches P.Paray, Berlin 1972
10. Hayakawa I., Linko Y., Linko P.: Mechanism of high pressure denaturation of protein. Lebensm. Wiss.u. Technol.1996, 29, 756-762
11. Horgan D.J.: Effext of pressure treatment on the sarcoplasmic reticulum of red and white muscles. Meat Sci. 1980-81, 5, 297-305.
12. Kloczko i., Chudoba T.: Zastosowanie wysokich cisnien hydrostatycznych do utrwalania przetworow rybnych, Przem. Spoz. 1997, 51, 46-48.
13. Kotter L., Prändl C., Terplan A.: Zur Prüfung des Safthaltvermogen von Fleisch beim Erhitzen. Fleischwirtschaft 1968, 48, 439-445.
14. Macfarlane J.: Pre-rigor pressurisation of muscle effects on pH, shear value and taste panel assessment. J. Food Sci. 1973, 38, 294-298.
15. Macfarlane J.: Pressure induced solubilization of meat proteins in saline solution. J.Food Sci. 1974, 39, 542-547.
16. Mertens B.: Developments in high pressure food processing (part I). International Food Manufacturing ZFL 1993, 44, 100-104.
17. Okamoto M., Kawamura Y., Hayashi A.: Application of high pressure to food processing texturial comparison of pressure- and heat-induced gels of food proteins. Agricult. Biol. Chem. 1990, 54, 183-189.
18. Schőberl H., Russ W., Schmid J., Meyer-Pittrof R.: Hochdruckbehandlung von zerkleinertem Rindfleisch. Fleischwirtschaft 1997, 77, 526-528.
19. Shigehisa T., Ohimori T., Saito A., Hayashi R.: Effect of high hydrostatic pressure on characteristic of pork slurries and inactivation of microorganisms associated with meat products. Internat. J. Food Microbiol. 1991, 12, 207-216.
20. Suzuki A., Watanabe M., Iwamura K., Ikeuchi Y., Saito M.: Effect of high pressure treatment on the ultrastructure and myofibrillar protein of beef skeletal muscle. Agric. Biol. Chem. 1990, 54, 3085-3091.
21. Tauschner B.: Pasteurisation of food by hydrostatic high pressure: chemical aspects. Z. Lebensm. Unters. Forsch. 1995, 200, 3-13.

22. Trout G.R.: Variation in myoglobin denaturation and color of cooked beef, pork and turkey meat as influence by pH, sodium chloride, sodium tripolyphosphate and cooking temperature. J. Food Sci. 1989, 54, 536-540.
23. Tyszkiewicz I.: Perspektywy cisnieniowania technologii miesa. Gosp. miesna 1997, 49, 26-30
24. Warris P. D.: The extraction of haem pigments from fresh meat. J. Food Technol. 1979, 14, 75-80.

Submited:

Wladyslaw Korzeniowski, Barbara Jankowska, Aleksandra Kwiatkowska
Faculty of Food Science, The Chair of Meat Technology and Chemistry
The University of Agriculture and Technology
Plac Cieszynski 1, 10-718 Olsztyn-Kortowo, Poland
Tel. + 48 89 52 33 295