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Original scientific paper

RESEARCH OF FUNCTIONAL AND TECHNOLOGICAL PARAMETERS OF HIGH PRESSURE PROCESSED MEAT

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Abstract

High hydrostatic pressure (HHP) technology has been widely used in the developed countries food industry for production and preservation of raw materials and products. In our country the possibility of a new processing method is being now tested only on experimental installations. For research we selected a pressure range from 200 to 700 MPa, the exposure duration at room temperature was 20 minutes. This article presents the results of the high pressure impact on pH, water-binding capacity of broiler chickens meat, moreover comparative assessment of range of losses that occur during heat treatment and high hydrostatic pressure were analyzed. The dynamics of change of the ultimate sheer stress depending on the HHP value is shown. It is established that the new technology in the selected range does not significantly affect the pH value. However the value of water-binding capacity increases along with increasing of pressure: during processing by 200 MPa it increases by 10.5%, within the range of 200–300 MPa it increases by additional 3.0%, and within the range from 300 to 700 MPa the value increased only slightly. Significant changes were observed in the determination of losses while technological processing of meat. Thus the losses during conventional boiling of broiler chickens fillets were 28.5% higher than during high-pressure processing. It is noted that within the range of 200–700 MPa this parameter increases by only 4.8%. As the pressure increased, the texture of the meat becomes denser, as evidenced by the results of the study of the structural and mechanical properties of the raw material. Based on the results of the implemented work, it is recommended to use HHP technology within the range of 600–700 MPa, processing time of 20 min at 20 ± 1 °C for production of poultry meat products.

Introduction

The use of meat for production of various meat food products is determined by a set of functional-technological properties (FTP). They characterize the ability of the meat to retain water, fat, to form emulsions, gels, to form the structure and they determine organoleptic properties of meat products as well as the yield and losses during heat treatment.

FTP values depend primarily on meat proteins containing a large number of groups capable of interacting with water and fat molecules, as well as to interact among each other. The interaction of the protein-water system determines the following FTPs: water binding capacity, solubility, extraction and swelling.

The protein of fresh meat has maximum activity and is the most technologically advanced, forming stable systems. When exposed to high temperature, to freezing, machine processing, the stabilizing properties of the protein decrease. Therefore, the study of the functional and technological properties of meat allows managing the process into the right direction, eliminating the factor of chance [1,2,3,4,5,6,7,8].

In recent years a qualitatively new method of meat processing by high hydrostatic pressure (HHP) has emerged in the field of food production and food processing. The main objective of this technology is to obtain from protein and other substances the full-scale, high-quality products with a prolonged shelf life [9,10,11,12,13].

High pressure treatment (HP) is used in countries of Western Europe, North America and Japan, where population demands for new food products, which in the scientific literature are called new forms of food [14,15,16].

The industrial introduction of HHP technology has been rapidly developing, thus replacing a significant part of traditional food products that are produced using thermal methods [17,18]. The allowable volume of replacement is determined by the effectiveness of this processing method and the functional properties of the raw materials [19,20,21].

The quality of the finished product directly depends on the modes of technological operations. For the present day the use of HHP for the processing of food raw materials and food production is not well studies, so this research topic is relevant and actual.

The aim of the work was to study the impact of unconventional processing of HP on the functional and technological properties of poultry meat.

Materials and methods

The object of the research was broiler chicken fillet chilled down to a temperature of from — 2 °C to + 4 °C inclusive, with storage period not more than 24 hours (according to GOST 31962–2013 «Chicken meat (carcasses of chickens, chickens, broiler chickens and parts thereof)».

The experimental samples were processed with pressure at 200, 300, 400, 500, 600, and 700 MPa in five repetitions, the duration of exposure in the static mode was 20 minutes. In order to exclude the thermal effect on the product (temperature factor), the experiments were implemented at 20 ± 1 °C. To isolate the meat in the high-pressure chamber from the working fluid, samples 4 × 4 × 6 cm in size were packed under vacuum in heat-shrinkable film made of food-grade polyethylene.

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Control samples — the raw (chilled) poultry meat and boiled poultry meat cooked until culinary readiness.

The impact of HHP on poultry meat was studied on an automated high-pressure unit (AUVD), developed and manufactured at the Donetzk National University of Economics and Trade named after Mikhail Tugan-Baranovsky, which allows registering object parameters before processing; create pressure and temperature while holding the food product in a high-pressure chamber from several minutes till one day, to register volume and temperature, to reduce pressure, to study changes in objects that have been exposed to above-mentioned modes. The necessary pressure in the HP chamber is created by a hydraulic press, which transfers force to the piston of the chamber. The hydraulic unit with a pump and the press device controls the pressure in the chamber according to the commands from the personal computer located in the installation control unit.

PES-3, polyethylsiloxane liquid, which is a dielectric, does not cause corrosion of parts, pressure hysteresis, and as the working fluid reduces the likelihood of jamming. PES-3 is neutral to the researched objects, it is odorless, environmentally friendly, suitable for operation at high pressures and temperatures from — 40 °C to +100 °C, is non-combustible, has low-viscosity, has moderate compressibility due to which it accumulates relatively small elastic energy, which reduces the likelihood of serious consequences in case of the chamber destruction [22].

In this research the generally approved, accepted, standard and original research methods were used [23, 24, 25].

The pH value was determined by potentiometric method using a pH-150MI ionomer with a glass electrode with a resolution of –1.00 to +14.00 pH and an error is ± 0.05. To determine the pH an aqueous extract of muscle tissue was prepared in a ratio of 1:10 according to the method of Krylova N. M., Lyaskovsky Yu. M.

Water binding capacity was determined by pressing method according to Grau R. and Hamm R. in the modification of Volovinsky V. P. and Kelman B. Ya.

We proposed an improvement of this method: after pressing the samples, a measuring length of 1 cm was marked on the filtering paper for its further scaling. After that scanning and computer processing in the KOMPAS-3D program were performed. This program allows to determine automatically the internal and external area of the spot using scanned pattern, which improves the accuracy of measurements.

The quantitative value of the weight loss of the product (X,%) during processing was determined by the formula

$$X = \frac{(m_1 - m_2) \cdot 100}{m_1}, \% \qquad (1)$$

where m_1 — weight before technological processing, g;
m_2 — weight after technological processing, g.

The device PM-3 was used to determine the structural and mechanical parameters.

Results and discussion

The pH value is one of the main characteristics in the meat products manufacture. The pH can be used to define the quality of meat after slaughter, storage stability, and the formation of red color of meat products. Water binding capacity also depends on this parameter.

When studying the effect of hydrostatic pressure in the range from 200 to 700 MPa on hydrogen ions concentration, it was noted that HHP does not lead to significant changes in pH, which for all samples remained within the range of 5.98 ± 0.12 pH.

Water binding capacity (WBC) is one of the main FTP, which affects the yield rate of the finished products, juiciness and more, therefore we conducted researches aimed at studying the dependence of the WBC value on the processing modes of the HP.

In our research we modified the standard methodology for determination of WBC. The pressing method is based on the release of water from the experimental sample during pressing, the sorption of the released water, filtering paper and the determination of the amount of released moisture by the area of the stain that remains on the paper. Due to the fact that in practice it is difficult to determine accurately the areas of the stains from the compressed meat and adsorbed moisture, we have improved the method, which allows determining these values using computer graphics.

When determining WBC after pressure processing from 200 to 700 MPa for 20 min, significant differences of this parameter in experimental samples were revealed (Figure 1).

The WBC value for chilled meat was 62.9%. When using a pressure of 200 MPa this parameter increased by 10.5%, and when processing of meat at 300 MPa, the WBC value increases by another 3.0%. Within the pressure range from 300 to 700 MPa, the WBC value has not changed significantly.

It is possible that the increase in WBC is caused by the following changes in protein molecules: upon mechanical action of HHP on poultry muscle fibers, myofibrils are destroyed with the release of myofibrillar proteins. This is accompanied by the breaking of electrostatic bonds and the formation of ionized groups that bind water.

Based on the obtained data, it can be concluded that the emergence of additional centers accessible to water after pressure processing contributes to an increase in the WBC of poultry meat.

One of the main parameters of the feasibility of using one or another technological processing method for poultry meat processors is the determination of weight loss. By weighing the samples before and after HHP processing, it was found that the values of this parameter increased with pressure increase from 200 to 700 MPa by 4.8%, but the samples had lower values of this parameter over the whole pressure range in comparison with the boiled meat. Weight loss after processing at 700 MPa is lower by 28.5% in comparison with the thermal processing of poultry meat (Figure 2).

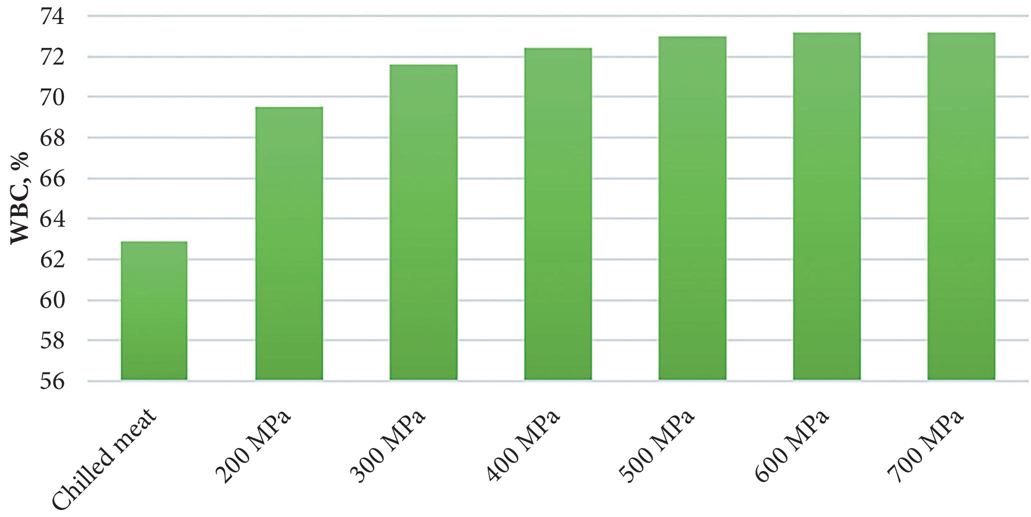

Figure 1. Changes in WBC value (%) of samples depending on pressure

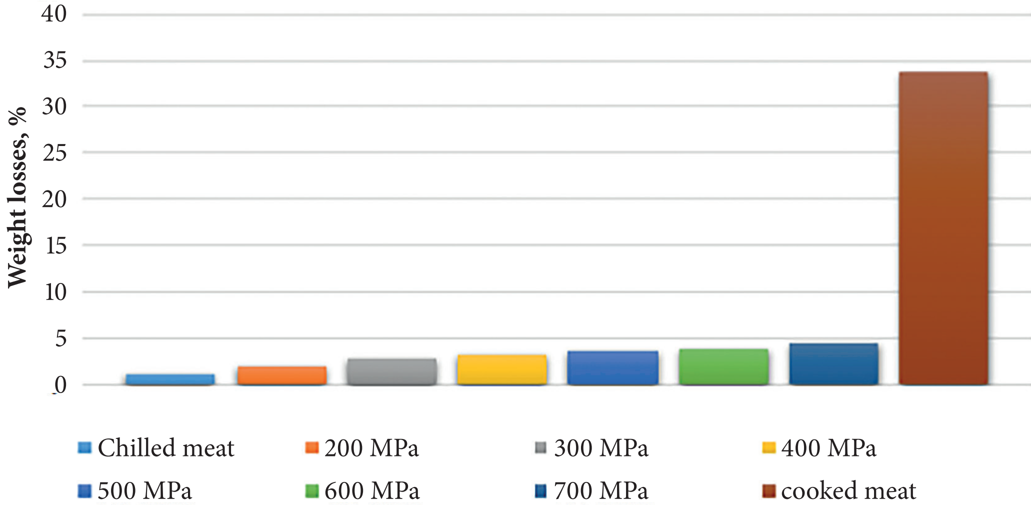

Figure 2. Change in the value of weight loss (%) of samples depending on the pressure

Structural and mechanical properties are characterized by parameters such as the texture and juiciness of the meat products. Therefore, the effect of high pressure on the ultimate shear stress was studied. The results of the study are presented in Figure 3.

Studies have shown that at a pressure of 200 MPa the ultimate shear stress is 0.41×10^{-5} Pa and gradually increases to a value of 0.54×10^{-5} Pa, which corresponds to the processing of samples at 500 MPa. Within the range from 500 to 700 MPa, a significant increase in the ultimate shear stress was observed: the value of the studied parameter increases under these pressure modes by 40.74%.

We consider that the increase of the ultimate shear stress value in the samples under study occurs due to the compaction of the meat structure under the influence of HP and the pressing out of bound moisture, depending on the

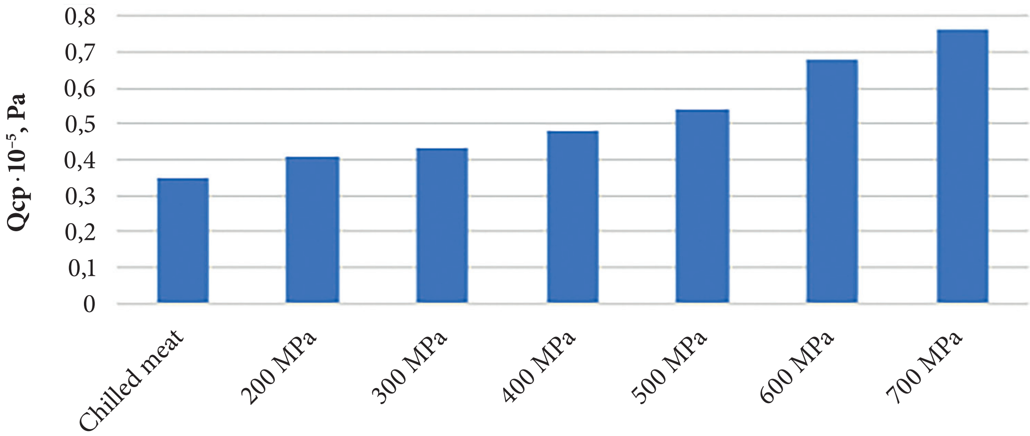

Figure 3. Changes in the value of the ultimate shear stress ($Qav \cdot 10^{-5}$, Pa) of samples depending on the pressure

denaturation changes in the poultry meat proteins. Reference sources [9] indicate that the elasticity of muscle fibers increases due to the additional interaction of dipoles with water molecules, which dipoles are formed in the protein structure under the influence of HHP. Such hydration of protein molecules has an ordered structure, which density is much higher than conventional.

Considering the results obtained and previous [11] it is possible to recommend for the production of finished products from poultry meat the HHP range from 600 to 700 MPa, processing time of 20 minutes.

Conclusion

As a result of studies the significant differences in the water binding capacity value were revealed: when using a pressure of 200 MPa this parameter increased by 10.0%, while processing at 300 MPa WBC increased additionally by 3.0%. In the pressure range from 300 to 700 MPa, the value of the water binding capacity has not changed significantly.

It was proved that the weight loss increases with pressure increase from 200 to 700 MPa by 4.8%, and after processing with 700 MPa this weight loss parameter is lower by 28.5% in comparison with weight loss after heat treatment of poultry meat.

The ultimate shear stress gradually increased within the range from 200 to 500 MPa by 24%. In the range from 500 to 700 MPa, a significant increase of 40.74% was observed, which may indicate tissue compaction caused by HHP processing.

Thus the processing of broiler chicken fillets with high pressure within the range from 200 to 700 MPa for 20 minutes at +20 °C improves the structural-mechanical and functional-technological properties. This technology reduces the amount of loss, compared with heat treatment (boiling), which is important for determining the yield rate of finished products in the processing of raw material of this type.

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