

Increasing the level of hydration of biopolymers in meat processing systems based on the use of acoustically activated brines

L. Tsirulnichenko^{1,*}, I. Potoroko¹, O. Krasulya², I. Gudina¹

¹South Ural State University, Higher School of Medicine and Biology, Department of Food and Biotechnology, 85 Lenina Avenue, 454080, Chelyabinsk, Russia

²Moscow State University of Technologies and Management named after K.G. Razumovskiy, Department of regulation of raw food products and examination of goods, 73, Zemlyanoy Val, 109004, Moscow, Russia

*Correspondence: linchikz@mail.ru

Abstract. The study aims to develop effective ways to improve the level of protein hydration of poultry. We studied the chemistry of the process of moisture binding by minced meat produced from pectoral and femoral muscles of broiler chickens. The reference brines were prepared from potable water and the test brines were sonicated. The samples which were held for a predetermined time and evaluated for structural integrity and heat treatment losses. The parameter values shown in the experimental session turned out to be higher in comparison with that shown in the reference session. A positive effect of ultrasound on the increase of hydration properties of poultry proteins and reduction of brine treatment time by more than 2 times and reduction of losses during heat treatment by 10% were recorded.

Keywords: ultrasonic treatment, meat processing technology, cavitation, hydration

INTRODUCTION

Hydration (from Greek hydor ‘water’) usually refers to the process of binding water with chemicals. Dehydration refers to the process, which is reverse to hydration, i.e. the loss of water bound by substances. Meat processors, especially those working with frozen raw meat, can observe that defrosting is accompanied by the process reverse to hydration, the control over which has a significant importance. Modern science dealing with food production pays much attention to solving the problem of safe and maximum moisture binding.

Currently, poultry is one of the most commonly consumed meat among all types of meat worldwide. Quality characteristics of poultry meat are influenced by many factors: genes (bird species, breed, cross, age), feed (ration type, nutrient balance), technology (breeding method, cramming duration, management conditions, preslaughter treatment, slaughter and processing), etc. (Shapiro & Mercier, 1994).

Therefore, it is quite difficult to ensure stable quality of finished poultry products. This is due to the high variability in the quality of raw meat in terms of chemical composition and the wide spread of PSE (Pale, Soft and Exudative) and DFD (Dark,

Firm and Dry) meat observed when raw meat has low moisture binding ability or poorly retains moisture during processing, especially at the brine treatment stage. Such problems for food technologists are associated with the risk of rejects. Therefore, producers resort to a variety of functional additives, for example, the use of phosphates which help retain moisture during brine treatment and make meat succulent. However, food safety in this case becomes compromised.

One of the most promising and alternative ways to increase the water-binding capacity and thermal resistance of raw meat biopolymers is the use of acoustically activated brines (Povey, 1998). Currently, the food industry developed methods for preparing aqueous solutions of electrolytes with the use of ultrasonic cavitation (Shestakov & Babak, 2012). The whole process comes down to primary ultrasonic treatment of water followed by mixing it with other components of the brine (Pilipenko et al., 2012). Electrolyte ions in such water acquire dense solvate shells made of free water molecules, i.e., the ions are immobilized by them which prevents their association. As a result, mass-exchanging and hydration processes are intensified during brine treatment of meat products (Shestakov et al., 2011).

Studies of the use of activated liquids in the meat industry defined the main directions of their use in salted meat production. It was found that the use of brines based on electro-activated water in the salted meat production contributes to a more uniform distribution of brine ingredients and speeds up the physico-chemical and biochemical processes occurring during the brine treatment of meat. Of special interest are the biopolymer hydration ability and a pronounced bactericidal effect of such cavitation-activated media.

These effects formed the basis of a working hypothesis about the possibility of increasing the thermal resistance of raw meat biopolymers using acoustic vibrations in the preparation of brines injected into the raw meat.

The goal of this work is to study the applicability of acoustic vibrations generated by ultrasound to increase the level of hydration of poultry biopolymers.

MATERIALS AND METHODS

Raw poultry

Model samples of broiler chicken minced meat were used in the study. We used broiler chicken minced meat of different thermal state (chilled and defrosted) with different morphological characteristics: on the basis of breast ('white' meat) and thigh ('red' meat) muscles, their 1:1 mixture ('mixture').

Broiler chicken meat (dressed chicken) used in the preparation of test and reference samples demonstrated the following properties: the protein mass fraction varied from 16 ± 0.4 to $20 \pm 0.6\%$; the fat mass fraction from 10 ± 0.2 to $16 \pm 0.4\%$, and pH from 5.4 to 6.4.

We studied the broiler chicken meat produced by Russian poultry complexes in the Chelyabinsk, Kurgan, Sverdlovsk and Tyumen regions. We selected 100 samples from each batch, and repeated the survey at least 15 times.

Minced meat model sample (emulsion) preparation method

The meat was ground through a 2.5 mm grate. The treated table salt solution (2.5%) was added to the treated meat. All samples were divided into two batches: for reference

and test. For the preparation of reference samples we used tap water-based brines, and the test batch – water sonicated with an ultrasound technological device UZTA-0.4/22-OM (Volna, Russia). The amount of added brine was 30% by weight of the raw meat.

Study procedure

The treated minced meat model samples were held for a predetermined time and monitored for changes in shear viscosity and thermal treatment losses. The experiment was performed at temperatures close to the process. Shear viscosity was measured with a rheometer Brookfield DV-III Ultra. Heat treatment ‘losses were determined’ by weighing.

Mathematical measurement processing was carried out by conventional variational statistics methods and expressed as the arithmetic mean (M) and its standard error (m). We used the Mann – Whitney test (U) to determine the statistically significant differences between the test and reference groups. Differences were considered significant at $p < 0.05$. Statistical interrelations were studied using nonparametric correlation analysis by calculating the Spearman correlation coefficients (R_s).

RESULTS AND DISCUSSION

Raw meat brine treatment is very closely related to the process of hydration of meat biopolymers. Minced meats are emulsions, i.e. dispersions comprising dispersed medium – water – and dispersed phase – particles of the crushed missela muscular tissues and macromolecules. According to Rebinder's (1979) classification, meat emulsions refer to coagulation emulsions, where a solid carcass is formed in the hydration of the dispersed phase resulting in the advanced structural and mechanical properties of the finished products. Therefore, their quality is directly dependent on the amount and form of moisture binding, primarily with the protein components of minced meat. As a rheological property, dynamic viscosity most fully characterizes the course of the hydration process in the mechanical treatment of minced meat.

Acoustic vibrations in water generate enormous pressure pulses in the water which, correspondingly, cause deformations travelling in the water at the speed of sound. The transformation of the potential energy of such deformations implements an above-thermal mechanism of destruction of molecular associates whereby only water passes into a thermodynamically non-equilibrium state, and salt dissolved therein completely dissociates into ions, which will be immobilized by polar monomolecular water or tightly bound in the forming protein solvate shells.

Let us consider an example of the effect of activated brines on the rheology of meat emulsions below.

A two-way analysis was conducted to determine the optimal mode for acoustic influence of ultrasound based on the thermal condition of the meat. We selected power and duration of ultrasonic treatment as variables. Monitored parameter: level of hydration (content of moisture in the product after thermal treatment) on Fig. 1.

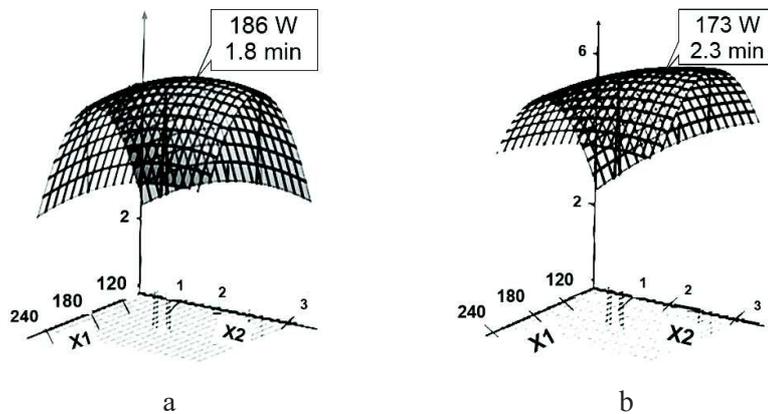


Figure 1. Dependence of the level of protein hydration of poultry on the power and duration of ultrasonic treatment for minced meats from chilled (a) and defrosted (b) raw meat (X_1 – power, W, X_2 – time, min).

Hence, salt brines injected into the test samples were treated under the following conditions – frequency 22 ± 1.65 kHz, power 186 W, exposure 1.8 min for minced meat from chilled raw meat and power 173 W, exposure 2.3 min for defrosted raw meat.

Results of the study of the shear viscosity of minced poultry are shown on Figs 2 and 3.

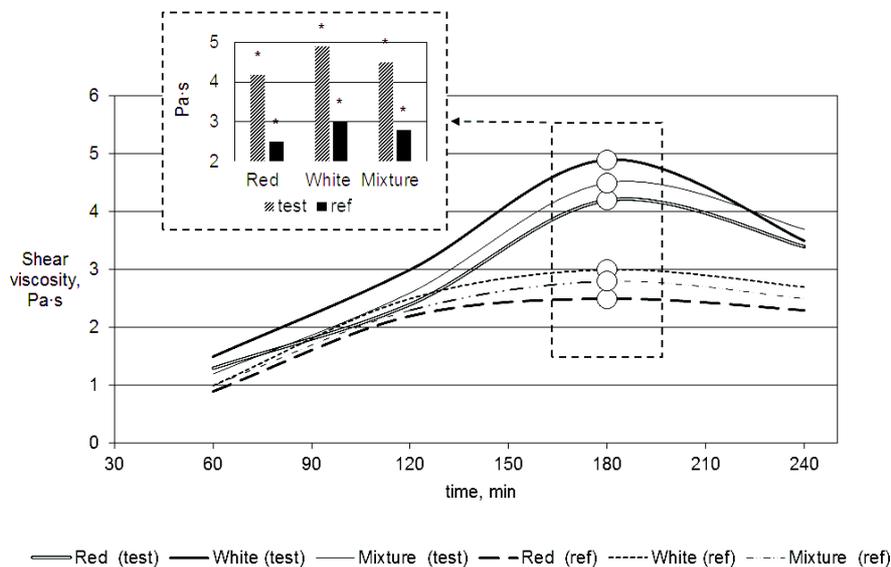


Figure 2. Shear viscosity of minced meats from chilled broiler chicken meat. (deviation does not exceed 0.3 for all indicators).

Gorbatov (1979) established the structure tightening period for thinly minced meats: after 2–4 hours of holding at 22 °C minced meats demonstrate the highest

structural and mechanical characteristics due to the thixotropic tightening of their structure.

Tightening of minced meat structure is observed after 180 minutes of holding. The test samples showed higher shear viscosity relative to the reference samples, i.e., muscle fibers saturate with moisture more fully and particles swell better.

The highest viscosity values were registered for chilled raw meat: white meat – 4.8 Pa·s; red meat – 3.7 Pa·s; mixture – 4 Pa·s (averaged values of viscosity). The obtained dynamic viscosity distribution values depends on the chemical composition of muscle development: The fat content in thigh muscles (red meat) is greater than that in pectoral muscles (white meat) resulting in the increase of the surface tension at the water-tissue interface and decrease in the biomass wettability, which ultimately determines the decrease in viscosity.

Defrosted test samples demonstrated high viscosity values, which allows us to speak about the normal course of the process of saturation of biomass with moisture and its retention in the meat system, and solve the problem of low technological properties of defrosted raw meat.

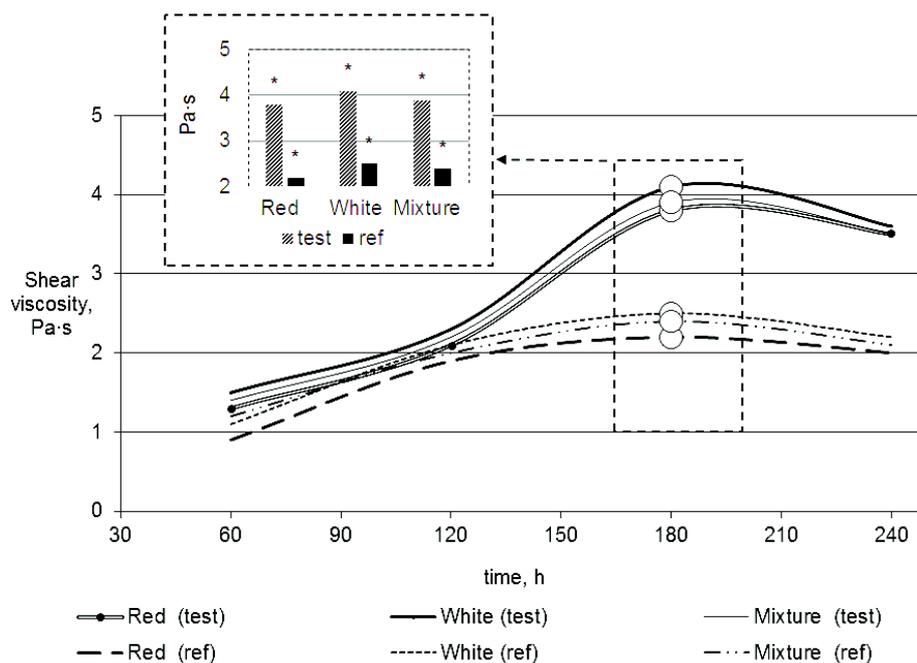


Figure 3. Shear viscosity of minced meats from defrosted broiler chicken meat (deviation does not exceed 0.3 for all indicators).

It should also be noted that the reference samples of minced meats are resistant to increased temperatures and prolonged mechanical stress – in the final phase of the experiment: no sharp decrease in the structural and mechanical properties (viscosity) was observed. At the same time we noted a sharp decrease in the shear viscosity trend of the reference samples which was caused by grinding of the remaining muscle fibers and connective tissue and changes in moisture bond forms.

Similar processes can be observed during chopping: minced meat particles must be bound with such amount of water which turns them into a homogeneous mass.

The positive trend in the structural and mechanical characteristics is consistent with positive changes in water-holding capacity observed in the test samples of coarse minced meat based on breast muscles of chilled poultry.

In the sausage production technology holding of coarse minced meats before chopping may take up to 24 hours for the purpose of deeper penetration of brine components.

We have found that acoustic activation has a beneficial effect on the holding time of coarse minced meat before chopping (Fig. 4).

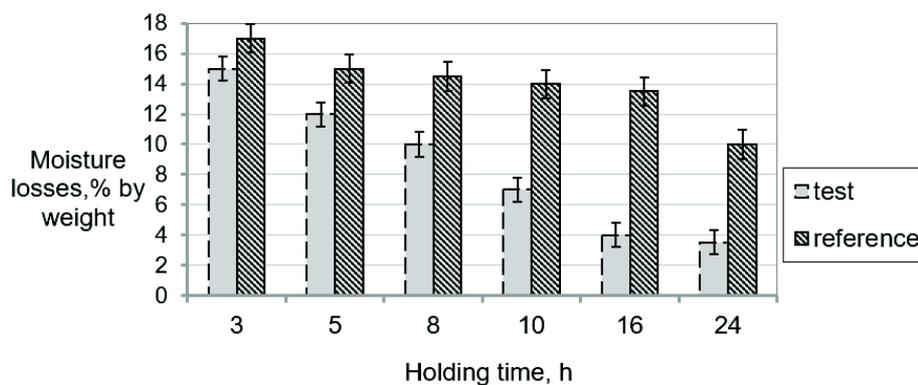


Figure 4. Dependence of the amount of thermal treatment losses of minced meats on the holding time. Statistically significant differences ($p < 0.05$) between test and reference samples by the Kruskal-Wallis criteria.

The test samples have specified characteristics as early as after 3 hours of holding, thereby reducing the time required by 2 times. For the test samples moisture losses during thermal treatment amounted to 10%, which is 5% lower than the reference samples. We noticed that lower moisture loss increased the yield of finished products by 5%. Using calculation methods we found that the acoustic effects of ultrasound on the brine can reduce the amount of water-retaining additives injected as per formula by up to 75%, shorten the maturing period by 2 times on average.

CONCLUSIONS

Acoustic vibrations generated by ultrasound increase the level of hydration of poultry myofibrillar proteins.

Acoustic activation of liquid brine media improves the functional and process properties of poultry. This will retain enough moisture in the finished meat products and add extra juiciness.

It was established in the course of the study that the application of brines leads to the reduction of time required to hold minced meat, and that translates directly into intensification of the technological process and reduce the risk of defects.

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