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EFFECT OF ULTRASOUND PROCESSING OF MEAT BEFORE FREEZING ON ITS TEXTURE AFTER THAWING

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ABSTRACT

The paper presents the results of studies on ultrasound processing of meat after slaughter on the changes of texture properties after freezing and thawing. The studies were carried out on *M.semimembranosus* of young slaughter cattle with a liveweight of 450-500 kg. The samples were processed with ultrasounds of the frequency of 25 kHz and intensity of 2 W/cm^2. After slaughter they were chilled, frozen and thawed. The parameters of texture (hardness, cohesiveness, elasticity) of thermally treated meat were measured by TPA test (50% deformation, 10 mm/min). Texture tests were conducted with the use of Instron device model 4302.
The results showed that after slaughter ultrasound treatment changes the meat texture after thawing (hardness, cohesiveness, elasticity). The quality (drip loss, heating loss, texture) of frozen meat, thawed and heated at the temperature of 50, 60 and 70^{o}C were changed after ultrasonic treatment.

Key words: meat, ultrasounds, freezing, thawing, texture.

INTRODUCTION

Freezing is a traditional method of increasing durability of food. A lot of investigations have attempted to determine the mechanism of freezing-thawing process and its influence on meat properties. The quality of a product after thawing is related to a great number of factors, the most important of which are the kind and structure of material (product), thermal properties and the speed of transforming water from the liquid state to the crystalline one [6, 7, 10, 11].

The properties of meat are determined by a large number of factors – especially perimortal treatment – before (form of animal) and after slaughter (conditions that are imposed on the carcass). The main determinant of meat quality is the course of anaerobic glycolysis. Meat is characterised by very complex tissue structure, with a big amount of water found in specific protein macro- and microstructures, which undergo changes during storage after slaughter and under the effect of outer factors, e.g. ultrasounds [4, 9].

Water (the basic compound of muscular tissue) is characterised by specific polar structure of a particle [5]. It has the ability to create hydrogen links between its own particle and various chemical groups of biological compounds, especially the proteins of meat. It is able to consolidate or create new conformation structures in protein molecule [5].

Meat freezing is connected with crystallisation of water which causes a number of phenomena of physical and biological character and which are observed in thawed meat [3, 8, 10]. The changes taking place in the muscular tissue while thawing are associated with the intensity of heat exchange [3, 9] and changes in the physico-chemical properties of protein structures of myofibrils [4, 11]. The basic problem is the amount and size of the ice crystal while freezing [3, 7, 12]. Meat quality after thawing is much influenced by the so-called phase of crystal germination, which takes place below the initial cryoscopic temperature. While the crystal germs are formed, latent crystallisation heat is released, which can cause local increase of temperature and consequently – the formation of big ice crystal [8, 12]. This phenomenon can be reflected in the form of excessive thawing outflows, cohesiveness changes, and above all in a lower organoleptic quality of the substance.

The tissue structure and especially the interactions between actine and myosine and water distribution in the protein structures of the muscular cell influence the crystals of ice formation while freezing meat [5, 10]. Changes of the protein structures of meat after slaughter can cause accumulation of big concentrations of water in definite places of the muscular tissue or such its distribution which can be favourable for the formation of a big amount of crystal germs while freezing [2, 5, 6].

Investigations into the effects of ultrasonics began in the 19th century. The first development of ultrasonic technology was submarine detection in World War I. There are a lot of applications of ultrasonic technique, e.g. cleaning, cell-disruption, emulsification, extraction, homogenisation, pasteurisation, testing, process monitoring. But the applications are determined by frequency and power level of the waves. Ultrasonic non-destructive testing is characterized by high frequencies (from 100 kHz upward) and low power levels (up to about 0.1 W) while leaving the material unchanged. Another method uses medium and high power levels (from few Wats upward) and lower frequencies (up to about 100 kHz). It changes the physical and chemical properties of materials during ultrasound propagation and/or causes delayed transformation. Ultrasound is attenuated in meat and in fat especially. Dissipation of ultrasound waves energy causes heating of tissues, destruction of cells and enzymes, diffusion

through biological membranes and other phenomena. The studies concerning the effect of ultrasounds on the muscular tissue showed that during sonification its physical, mechanical and structural properties undergo changes [4, 9].

MATERIALS AND METHODS

The present study was designed to evaluate the influence of post-slaughter processing of meat with ultrasound of low frequency on the texture of thawed and thermally processed meat.

The studies used semimembranosus muscle (*M.semimembranosus*) of young slaughter cattle (n=6) of Black and White lowland breed of a liveweight 450-500 kg (similar grade, size and age). The cattle were slaughtered at an industrial beef processing plant. Muscle of the mass 1.2-1.4 kg was cut off from beef halves 90 minutes after slaughter. It was divided into three parts of similar masses and cubic shapes. The first (n=6) was the control sample (K), the second (n=6) and third (n=6) were treated (1 minute – U1, 2 minutes – U2) with ultrasounds (25 kHz, 2 W/cm^2). The samples were chilled down to the temperature of +6^{o}C. The U1 and U2 samples were processed with ultrasounds the next time after 12 hours. They were kept up to 48 hours (after slaughter) in chilled conditions (+6^{o}C), weighed, vacuum-packed and stored for one month in a freezer at the temperature of -21^{o}C. The samples were thawed at room temperature (+18^{o}C) for 24 hours and dewetted using the blotting-paper. The weight loss of the thawed meat sample was expressed as a percentage of the weight before freezing to give the drip loss.

The pH of minced meat was determined by homogenizing 10 g of mince in 100 ml distilled water at the temperature 18^{o}C, then measuring the pH of the suspension with the electronic pH-meter. Three measurements were taken on each sample and the mean value was used for statistical analysis.

Images of meat structure have been obtained by optical and electron (Tesla 3S-500) microscopy. Samples were photographed with Kodak Tri-X film at a magnification of ×100 and ×8000.

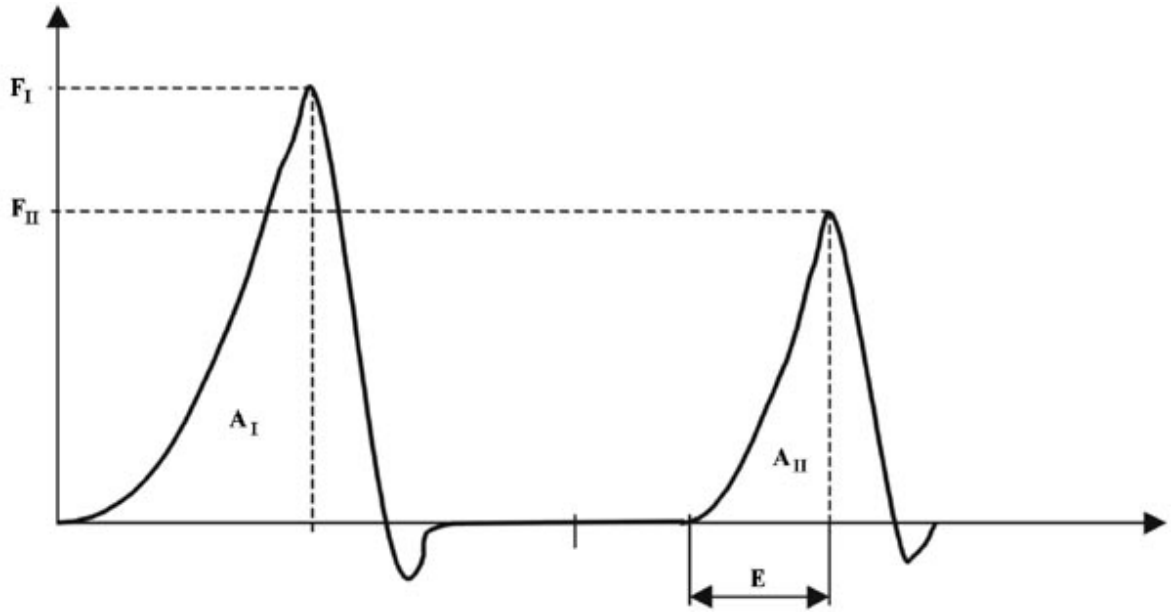
The amount of the thermal loss was estimated. The cubic (27 cm^3) meat samples were packed in polyethylene bags and heated in water bath at the temperatures of 50, 60 and 70^{o}C for the period of 30 minutes. Samples are dewetted using the blotting-paper. The thermal loss of the heated meat sample was expressed as a percentage of the weight before heating to give the cooking loss.

The TPA test was performed on the meat samples heated at the temperatures of 50, 60 and 70^{o}C. Cubic meat samples (8 cm^3) were deformed (50%) with 10 mm/min parallel to the direction of muscle fibres. The relations (fig. 1) between the force and the deformation was the base of the texture parameters [1]:

- hardness I – T1 – maximum strength (F1) occurring during the first deformation (N);
- hardness II – T2 – maximum strength (F2) occurring during the second deformation (N);
- cohesiveness (S) – relation between the size of the area (A2) under the curve characterising the second deformation to the size of the area under the curve of the first deformation;

- elasticity (E) – value L by which the height of a meat sample increased between the first and second deformation (mm).

Fig. 1. TPA - typical force-deformation curve of meat sample [1]



A texture test was conducted with the use of Instron machine model 4302 with Series XII software.

The studies were conducted in 6 repetitions and replicated 3 times, and they were statistically analysed, using STSC Statgraphics.

RESULTS AND DISCUSSION

The initial pH of meat samples was within the range 6.7-6.9. It was within the range 5.55-5.60 after thawing (tab. 1). There are no significant changes of pH-values of meat after ultrasonic treatment (compared to pH of control sample – K) [6].

Table 1. Drip loss and pH changes after meat chilling and thawing

Sample	Drip loss (%)		pH
	chilling	thawing	
K	2.14 ± 0.2	10.5 ± 2.1	5.55
U1	1.77 ± 0.3	8.6 ± 2.0	5.60
U2	0.95 ± 0.1	8.0 ± 2.0	5.60

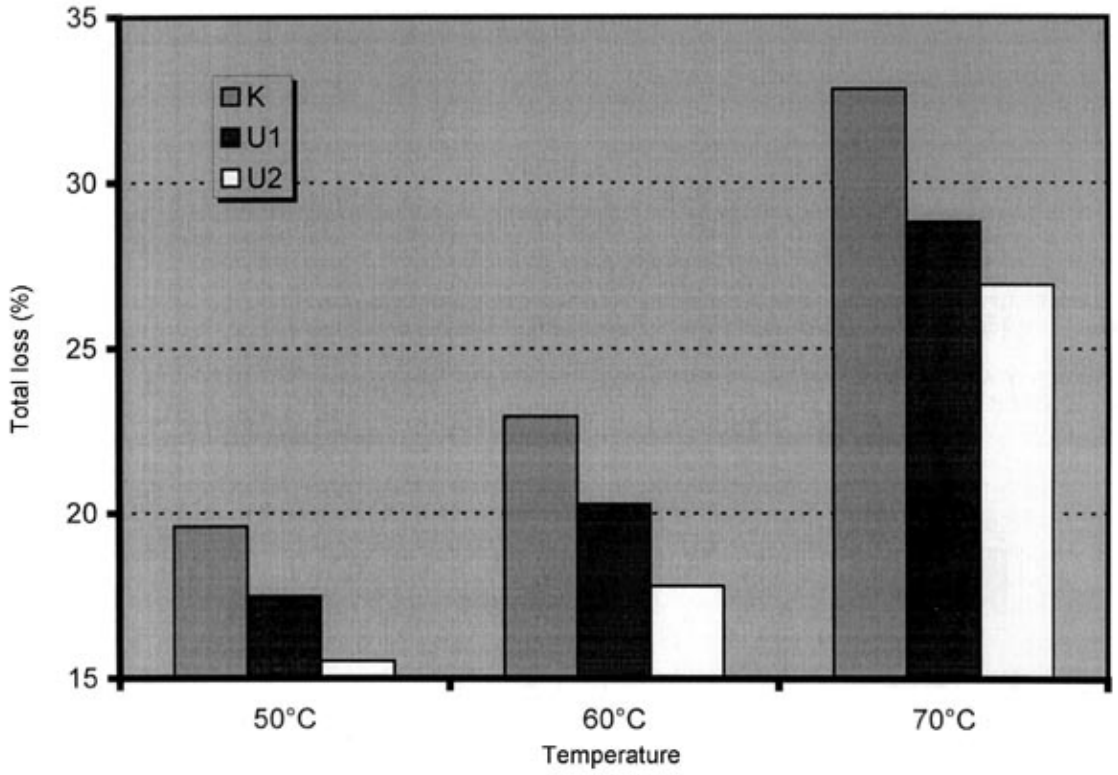
The physical properties of thawed meat treated with ultrasound after slaughter are changed. The drip loss of the thawed meat sample after post-mortem ultrasonic treatment (U1, U2) is significantly lower than weight loss of control (K) sample (tab. 1). The control sample (K) is characterised by the highest drip loss after the chilling (2.14%), the greatest thawing outflow (10.5%) and higher values of loss after thermal treatment (tab. 2). The thermal loss of the control sample (K) was approximately 1% higher than thermal loss of U2 sample at 50°C. Similar tendencies can be observed after processing at 60°C and 70°C (pasteurising

temperature of meat products). The difference between thermal loss of control sample (K) and sample treated with ultrasound (U2) was about 3.5% at 70°C. There are not statistically significant differences between thermal loss of control sample (K) and sample 1-minute treated with ultrasound (U1). The longer exposition (2 minutes) changes the conditions of water holding capacity in meat samples during thermal processing. The highest total loss (fig. 2) characterizes control sample at 50°C, 60°C and 70°C, but the smallest loss – the samples ultrasonically treated (U1 and U2).

Table 2. Thermal loss of thawed meat after treatment at different temperatures

Sample	Loss (%)		
	50°C	60°C	70°C
K	8.2 ± 2.1	12.0 ± 1.8	23.3 ± 2.1
U1	8.1 ± 0.9	11.2 ± 1.6	20.7 ± 1.9
U2	7.3 ± 1.1	9.8 ± 1.5	19.8 ± 1.0

Fig. 2. Total weight loss (chilling+thawing+thermal at 50, 60 and 70°C) of meat samples



Studies of the TPA-parameters confirmed changes of the physical properties of meat caused by post-slaughter ultrasound treatment. The texture (tab. 3-5, fig. 3, 4) of thawed and heated meat is a result of changes of water holding capacity (tab. 1, 2). Hardness of U1 and U2 samples (22.0 N and 20.1 N) is significantly lower than hardness of control sample K (28.0 N) at 50°C (fig. 3). Cohesiveness (fig. 4) of the samples U1 (0.44) and U2 (0.49) is significantly higher compared to sample K (0.40). The elasticity (fig. 4) of U1 (6.7) and U2 (2.5) samples is lower compared with the control sample K (7.2).

Table 3. Characteristics of texture of thawed meat after thermal treatment at 50°C

Sample	T1 (N)	T2 (N)	S	E (mm)
K	28.0 ± 3.1	20.7 ± 1.2	0.40 ± 0.1	0.72 ± 0.5
U1	22.0 ± 1.2	17.4 ± 2.1	0.44 ± 0.1	0.67 ± 0.6
U2	20.1 ± 2.1	15.2 ± 2.2	0.49 ± 0.1	0.25 ± 0.7

Table 4. Characteristic of texture of thawed meat after thermal treatment at 60°C

Sample	T1 (N)	T2 (N)	S	E (mm)
K	33.7 ± 3.0	28.7 ± 2.2	0.50 ± 0.2	0.95 ± 0.2
U1	27.5 ± 2.5	23.5 ± 2.1	0.43 ± 0.2	0.71 ± 0.4
U2	36.0 ± 1.1	30.5 ± 1.9	0.47 ± 0.2	0.77 ± 0.5

Table 5. Characteristics of texture of thawed meat after thermal treatment at 70°C

Sample	T1 (N)	T2 (N)	S	E (mm)
K	24.2 ± 2.5	22.5 ± 1.2	0.60 ± 0.1	0.95 ± 0.2
U1	<32.5 ± 4.1	28.2 ± 2.3	0.45 ± 0.3	0.97 ± 0.3
U2	29.5 ± 3.2	26.2 ±1.2	0.52 ± 0.2	1.02 ± 0.2

Thermal processing of meat at 60°C increases the examined TPA-parameters (as compared to the sample processes at 50°C). There are observed irregular differentiation of texture parameters between samples. The highest value of hardness (T1 and T2) is observed (fig. 3) for the meat processed with ultrasounds for 2 minutes (U2 – 36.0 N), while the lowest for the meat processed for 1 minute (U1 – 27,5 N). Cohesiveness (S) was within the range from 0.43 (for U1) to 0.50 (for K sample) and elasticity (E) was within the range from 0.71 (for U1) to 0.95 (for K sample) (fig. 4). These parameters of texture correlate to meat hardness (T1 and T2).

Fig. 3. Hardness (T1 and T2) of meat after treatment at 50, 60 and 70°C

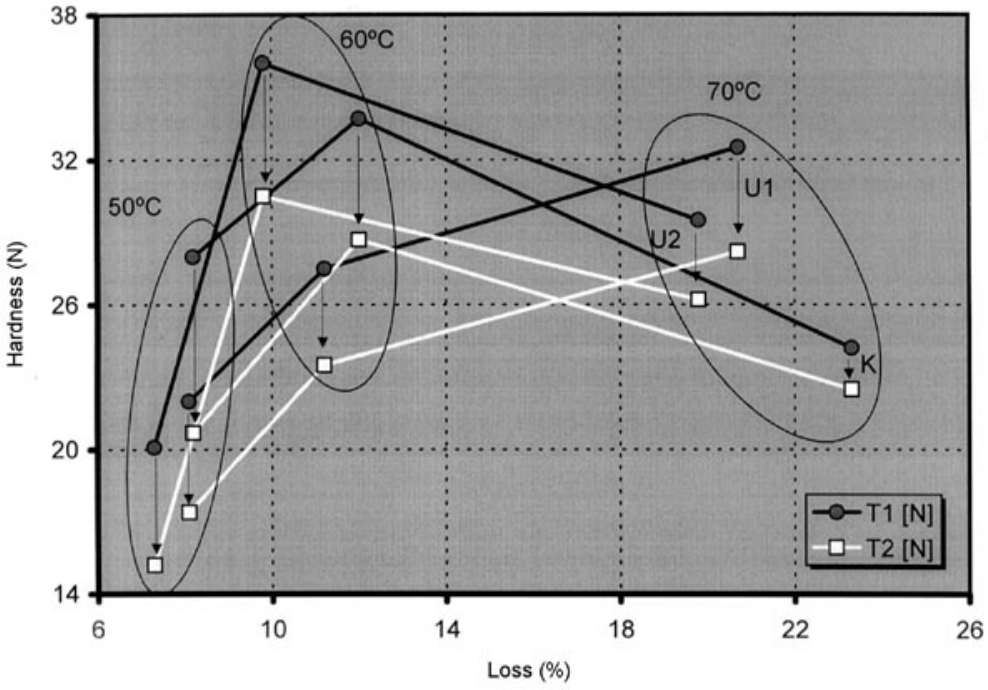
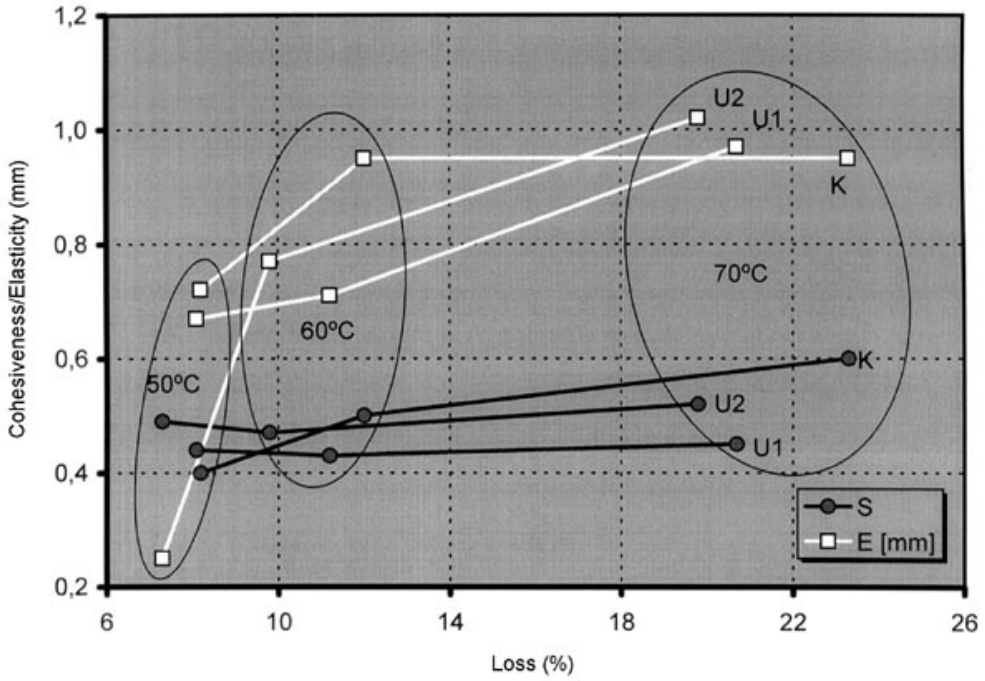


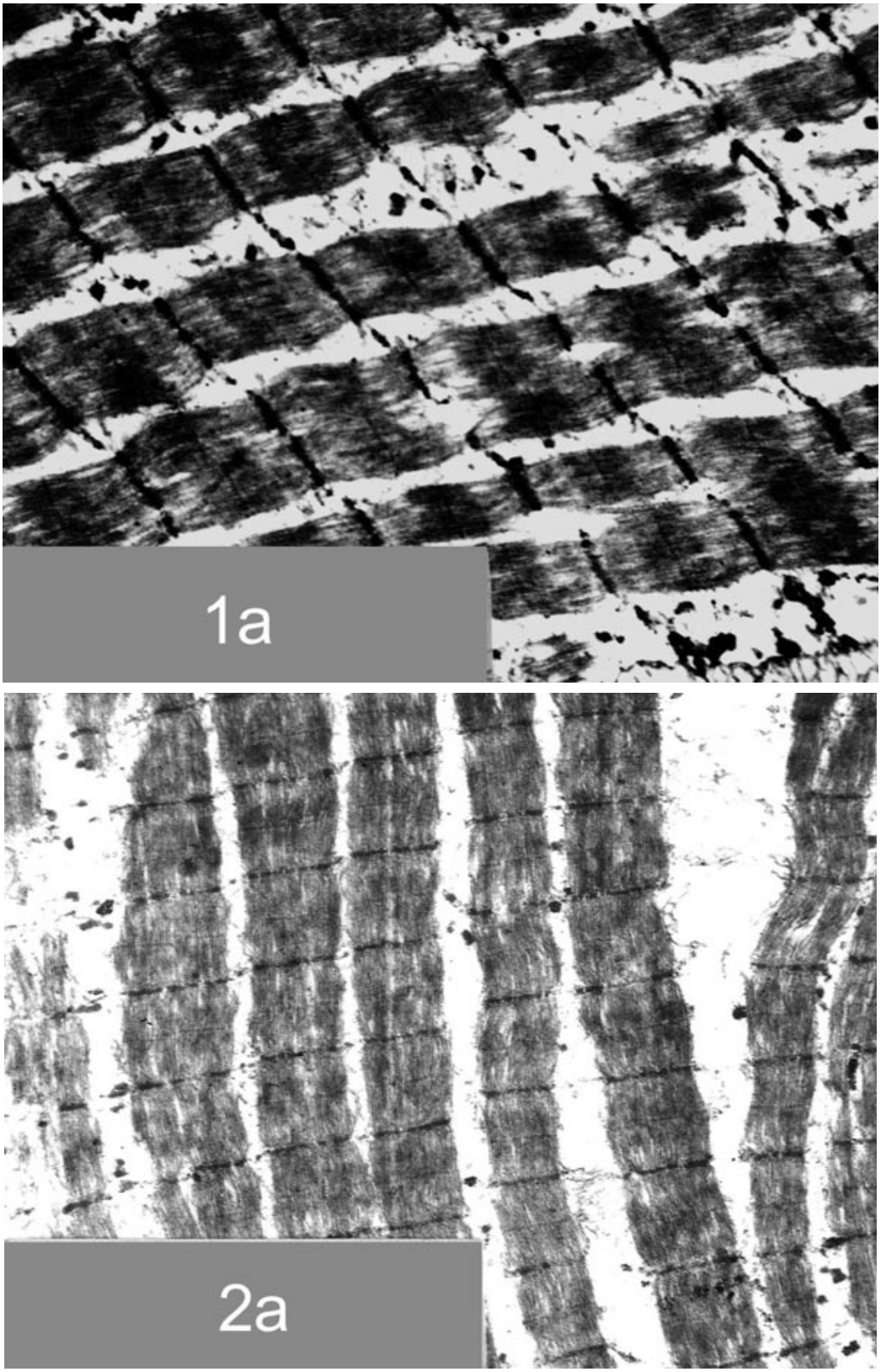
Fig. 4. Cohesiveness (S) and elasticity (E) of meat samples after treatment at 50, 60 and 70°C

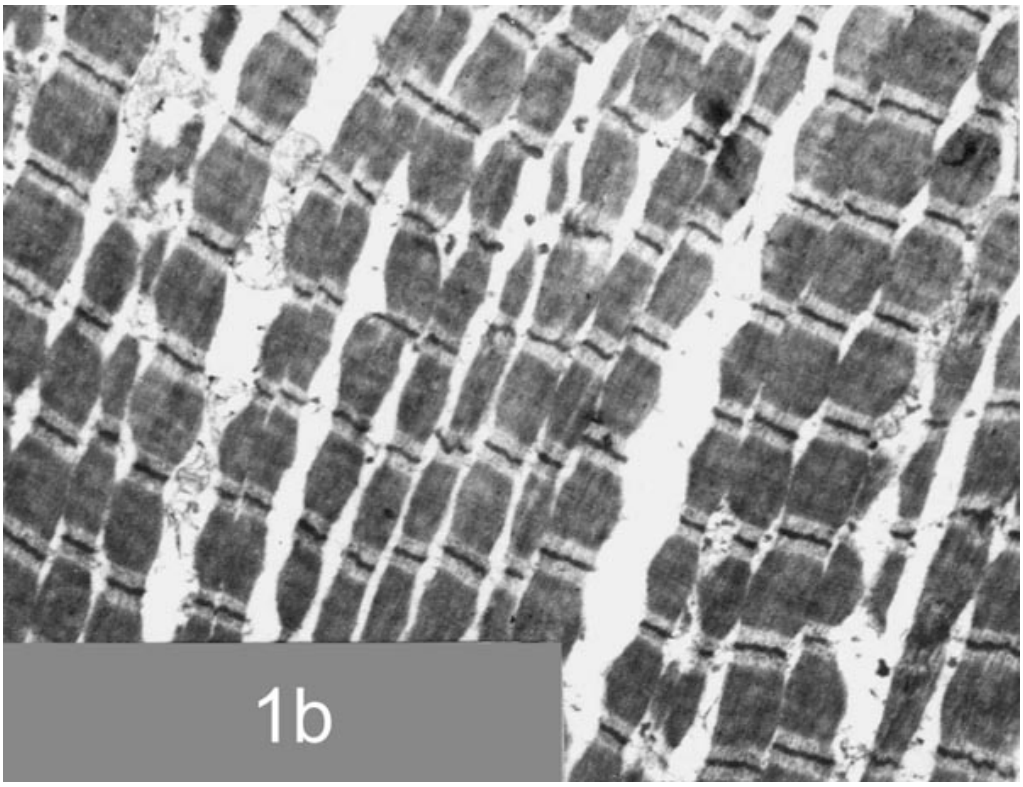


Ultrasound treatment of meat increases its hardness (T1 and T2) and elasticity (E) after processing at 70°C, compared to the control sample (K). The hardness (fig. 3) of control sample (K) is equal to 24.2 N, sample U1 – 32.5 N and sample U2 – 29.5 N. The difference is statistically significant. Pasteurisation temperature decreases the cohesiveness of ultrasonically treated samples from 0.60 to 0.45 for U1 and 0.52 for U2 sample and increases the elasticity from 0.95 to 0.97 for 1-minute treated sample (U1) and 1.02 for 2-minutes' ultrasonically treated sample (U2) (fig. 4).

The examination of microstructure (fig. 5 and 6) showed that ultrasound destroys morphological elements of tissue. The photo images show structural degradation of myofibrilar proteins. A lot of Z-discs broke the area, while I-bands and M-line were virtually disintegrated (fig. 6). The myofibrils and sarcomers were completely destroyed in ultrasonically treated samples (U1, U2) especially after thawing (fig. 6). The border of A and I-bands is dislocated compared with control and U-samples. Z-lines are fragmented and M-band lost their homogeneity.

Fig. 5. Micrographs (×8000) of *M.semimembranosus* (1a - 48 h post mortem, 2a - thawed, 1b - control sample, 2b - sample processed with ultrasound)





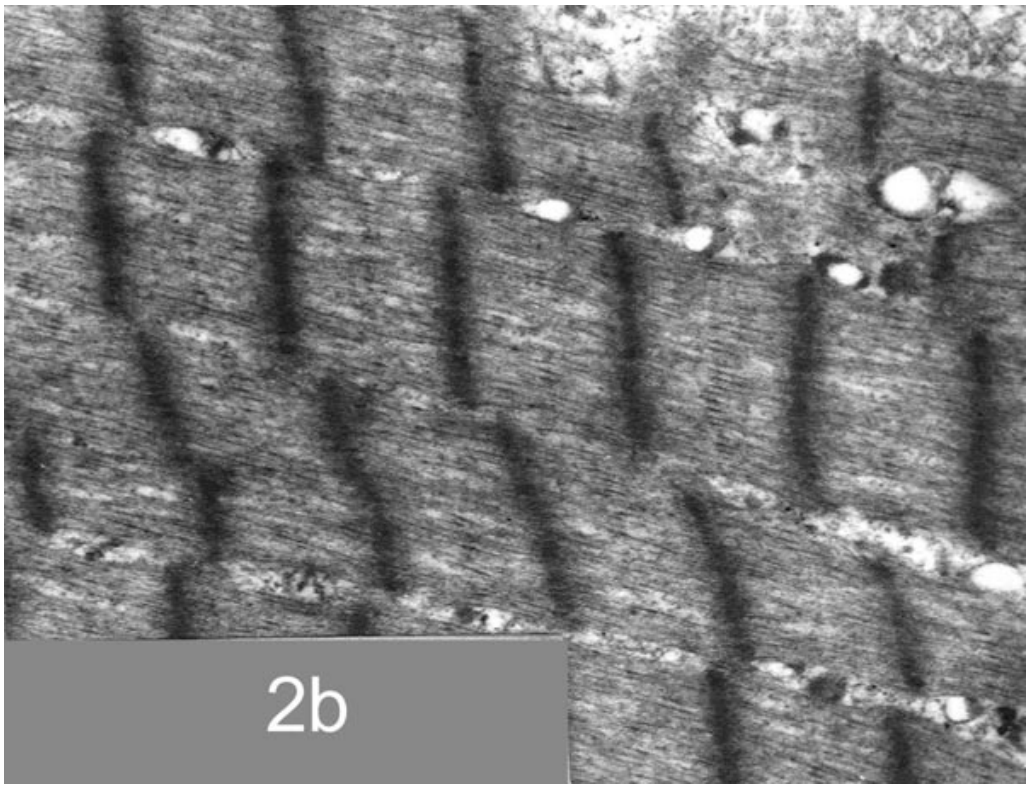


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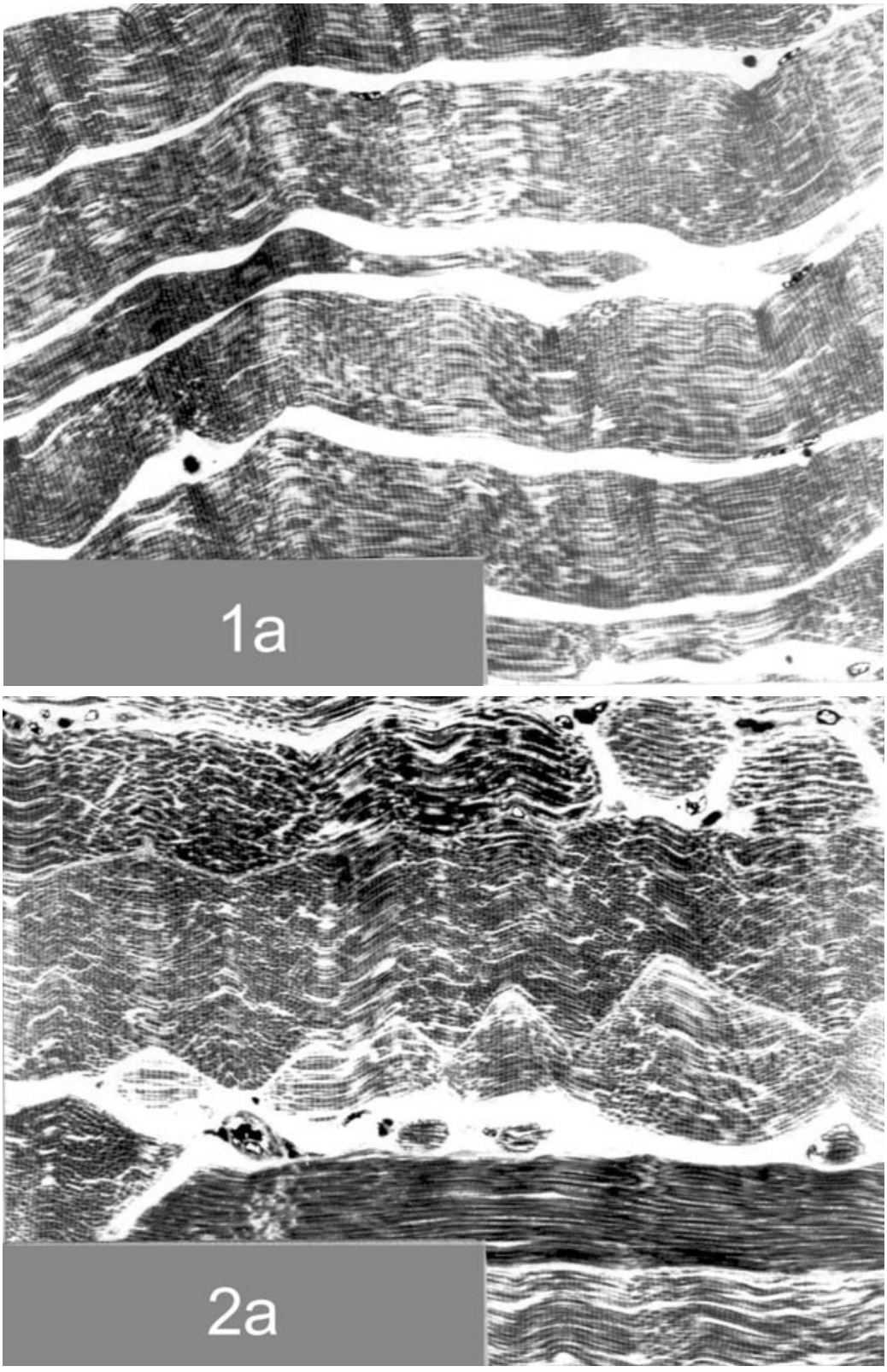
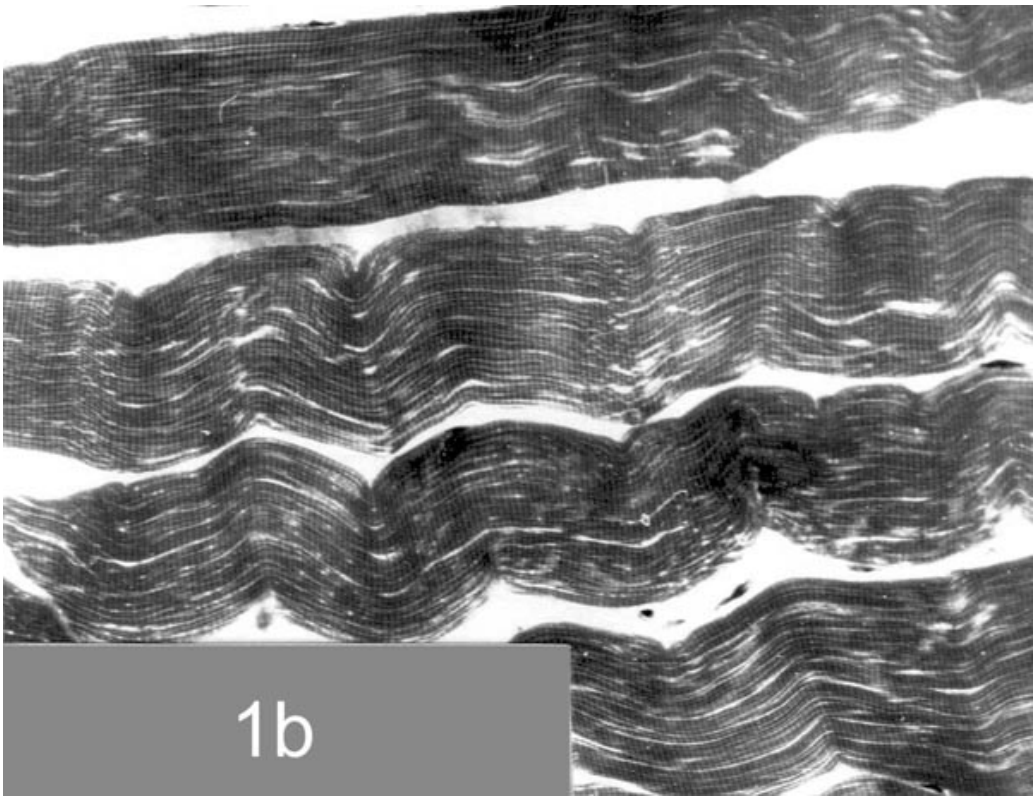
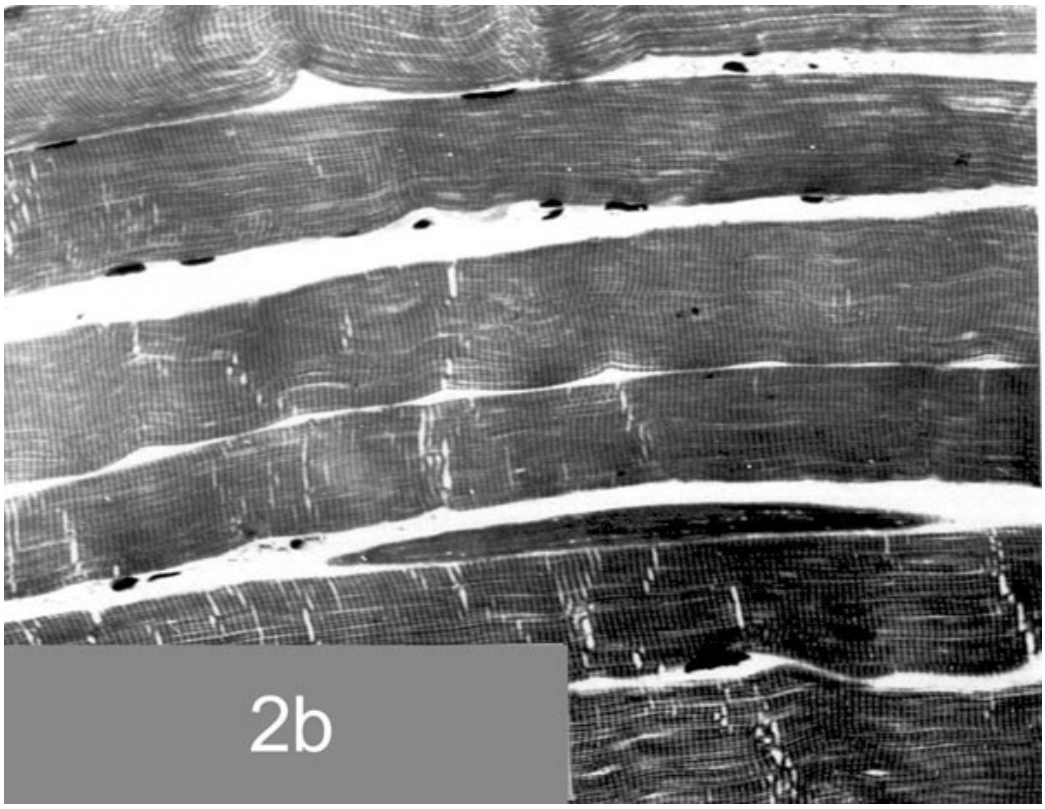
Fig. 6. Micrographs (×100) of *M.semimembranosus* (1a - 48 h post mortem, 2a - thawed, 1b - control sample, 2b - sample processed with ultrasound)







It can be supposed that the post-slaughter time and state of rigor mortis (dependent on parameters of ultrasound treatment) take a special role in the formation of meat properties. The studies show [4] that processing with ultrasound changes the interaction between myosine and actine after slaughter. It increases the number of calcium ions in sarcomere cytosole [13]. Results of investigations of meat after slaughter, especially ultrasonically

treated, show changes of the properties of germs and ice crystals formation. There are formed a greater number of smaller crystals in the cell instead of bigger ice elements. Increased thawing loss in the control group can point out that the meat was in the rigor mortis phase during its freezing. The changes influence the water holding capacity of meat and ability to retain its own water. The studies cannot clearly show which protein elements of the fibre structure could have affected the differentiation of the results. Apart from technical properties of freezing, one should think that it follows from the changes in the proteins of myofibrilles and maintenance of rigor mortis, which is an interaction between myosine, actine and changes in Z line.

CONCLUSIONS

There is no significant influence of ultrasound (low frequency, middle power) treatment on the pH of meat samples. The pH of samples is unchanged and within the range 5.55-5.60 after thawing.

Results of the studies showed a significant influence of meat processing with ultrasound on the parameters of its texture (hardness, cohesiveness, elasticity). The 1st and 2nd hardness (T1, T2) of ultrasonically treated meat samples (U1, U2) after heating at 50^{o}C are lower than those observed for control sample (K). But hardness of U1 and U2 samples heated at 70^{o}C is significantly higher than hardness of K-sample. The differentiation is observed for cohesiveness (S) and elasticity (E) of meat after thawing and heating. Post slaughter ultrasound treatment increases cohesiveness and decreases elasticity of meat sample at 50^{o}C. These tendencies are reversed at 70^{o}C, cohesiveness is lower and elasticity is higher for U-samples (compared to control samples).

The effects of ultrasound treatment are observed at weight loss of meat samples after thawing and heating. The losses of U-samples are significantly lower than losses observed for control sample after chilling and thawing. Thermal loss of control meat sample (K) at temperatures within the range 50-70^{o}C is significantly different from ultrasonically treated samples (U1, U2). The U-sample show a lower drip loss (a higher water holding capacity compared to K-sample).

The parameters of texture depend on water holding capacity (WHC) of meat. The heating changes the meat properties and WHC. But the ultrasound treatment changes the structure of meat tissue (the changes within the protein molecules, cell especially) and increases the WHC of meat. The photo images of microstructure confirm the observations.

Post slaughter ultrasound treatment would help change the texture properties of meat and increase water holding capacity after thawing and thermal processing.

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