Improvement of grain processing via ultrasonic treatment

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Improvement of grain processing via ultrasonic treatment

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Abstract. The theoretical study made it possible to define the main correlation dependences affecting the efficiency of grain preparation for milling. Experimental studies allowed improving the technology of grain softening and washing. Design and operating parameters of ultrasonic facility and technology ensuring high degree of grain cleaning and moistening were studied and structured, namely: ultrasound frequency – 18 kHz; process temperature – 30-40 °C; processing time – 30-40 s; intensity of ultrasonic waves – 1 W/cm^2.

1. Introduction
Flour production is a complex technological process requiring huge capital investments. Technological methods of grain preparation for milling are crucial for the production of high-quality flour. In Russia besides large producers, small enterprises and farms are engaged in grain processing. The flour-milling industry of Russia covers the needs of the population for the necessary volumes of flour, but at the same time poor technological infrastructure and engineering backwardness of many mills prevents its effective development [1]. The purpose of the study is to improve the technology of grain preparation for milling due to intensification of grain moistening.

2. Materials and methods
The processing properties of grain were defined according to standard technologies (GOST 10847-74, GOST 13586.5-93, GOST 13586.1-68, GOST 9450-76, GOST 10846-91). The impurity of grain with mineral mixtures was assessed via microanalytical method based on the mean square summation of pollution areas with agglomeration in a groove and seed hair. Grain was processed on laboratory ultrasonic facility UZU-4 by changing ultrasonic frequencies and temperature of processing.

3. Results of grain analysis
Many scientists study the ultrasonic influence on biological objects. In science and technology ultrasound have been used since the late 1950s. Such scientists as Bergman L., Olshansky N.A., Kogan M.G., Domchuk I.S., Arkhipova T.I., Danilovtseva A.B., etc. were studying the ultrasound phenomanon.

Low frequency ultrasound is applied in various fields of food industry. It is used to intensify extraction, homogenization, to accelerate meat salting, cleaning, sterilization, etc. [2-9]. The *Saratovskaya 29* grain was used for pilot studies. This choice was made due to large distribution of this grade in the Volga region. Grain with the following physical and chemical characteristics was used in the study: moisture – 12.5%; ash-content – 1.9%; gluten – 24.5%; endosperm micro-hardness – 150 MPa (15 kgf/mm^2); protein – 11.5%.

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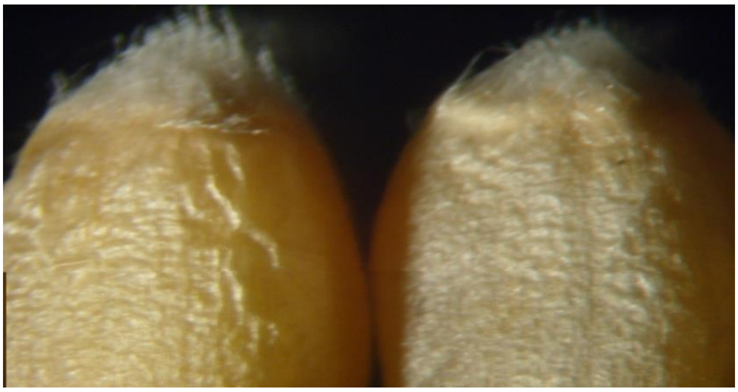
The pilot studies showed that the impact of acoustic cavitation liquid on grain in a laminar flow generated by ultrasonic waves with a frequency of 18-18.5 kHz and ultrasonic intensity of at least 1 W/cm^2, called the cavitation threshold, is expressed as with high peak values of pressure and oscillating speed. There are strong hydrodynamic disturbance in the cavity representing strong pulses of compression (microshock waves) and microstreams generated by the pulsing bubbles.



(a) (b)

Figure 1. Condition of grain surface (×4): (a) processed by acoustic cavitation in water; (b) raw grain.

The micro-hardness of wet grain skin, falling within 27-31.6 MPa, is substantially lower than the pressure arising due to bubble collapse up to 100 MPa. Multiple hydraulic cumulative shocks arising due to collapse of cavitation bubbles clean grain from pollutants and destroy grain skin and ensure its partial separation from aleurone layer, which reduces time and energy for its full separation in the future. Figure 1 shows samples before and after acoustic treatment.

Figure 2. Grain processed by acoustic cavitation during 30 sec. (×4).

The following parameters were used in the study: temperature range – 20; 25; 30; 40 °C; ultrasonic frequency – 18; 18.15; 18.3; 18.5 kHz; insonation time – 20; 40; 60; 80 sec.

The end of acoustic cavitation impact on grain leads to the formation of microcracks filled with water. The first sign of grain saturation with water is its swelling (Figure 2).

Ultrasonic treatment allows cleaning the grain surface from mineral mixtures and insect pests even in hard-to-reach places: seed hair and groove (Figure 3).

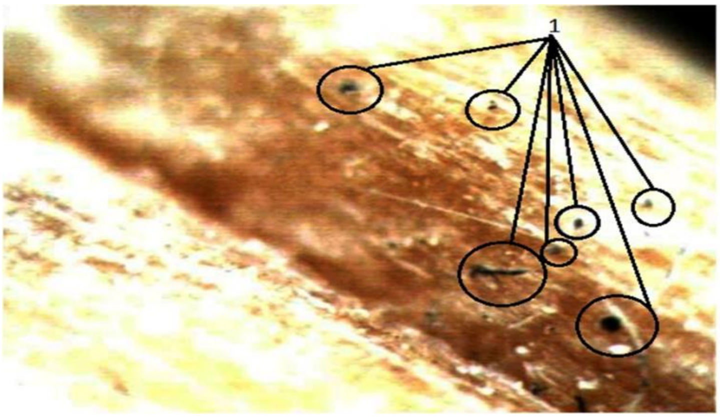


Figure 3. Mineral pollution in a grain groove (×4): 1 – single surfaces of particles of mineral mixtures.

The dependence of water heating temperature over insonation at constant oscillation frequency of 18 kHz is established. High quality of grain cleaning is already observed at a water heating temperature of 30°C and its cleaning within 40 seconds (Figure 4a). Further temperature drop causes the need to increase insonation time, which is not advisable for production reasons.

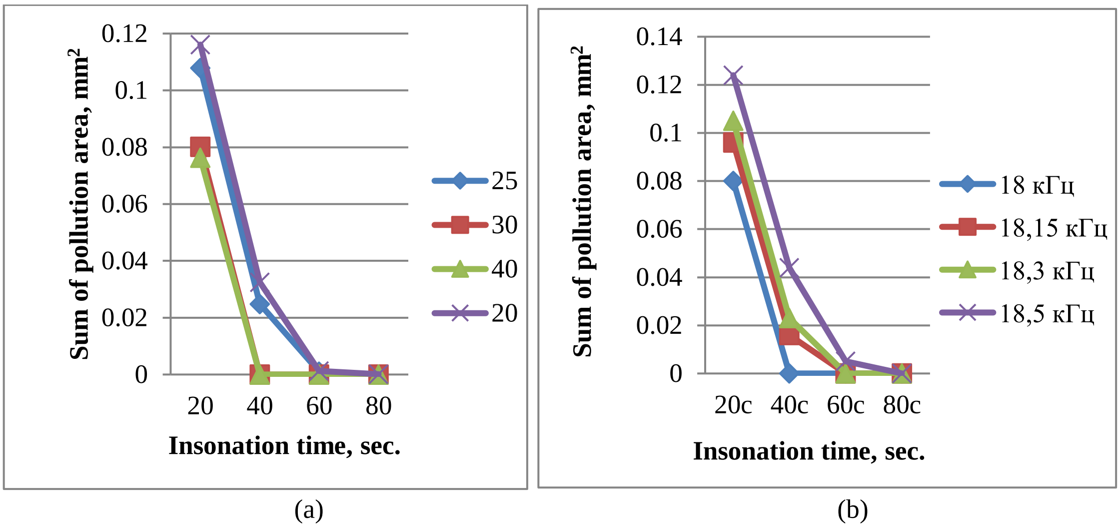


Figure 4. Dependence diagram of change of the total area of grain surface pollution: (a) on processing time and water temperature at a frequency of ultrasonic oscillations of 18 kHz; (b) on variables of processing time and frequency of ultrasonic oscillations at processing temperature of 30 °C

Figure 4b shows that the level of grain surface pollution depends on the frequency of ultrasonic oscillations and processing time. Pollution reduces with the increase of processing time and decrease of frequency. Thus, the rational modes are set: water temperature – 30 °C, oscillation frequency – 18 kHz.

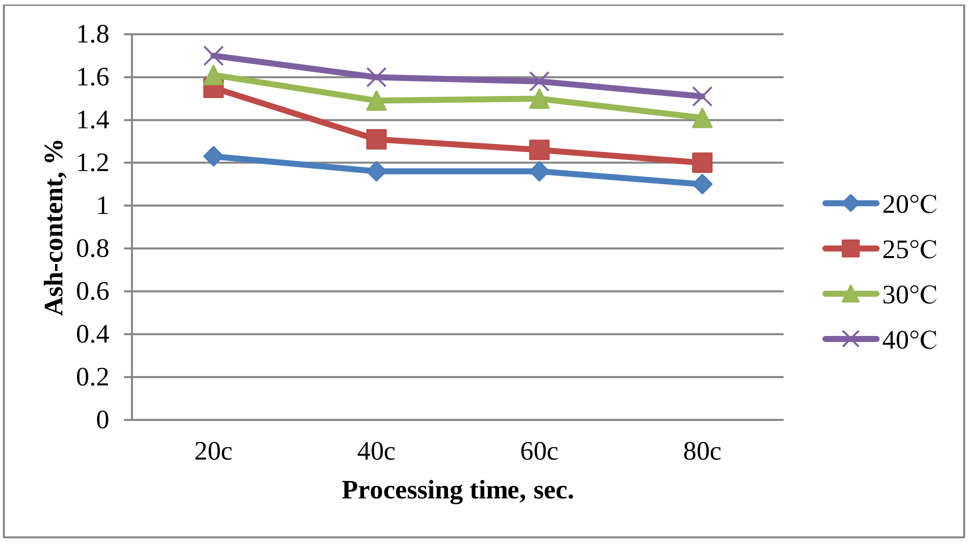


Figure 5. Dependence diagram of grain ash-content on processing time and water temperature at a frequency of ultrasonic oscillations of 18 kHz

The study showed that the grain ash-content is in direct dependence on the cleaning quality a grain skin from mineral sediments and contamination. The best indicators of ash-content reduction are received through ultrasonic treatment at a frequency of 18 kHz with water heating temperature of 40°C. The ash-content is thus stabilized at the level of 1.16%.

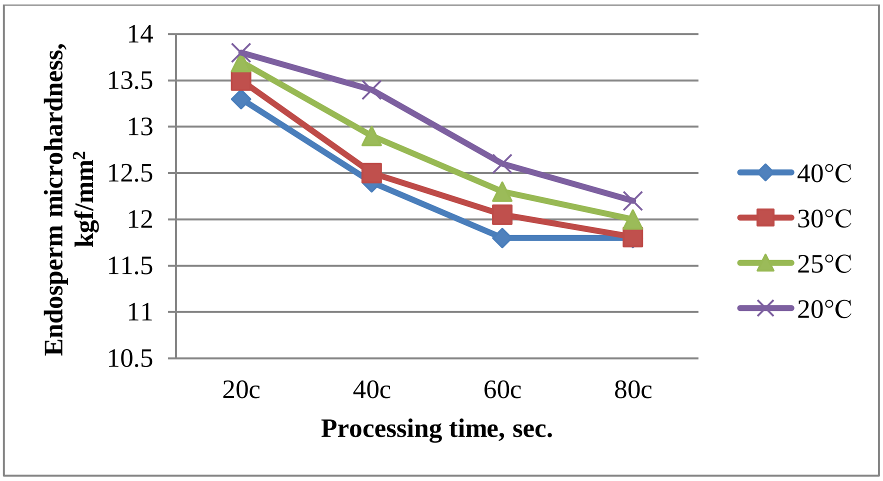


Figure 6. Dependence diagram of endosperm microhardness on variables of water temperature and processing time at a frequency of 18 kHz

Endosperm microhardness decreases with the increase of processing time and temperature. Microhardness is stabilized and reaches optimum technological properties of 13.4-13.0 kgf/mm^2 at a frequency of ultrasonic oscillations of 18.0 kHz, water heating temperature of 30-40°C and processing time of 30-40 sec (Figure 6).

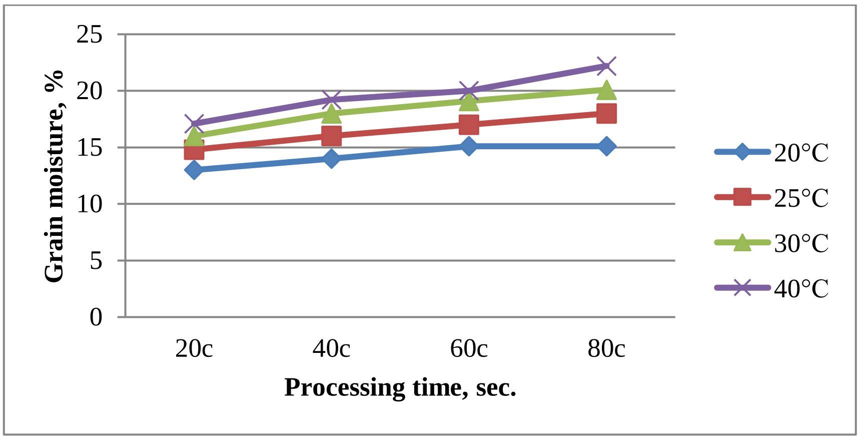


Figure 7. Dependence of grain moisture on water temperature and processing time at a frequency of 18 kHz

Ultrasonic processing stabilizes the process of grain moistening. The required grain moisture parameters are caused by the need to mainten the operating modes at a frequency of ultrasonic oscillations of 18.0 kHz, water temperature of 30-40°C and processing time of 20-30 sec (Figure 7).

4. Conclusion

The technology of improving grain process parameters and acceleration of grain moistening due to cumulative acoustics was developed. The proposed technology reduces ash-content by 60-70%; grain moisture is leveled and stabilized at 14.5-17%; endosperm microhardness is set at the required level – 13.4-13.0 kgf/mm^2.

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