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Influence of Ultrasonic Active Water on Hydrothermal Processing of Wheat Grains Grown in Dry Climates

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ABSTRACT

Aim and Objective: In this paper, with the increase of the world's population, it is becoming increasingly important to expand the production and variety of food products and ensure their natural ecological purity, and the high potential properties of bread using hydrothermal treatment combined with ultrasonic treatment of water describes the pre-grinding process of wheat grown in dry climates to produce a variety of flours.

Method: Abnormal physicochemical properties of water for pre-processing of wheat grains were studied. For the pre-mill process, methods of water activation using ultrasonic waves in hydrothermal treatment have been proposed. The effect of different frequency modes of ultrasonic treatment on the physicochemical properties of water was studied in the frequency range from 80 Gts to 43 kHz for the process of wheat grown in Uzbekistan to hydrothermal milling.

Result: In the hydrothermal treatment of low-transparency wheat grains, wetting of up to 15% with water under the influence of ultrasound at a frequency of 80 - 100 Hz was found to be effective. Such processing has been studied to improve flour yield and baking properties.

Key Words: Activated water, Wheat grain, Ultrasonic activation, Baking properties

INTRODUCTION

The past few decades have been a period of dynamic change across the world. With the increase of the world's population, it is becoming increasingly important to expand the production and range of food products and ensure their natural ecological purity. Technological shortcomings in the production of high-quality food products from raw materials with low quality or functional properties below than standard requirements have been decreased by multifunctional or special additives.^{1,2,3}

In Uzbekistan, enough wheat is grown to meet the needs of the population, but the rational use of the technological potential of wheat in its processing and improving the baking properties has not been well examined. In particular, it was noted that the quality of autumn soft red wheat grown in Uzbekistan, meets the requirements of class IV (wheat gluten < 25%, gluten deformation index (GDI)<105-120 cu). It means that this type of wheat cannot be recommended to the production of flours for sorted bread and pasta.

In the daily diet of the population, bread is the main food product and it is important to be free of synthetic additives. This is because the effects of consuming bread, pasta and flour confectionery products produced using these multifunctional and quality-enhancing additives, on the human body have not been sufficiently studied.

The research results show that an increase in the yield leads to a decrease in the baking properties of grain (Makhammadiev, 2019; Sattarov and Makhammadiev, 2016). For instance, in Kostanay province, one of the main wheat-growing regions of Kazakhstan, from 2013 to 2015, the amount of class III wheat decreased significantly (from 89.9% to 53.9%). The amount of grain of class IV and V increased by 9.4% to 41.2% between 2013 and 2015, and this figure was observed in all regions of the country where wheat is grown.¹⁰

In developed countries, targeted types and varieties of flour for the production of bread, pasta and flour confectionery have been being produced and their functional properties

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also have been improved.

Taking into account that hard wheat is not grown in our country, the production of bread, pasta and flour confectionery products from autumn soft red wheat (type IV) grains that meet the standard requirements is an important, but difficult task.

Studies have shown that the effect of hydrothermal treatment conditions and anomalous properties of water is important in the preparation of local wheat grains for the milling of sorted flour. (Ravshanov et al., 2018; 2019).

In the study of biological transformation processes in wheat grain, the continuous change of water structure, due to the abundance of hydrogen bonds, changes in the basic state of all biophysical and biochemical processes that take place in the grain (Shestakov et al., 2013). Because of intermolecular hydrogen bonds, water has an associative structure or water is not in a completely monomolecular (H_2O) form but consists mainly of associations, more precisely the bulk of the water is in the form of an unstable $(H_2O)_n$ structural polymer compound. ^{4,5,6}

Hydrogen bonds and the resulting associations (aggregates) have a significant impact on all anomalous properties of water, moistening of individual tissues in the grain during hydrothermal treatment, the nature of the impact, bond strength, moistening kinetics, swelling, dehydration and other technical and technological properties.

Since water is polar, its associated molecules do not form bonds with molecules of other substances (Shestakov et al., 2013). Therefore, the hydration property of water depends on the ratio of microphases. An increase in the amount of monomolecular microphase, which is not associated with thermal or other exposure to water, allows increasing the efficiency of the hydrothermal treatment regime.

To obtain the same efficiency in grain conditioning, it is possible to make a comparative analysis by comparing the amount of energy expended to activate the water, which is affected by different methods, with the data in references. Conditioning grains by heating water and activating it to turn into steam is one of the common methods. The heat capacity for vaporization and electrolytic dissociation of water molecules (main factor of electrochemical activation) are 44 kJ/mole and 57 kJ/mole, respectively. Research into the area of energy consumption for the activation of water molecules has demonstrated that this value in cavitation reactors through the cavitation effect is 15-18 kJ/mole. In this case, the water is not heated to a temperature that leads to the denaturation of biopolymers in the grain.

This work examined the effect of water activated by ultrasonic processing on the transparency of wheat grains, yield and quality of flour in the preparation of wheat grains grown

in Uzbekistan, for hydrothermal treatment.

RESEARCH MATERIALS AND METHODS

Moisture, protein content and natural weight of wheat grain samples were determined by Infratec-NOVA. Gluten content and transparency analyzed by Perten Inframatic 9500 IK (Denmark, Sweden) and Yantar (Russia) diaphanoscope laboratory equipment.

Samples of wheat grain with physicochemical quality indicators were prepared for hydrothermal treatment in a set of laboratory sieves PND (Russia) for the separation of extra impurities and fine grains and purified from metal magnetic additives using PVF-M (Russia) laboratory equipment.

- Ultrasound-activated water was used to enhance the effect of the hydrothermal treatment regime. At first, the physicochemical properties of ultrasound-activated water were analyzed (Ravshanov et al, 2019). According to results, the physicochemical properties of water (Conductometric ash, Specific resistance, Salinity, Electrical conductivity and Total solute content) affected by ultrasound for 60 seconds at frequencies of 10–1000 Hz, 20 kHz, 22 kHz, 40 kHz and 44 kHz, were studied. Experimental results show that ultrasound at values above 80-200 Hz did not significantly affect the above-mentioned physicochemical properties of water. Ultrasonic impact to the water was given by UZDN-2T (Russia) and its physicochemical parameters were determined using Conductometer Seven 2GoTM (Switzerland). Hydrothermal treatment was carried out following the “Rules of organization and conduct of technological processes in mills” (Rules for the organization and conduct of the technological process at flour mills, 1991).

In the laboratory, a simple method of hydrothermal treatment of wheat grain was used. Firstly, the grain moisture was determined and the amount of water for the required moisture was calculated by Egorov method.^{7,8,9}

The hydrothermal treatment was carried out in a three-stage method as proposed in industrial mills. The amount of water was calculated as following:

$$W = G \cdot \left(\frac{100 - w_1}{100 - w_2} - 1 \right)$$

where: G –mass of the grain sample; w_1 – initial moisture content of the grain sample, %; w_2 – targeted moisture content of the grain sample, %

- 300 g of the separated wheat grains soaked in drinking and ultrasonic-affected water in three stages, as the hydrothermal processing conditions carried out in industrial mills, and different times were set to study the effect of stagnation time. The impact of the hydrother-

mal treatment conditions on the transparency of wheat grain was studied.

- Based on the developed hydrothermal treatment condition, the flour yield and its effect on baking properties at different humidity were studied. Hydrothermally treated wheat grains were milled at the COMBINED MILL-Y16 (Turkey) laboratory mill. The milled sample was separated on the RL-3 laboratory sieve, and the flour yield was measured using CAS XE-1500 (South Korea) equipment. Quality indicators of milled flour were analyzed on NIRSTM DS2500 (Denmark) and IDK-5M (Russia).

RESULTS AND DISCUSSIONS

The variety of physicochemical quality of wheat grains obtained for the research allows obtaining relatively objective information about the impact of the hydrothermal treatment modes. The effect of hydrothermal treatment mode on wheat grain transparency has been considered.

The physicochemical properties of solid bulk materials have been determined by several indicators. For wheat grain as a raw material in the milling of sorted flour, its geometric characteristics (size, shape, volume, outer surface area), size and flatness of the grain mass, the volumetric mass of grain, the mass of 1000 grains, and transparency have main technological importance. Experiments have shown that when the volumetric mass of wheat grain decreases from 775 g/l to each 20 g/l, the yield of flour decreases by 1.0%, and this indicator for bran increases by 1.0%. It has been studied that the quality of flour also decreases as the volumetric mass of wheat grain decreases (Shaimerdenova, 2019).

Experiments have shown that the mass of 1000 grains has a significant effect on grain size, transparency, density, endosperm content and technological properties of this grain (Saini et al., 2012). When milling of the wheat flour, it was found that in a large fraction with a mass of more than 40 g per 1000 grains, the yield of flour was 3-5% higher than in a small fraction with a mass of less than 23 g per 1000 grains.⁹⁻¹³

Experimental results have shown that the endosperm is easily separated when milling transparent wheat grains, and the flour has a high value for bread production. Due to the low transparency of wheat grains grown in Uzbekistan, it is necessary to study the effect of the hydrothermal treatment at maximum use of their technological potential.

It has also been studied that in the pre-milling process of wheat grains, its transparency and humidity are decreased depending on the temperature and duration of the hydrothermal treatment (Egorov, 2005; Volokhova, 2003). At first, due to the number of experiments and complexity of its implementation the impact of pre-milling processes on the transparency of wheat grain, should be studied.

There was a difference in all physicochemical parameters of wheat grains, and the difference between the transparency was 8%. The effect of hydrothermal treatment conditions on wheat grain transparency has been proposed.

Figure 1 shows the experimental results obtained in the comparable conditions of different pre-milling processes on the transparency of wheat grain (sample I). Ultrasonic ranges: 0 (drinking water), 80, 100, 150 and 200 Hz; Exposure time: 60 seconds; Stagnation time: 2, 3 and 8 hours.

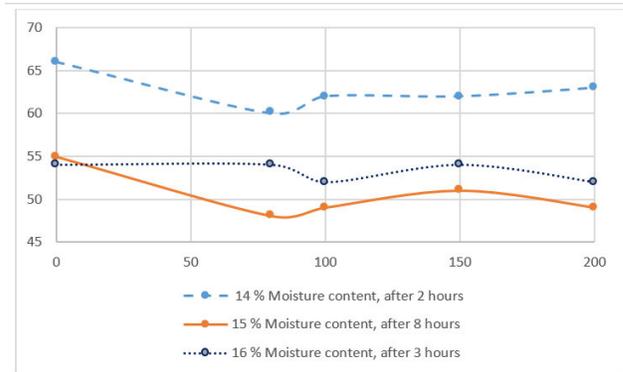


Figure 1: Comparable results of the effect of different pre-milling processes on the transparency of wheat grain (sample I).

According to experimental results, the lowest transparency was observed up to 60% at 80 Hz and 66% in drinking water when stagnated for 2 hours at 14% of humidity. At this value of humidity, no significant changes were observed at other frequencies of ultrasonic exposure. This grain sample was observed to be 15% wetted in ultrasonically exposed water at a frequency of 80 Hz and a 48% decrease in transparency when soaked for 3 hours.

It was observed that the transparency of this grain sample was decreased up to 48% in the conditions of 80 Hz ultrasonic exposure, 15 % of the wetting content and 3 hours of stagnation time. There was a significant difference compared to the transparency of the sample soaked in drinking water. Figure 2 shows the results of the change in the transparency of wheat grain for different values of wetting and stagnation time.

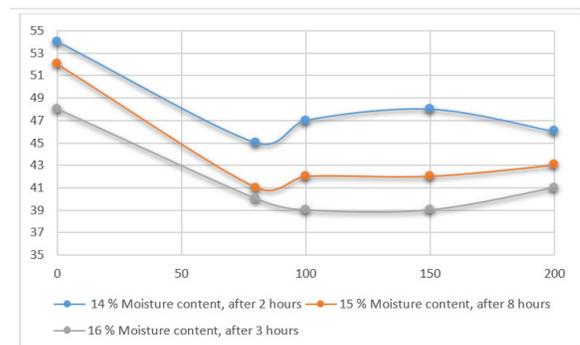


Figure 2: Transparency of wheat grain on different values of wetting and stagnation time.

This experiment was performed on a sample of wheat of category II with initial transparency of 66%. The sample of wheat grain wetted for 2 hours at 14.5% humidity with 80 Hz ultrasonic exposed water and drinking water. As a result, this transparency of grain samples treated using ultrasonic exposed and normal drinking water was reduced to 45% and 54%, respectively (Figure 2). The transparency of the wheat samples wetted for 8 hours at 16 % of humidity, was found to be reduced by 39 %. In a 15% moistened grain sample, the difference between the transparency values of samples wetted in drinking water and ultrasonic exposed water was 25%. In the research conducted by G.A.Egorov wheat grains with a transparency of 92% were soaked in 17% of drinking water for 16 hours, and the transparency reduced to 67% (Egorov, 2000). The results of this experiment show that with a decrease in wheat transparency, wetting up to 15% in ultrasound-affected water is effective.

Methods and conditions of hydrothermal treatment are used in the mill industry to improve the technological properties of wheat grains. Recent research in this area shows that modern hydrothermal treatment methods have been studied to reduce the specific energy consumption in the milling of sorted

flour, as well as increase the yield and quality of the target product (Volokhova, 2003; Perekrest, 2012; Ugrozov, 2005).

Methods and regimes of hydrothermal treatment of wheat flour grown in Uzbekistan have not been sufficiently studied. Therefore, the impact of methods and conditions of hydrothermal treatment on the pre-milling process of wheat grain was studied.¹³⁻¹⁶

The effect of treatments performed for the analyzing of the transparency was studied for other parameters (flour yield, colour, gluten content and quality) of the milling process of wheat grain. Hydrothermally treated wheat grains were milled at the COMBINED MILL-Y16 pilot plant (Turkey). The quality of the flour samples was analyzed. The humidity of a sample of wheat grain was increased from 9.7% to 14.6%, using drinking water and activated water following the “Rules for the organization and conduct of technological processes in mills”. The soaked wheat grain was stagnated for 8 hours, and 200 g of the sample was milled for 1.5 minutes. The prepared flour was sifted through sieve №38 for 3 min at a speed of 120 rpm. Stagnation time and initial moisture of grain were 8 hours and 14.6%, respectively. The results of the experiment are given in Table 1.

Table 1: The effect of the use of ultrasonically treated water in hydrothermal treatment on flour yield and quality (sample I).

Type of used water	Initial moisture of grain, %	field of flour, %	Gluten content, %	Gluten Deformation Index	Colour of flour
Drinking water	14.6	63.06	29.5	92	47
80 Hz	14.6	64.52	29.3	93	48
100 Hz	14.6	63.88	29.8	95	49
150 Hz	14.6	63.38	30.0	97	49
200 Hz	14.6	62.43	30.5	97	48
20 kHz	14.6	63.42	30.5	104	48
43 kHz	14.6	62.77	30.3	102	49

As shown in Table 1, in a sample of wheat grain treated with water-activated at 80 Hz, the flour yield was 64.52%, which is 1.46% higher than the grain soaked in drinking water and 2.09% higher than the minimum flour yield. Comparing to table 1, there were insignificant changes can be observed, in other parameters of the grain sample processed with water exposed at 80Hz ultrasound waves. In particular, the amount of gluten was found to be less than 1.2% compared to the sample soaked in drinking water, but it differed by 1 unit from the sample soaked in drinking water according to the GDI, and the colour increased by 1 unit. It can be concluded from the experimental results that a high result was achieved in the flour yield and its baking properties, in the wheat grain sample moistened with water activated by ultrasound at the frequency of 80 Hz.

The results of the experiments performed in this sequence on grain samples moistened to 17.1% are given in Table 2. As a result of the experiment, it was found that the grain yield and its baking properties were higher than other samples in grain samples moistened with water treated under ultrasound at 80 and 100 Hz. These indicators were close to those of wheat grain samples soaked in drinking water and 150 Hz ultrasound-treated water, and the difference between them was 0.17, 0.22, 0.31 and 0.5%, respectively. Stagnation time was 8 hours with 17.1% of initial moisture of grain. However, it was noted that the amount of gluten and its GDI values were significantly higher in samples wetted in ultrasonic-treated water at 80 and 100 Hz.

Table 2: The effect of the use of ultrasonically treated water in hydrothermal treatment on flour yield and quality (sample I).

N ^o	Type of used water	The yield of flour, %	Gluten content, %	Gluten Deformation Index	Colour of flour
1	Drinking water	60.68	27.2	84	55
2	80 Hz	60.71	27.7	80	58
3	100 Hz	60.9	27.2	81	58
4	150 Hz	60.4	27.2	83	57
5	200 Hz	58.8	27.4	84	58
6	20 kHz	58.6	27.2	82	58
7	43 kHz	58.4	27.2	84	58

The initial moisture content of the next group of sample II selected for the study was 10.8 and the transparency was 66%. 200 g of samples were moistened from 16.4 to 17.2% and stagnated for 20-24 hours. Wheat grains were hydrothermally treated with drinking water and activated water following the “Rules for the organization and conduct of technological processes in mills.” One group of moistened wheat grains was stagnated for 20 hours, and another group for 24 hours. 200 g of the sample was milled for 1.5 minutes. The prepared flour was sifted through sieve №38 for 3 min at a speed of 120 rpm. The results of the experiment are given in Tables 2, 3 and 4.

Table 3: The effect of the use of ultrasonically treated water in hydrothermal treatment on flour yield and quality (sample II). Stagnation time and initial moisture of grain were 20 hours and 17.2%, respectively.

N ^o	Type of used water	The yield of flour, %	Gluten content, %	Gluten Deformation Index	Colour of flour
1	Drinking water	57.84	28.3	81	52,7
2	80 Hz	58.33	28.5	79	52,7
3	100 Hz	58.54	28.4	79	53,3
4	150 Hz	58.16	27.5	82	53,4
5	200 Hz	57.93	27.6	82	53,9
6	20 kHz	59.17	26.8	82	53
7	43 kHz	58.27	26.9	82	52,2

Table 4: The effect of the use of ultrasonically treated water in hydrothermal treatment on flour yield and quality (sample II). Stagnation time was 24 hours with different values of initial moisture.

N ^o	Type of used water	Initial moisture of grain, %	The yield of flour, %	Gluten content, %	Gluten Deformation Index	Colour of flour
1	Drinking water	16.8	57.99	28.7	80	51.7
2	80 Hz	16.9	58.45	28.7	80	52.5
3	100 Hz	17.0	57.54	28.8	80	53.5
4	150 Hz	17.0	57.77	27.6	81	52.9
5	200 Hz	17.0	57.44	27.8	81	52.6
6	20 kHz	16.4	57.14	26.4	81	52.6
7	43 kHz	17.0	57.35	26.3	82	52.8

As shown in Tables 3 and 4, in the humidity range of 17.2% and 16.8–17.0%, two experiments were conducted in series. The significance of flour yield, gluten content, and GDI values, was observed in wheat grain samples soaked in water treated at 80 and 100 Hz ultrasonic waves.

Although the moisture difference between grain samples stagnated for 20 and 24 hours, was 0.2 – 0.8%, the yield of flour prepared from the grain stagnated for 20 hours, was observed to increase by 1%. Both of samples were processed hydrothermally using water treated by the ultrasonic wave at 100 Hz. The difference between the remaining samples increased insignificantly. The differences between the moisture content of the crushed grain and the moisture content of the flour were maintained, i.e. the uniformity of the drying process of the flour was noted. From this, it can be concluded that the differences in the drying of flour in wheat grain samples soaked for 20 and 24 hours remain unchanged.

In the hydrothermal treatment of wheat grains with low transparency, wetting up to 15% with ultrasound exposed water at

a frequency of 80 - 100 Hz was found to be effective. It has been studied that such processing improves the yield of flour and its baking properties.

CONCLUSION

The effect of wetting flour with water-activated with the increased moisture content of wheat grains and its effect on quality was analyzed in samples moistened to 17.1%.

Hydrothermal treatment of wheat grains with activated water has been noted to achieve a reduction in stagnation time due to an increase in the rate of water absorption into wheat grains and a decrease in energy consumption in milling processes.

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