Prospects of application of ultrasonic processing of half-finished products in baking technology

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Abstract: The food industry has a very wide range of methods and means of influencing raw materials to give them the required technological properties. One of the prospective and effective physical methods of processing raw materials and food products, according to a number of studies, is ultrasound, which helps to increase productivity, reduce energy costs, improve the quality of finished products, extend shelf life, and most importantly, ensure safe and minimally processed products. To prevent microbiological deterioration, the products are subjected to various treatments, the main of which is the effect of low temperatures (cooling, freezing) or high temperatures (pasteurization, sterilization). However, these methods either slow down microbiological processes or reduce the nutritional and biological value. In this regard, the study of innovative methods that guarantee the consumer safe and minimally processed products, one of which is the method of ultrasound processing becomes particularly relevant. The impact of ultrasonic waves on physical and chemical processes occurring during the cooling process can improve the quality of the finished product, increase storage time, reduce energy consumption and create products with new consumer properties.

1. Introduction
Growing competition in the bakery and confectionary industries requires the creation of updated technologies for the production of bakery and confectionery products that improve quality and reduce labor and energy costs.

The application of ultrasound processing in the preparation of bakery products that increase the nutritional value of food rations (without weight gain) in the organization of food for the military is relevant. As part of the implementation of the Strategy for the Development of the Food and Processing Industry for the period up to 2020 and the Food Security Doctrine of the Russian Federation, technical and technological solutions have been proposed aimed at increasing the nutritional value of baked goods.

The project strategy of development of food and processing industry of the Russian Federation is planned for the period till 2030. The main direction of the project is the development of principally new technologies and equipment providing deep, complex, energy and resource saving processing of agricultural raw materials on the basis of modern physical-chemical and electrophysical methods (including membrane, extrusion-hydrolytic, hyperbaric, cavitation and biotechnological methods) for creation of ecologically safe methods of food processing [1].
To prevent microbiological deterioration, products are subjected to various types of treatment, the main of which is the effect of temperature - cooling, freezing or pasteurization, sterilization. However, these methods only slow down microbiological processes, or reduce its nutritional and biological value [2].

To ensure uniform microbiological fermentation, ultrasound equipment must cover and evenly process the entire surface of the dough piece. At the same time, the flavour properties of buns from the dough half-finished product subjected to ultrasonic treatment do not differ from the control sample. It has been determined that the location of ultrasound generators near the experimental samples promotes the formation of large cavities (caverns) in them [3].

The mechanisms of exposure to ultrasound at different stages of the baking process may vary. When baking under the influence of an ultrasonic field in the baking chamber, the temperature and concentration fields change. This type of treatment intensifies heat and mass transfer as a result of appearance of acoustic currents connected with energy absorption in the baking chamber environment and in the boundary layer at the surface of products. The advantage of acoustic flows is the low thickness of their laminar boundary layer, which reduces the thickness of the temperature layer. This leads to an increase in temperature gradients, which increases the heat transfer rate.

In the course of theoretical studies it was found out that disturbances in the baking chamber air created by an ultrasonic generator intensify the heat exchange by turbulizing the boundary layer. In this case, the boundary layer makes oscillations, i.e. the surface of the product periodically creates vacuum, which contributes to the suction of new portions of the coolant - air. At the same time, the dough is baked faster and more evenly, productivity and product quality indicators increase [4].

It is important to drastically reduce the carcinogenic substances produced during cooling, despite the increased power of pulsed ultrasound 3-4 times. Under the influence of vacuum, the moisture gradient and the capillary effect of ultrasound, moisture moves extremely quickly from the inner layers to the bread surface. The humidity of the crust increases rapidly after baking, reaching a value of equilibrium humidity for cold bread. In this case, the mash cools down faster and more evenly, because when sounding ultrasound is repeatedly reflected from the walls of the chamber and products, and penetrates into all cracks and shells of the workpiece, reducing the thermal resistance of heat and mass transfer. The sound-capillary effect plays an important role, increasing by an order of magnitude the mass exchange with the steam environment of the device [5].

2. Research objective
The purpose of the study is to analyze the influence of the specified parameters of ultrasonic activation on the physical and chemical indicators of different types of tests.

Within the framework of the goal set, the following tasks are solved:

- determination of the influence of ultrasonic activation time on the physical and chemical parameters of different types of tests;
- dependence of physico-chemical indicators of different types of test on the power of ultrasonic activation.

3. Subject of study
The object of research was semi-finished products made of wheat dough - a classic recipe of bakery products, as well as the enrichment of products with lactic acid bacteria produced water replacement for lactic acid ferment "BioMatrix".

4. Materials and methods
Tables 1 and 2 show the results of the analysis of flour and baking yeast quality used in the study.

An ultrasonic bath with digital control and ODA-LQ40 heating was used for ultrasonic influence on the dough.
### Table 1. Top quality flour indicators

| Indicator name                               | Indicator Values                                      | Sample number |
|----------------------------------------------|-------------------------------------------------------|---------------|
| **Color**                                   | White or white with a creamy tint                     | 1             | 2             |
| **Smell**                                   | Typical wheat flour, odourless, not stale, not moldy  |               |               |
| **Taste**                                   | Typical wheat flour, with no foreign flavors, not sour, not bitter. |               |               |
| **Content of mineral impurities**           | When you chew flour, you can't feel the crunch.       |               |               |
| **Humidity, %, no more**                    | 15,0                                                   | 14,5          | 14,5          |
| **Grinding size, %; the rest on a sieve from a silk fabric in accordance with GOST 4403-77, no more.** | 5 Sieve No. 43                                        | 2,5           | 3,0           |
| **Raw gluten: quantity, %, not less than**  | 28,0                                                   | 30,0          | 32,0          |
| **Quality**                                 | Not below Group 2                                       |               |               |
| **Bread stock pest infestation**            | Not allowed.                                           |               |               |
| **Contamination of bread stocks by pests**  | Not allowed.                                           |               |               |

### Table 2. Bakery yeast quality indicators

| Indicator name                               | Indicator Values                                      | Sample number |
|----------------------------------------------|-------------------------------------------------------|---------------|
| **Color**                                   | Light yellow or light brown.                         | 1             | 2             |
| **Smell**                                   | Typical of dried yeast, without foreign smells: rotten, mildew, etc. |               |               |
| **Taste**                                   | Typical of dried yeast, without any foreign flavors. |               |               |
| **Humidity, %, no more**                    | 10,0                                                   | 9,5           | 9,5           |
| **Lifting force of yeast on the day of production (up to 70 mm dough lift), min, max.** | 70,0                                                   | 60,0          | 60,0          |
5. Discussion of results
The results of change in acidity of the test with different parameters of ultrasound exposure are presented in Table 3.

Table 3. Change of acidity of wheat dough with application of various parameters of ultrasonic influence

| Time, min. | Control | 60 W by 30s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30s. | 35 W by 60s. | 35 W by 90s. |
|-----------|---------|-------------|--------------|--------------|-------------|-------------|-------------|
| 0         | 2.0     | 2.2         | 2.6          | 4.0          | 2.4         | 2.2         | 3.8         |
| 30        | 2.4     | 2.6         | 2.8          | 4.2          | 2.6         | 2.8         | 4.0         |
| 60        | 2.8     | 3.0         | 3.0          | 4.4          | 2.8         | 4.0         | 4.2         |
| 90        | 3.0     | 3.4         | 3.2          | 4.6          | 3.2         | 4.2         | 4.4         |
| 120       | 3.4     | 3.8         | 3.6          | 4.8          | 3.4         | 4.4         | 4.6         |
| 150       | 3.8     | 4.4         | 3.8          | 5.0          | 3.6         | 4.8         | 5.0         |
| 180       | 4.4     | 4.8         | 4.0          | 5.2          | 3.8         | 5.2         | 5.4         |

According to the results of the table there are graphs of dependence of acidity of wheat test on different parameters of ultrasonic exposure (Figures 1,2).

![Figure 1](image1.png)  
**Figure 1.** Graphic dependence of acidity of wheat dough power and duration of ultrasonic exposure equal to 35W  

![Figure 2](image2.png)  
**Figure 2.** Graphic dependence of acidity of wheat dough power and duration of ultrasonic exposure equal to 60W
After the completion of the fermentation process, the fermentation activity of the dough was measured, which is increased by 25-37 % compared to the control sample.

The results of changes in the acidity of the dough with addition of BioMatrix lactic acid 20, 40 and 60 % with different ultrasound exposure parameters are presented in Table 4.

Table 4. Variation of acidity of wheat dough with addition of BioMatrix lactic acid 20, 40 and 60 % and with application of various ultrasound parameters

| Time, min. | Control | 60 W by 30 s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30 s. | 35 W by 60 s. | 35 W by 90 s. |
|------------|---------|---------------|---------------|---------------|---------------|---------------|---------------|
| Water change by 20% | | | | | | | |
| 0          | 1,6     | 1,8           | 1,6           | 1,6           | 1,8           | 2,0           | 2,0           |
| 30         | 1,8     | 2,0           | 1,8           | 1,8           | 2,0           | 2,2           | 2,4           |
| 60         | 1,8     | 2,6           | 1,8           | 2,0           | 2,4           | 2,6           | 2,6           |
| 90         | 1,8     | 3,0           | 2,0           | 2,2           | 2,6           | 3,0           | 2,8           |
| 120        | 2,0     | 4,4           | 2,2           | 2,4           | 4,0           | 3,6           | 3,0           |
| 150        | 2,0     | 5,2           | 2,4           | 2,6           | 4,8           | 4,4           | 3,2           |
| 180        | 2,2     | 5,4           | 2,6           | 2,8           | 5,2           | 5,2           | 3,6           |
| Water changes by 40% | | | | | | | |
| 0          | 3,0     | 1,4           | 1,4           | 2,8           | 1,4           | 1,4           | 1,4           |
| 30         | 3,2     | 1,8           | 1,4           | 3,0           | 2,8           | 1,8           | 2,6           |
| 60         | 3,4     | 2,4           | 1,6           | 3,4           | 3,2           | 2,0           | 3,6           |
| 90         | 3,6     | 2,8           | 1,8           | 3,8           | 4,0           | 2,6           | 4,2           |
| 120        | 3,8     | 3,2           | 2,0           | 4,0           | 4,6           | 3,0           | 4,8           |
| 150        | 4,0     | 3,6           | 2,2           | 4,2           | 5,0           | 3,4           | 5,4           |
| 180        | 4,2     | 4,0           | 2,6           | 4,4           | 5,4           | 3,8           | 6,2           |
| Water change by 60% | | | | | | | |
| 0          | 2,8     | 2,4           | 2,6           | 2,8           | 2,4           | 2,2           | 2,6           |
| 30         | 3,4     | 2,8           | 2,8           | 3,0           | 3,0           | 3,0           | 3,0           |
| 60         | 3,6     | 3,0           | 3,2           | 3,2           | 3,4           | 4,0           | 3,2           |
| 90         | 4,4     | 3,4           | 3,4           | 3,4           | 4,0           | 4,6           | 3,4           |
| 120        | 4,8     | 3,6           | 4,0           | 3,6           | 4,6           | 5,0           | 3,6           |
| 150        | 5,2     | 4,4           | 4,2           | 3,8           | 5,0           | 5,2           | 4,0           |
| 180        | 5,4     | 4,8           | 4,6           | 4,0           | 5,4           | 5,6           | 5,0           |

The results of changes in the test humidity with different ultrasound exposure parameters are presented in Table 5.

Table 5. Change of wheat dough humidity using different ultrasound parameters

| Time, min. | Control | 60 W by 30 s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30 s. | 35 W by 60 s. | 35 W by 90 s. |
|------------|---------|---------------|---------------|---------------|---------------|---------------|---------------|
| 0          | 47,50   | 47,00         | 47,25         | 45,50         | 47,50         | 46,00         | 44,24         |
| 60         | 45,75   | 45,25         | 46,00         | 45,25         | 46,00         | 44,75         | 43,71         |
| 120        | 45,00   | 44,25         | 45,25         | 42,50         | 45,50         | 43,50         | 42,50         |
| 180        | 44,00   | 43,00         | 43,50         | 40,50         | 44,00         | 42,50         | 41,00         |

By results of the table there are graphs of dependence of humidity of the wheat test on various parameters of ultrasonic influence (Figure 3, 4).
Figure 3. Graphic dependence of wheat dough humidity on the power and duration of ultrasonic exposure equal to 60W

Figure 4. Graphical dependence of wheat dough humidity on the power and duration of ultrasonic exposure equal to 35W

The results of change in dough humidity with water change for BioMatrix lactic acid ferment by 20, 40 and 60% with different ultrasound exposure parameters are presented in Table 6.

Having made an analytical assessment of the acidity and humidity of wheat dough, the optimal parameters of ultrasound impact on wheat dough without adding lactic acid bacteria were selected: 60W for 90 seconds. For wheat dough with the addition of lactic acid bacteria, other parameters have been selected: 60W for 30 seconds.

The results of measuring the lifting force of a wheat dough using ultrasonic equipment are presented in Table 7.

Based on the results of Table 7, a graph of the dependence of the lifting force of the wheat test on various parameters of ultrasonic exposure is constructed (Figure 5).
### Table 6. Change of humidity of wheat dough from water to BioMatrix lactic acid ferment by 20, 40 and 60% with application of various ultrasound parameters.

| Time, min. | Control | 60 W by 30 s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30 s. | 35 W by 60 s. | 35 W by 90 s. |
|------------|---------|---------------|---------------|---------------|---------------|---------------|---------------|
| Water change by 20% |         |               |               |               |               |               |               |
| 0          | 45,00   | 43,49         | 45,00         | 45,00         | 43,48         | 43,47         | 43,46         |
| 60         | 42,00   | 42,35         | 40,45         | 40,49         | 42,29         | 42,43         | 42,07         |
| 120        | 38,67   | 41,69         | 40,63         | 38,10         | 41,20         | 41,56         | 41,13         |
| 180        | 40,37   | 39,96         | 40,84         | 37,05         | 39,67         | 40,19         | 40,41         |
| Water change by 40% |         |               |               |               |               |               |               |
| 0          | 43,46   | 41,25         | 40,34         | 39,12         | 44,68         | 42,46         | 42,46         |
| 60         | 42,07   | 42,46         | 41,05         | 39,76         | 57,69         | 41,45         | 45,54         |
| 120        | 41,13   | 43,94         | 42,46         | 40,85         | 46,03         | 45,58         | 46,28         |
| 180        | 40,23   | 45,94         | 43,19         | 42,48         | 47,23         | 46,76         | 47,07         |
| Water change by 60% |         |               |               |               |               |               |               |
| 0          | 51,56   | 46,58         | 47,56         | 47,84         | 44,34         | 44,68         | 44,54         |
| 60         | 45,45   | 44,36         | 45,89         | 45,62         | 43,68         | 57,69         | 44,24         |
| 120        | 43,16   | 43,87         | 43,95         | 44,68         | 42,17         | 46,03         | 42,68         |
| 180        | 42,77   | 42,47         | 42,23         | 43,17         | 41,56         | 47,45         | 42,00         |

### Table 7. Change in the lifting force of a wheat dough using ultrasonic equipment

| Time, min. | Control | 60 W by 30 s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30 s. | 35 W by 60 s. | 35 W by 90 s. |
|------------|---------|---------------|---------------|---------------|---------------|---------------|---------------|
| PS, min    | 2.5     | 2.6           | 2.7           | 2.9           | 2.75          | 2.55          | 2.8           |

**Figure 5.** Graph of the wheat dough lifting power dependence on the power and duration of exposure to ultrasonic waves.

The lifting force of the test compared to the control, when using ultrasonic waves increased: 60 W for 30 s by 4%; 60 W for 60 s by 3.8%; 60 W for 90 seconds by 16%; 35 W for 30 seconds by 10%; 35 W for 60 seconds by 2%; 35 W for 90 seconds by 12%. 
The results of changes in the lifting force of wheat dough using ultrasonic equipment and water change for 20, 40 and 60 % with BioMatrix lactic acid leaven are presented in Table 8.

Table 8. Change in the lifting force of wheat dough using ultrasonic equipment and water change by 20, 40 and 60% with BioMatrix lactic acid leaven

| Time, min. | Control | 60 W by 30 s. | 60 W by 60 s. | 60 W by 90 s. | 35 W by 30 s. | 35 W by 60 s. | 35 W by 90 s. |
|------------|---------|---------------|---------------|---------------|---------------|---------------|---------------|
| PS, min    | Water change by 20% | 3 | 3.5 | 3.2 | 3.4 | 3.3 | 3.25 | 3.15 |
| PS, min    | Water change by 40% | 2.5 | 2.6 | 2.8 | 2.6 | 2.8 | 2.9 | 2.7 |
| PS, min    | Water change by 60% | 3 | 3.6 | 3.3 | 3.2 | 3.4 | 3.25 | 3.1 |

Dough strength compared to control with the use of ultrasonic waves and the replacement of 20% of the water for the lactic acid ferment "BioMatrix" increased: 60 W for 30 seconds by 16.67%; 60 W for 60 seconds by 6.67%; 60 W for 90 seconds by 13.33%; 35 W for 30 seconds by 10%; 35 W for 60 seconds by 8.33%; 35 W for 90 seconds by 5%. Dough strength compared to control with the use of ultrasonic waves and the replacement of 40% of the water for the lactic acid ferment "BioMatrix" increased: 60 W for 30 seconds by 4%; 60 W for 60 seconds by 12%; 60 W for 90 seconds by 4%; 35 W for 30 seconds by 12%; 35 W for 60 seconds by 16%; 35 W for 90 seconds by 8%. Dough strength increase compared to control, with the use of ultrasonic waves and the replacement of 60% of the water for the lactic acid ferment "BioMatrix" increased: 60 W for 30 seconds by 20%; 60 W for 60 seconds by 10%; 60 W for 90 seconds by 6.67%; 35 W for 30 seconds by 13.33%; 35 W for 60 seconds by 8.33%; 35 W for 90 seconds by 3.33%.

6. Conclusion
When using dairy acid ferment "BioMatrix" the time of ultrasonic activation is reduced to 30 seconds that promotes enrichment of the dough by dairy acid bacteria and leads to improvement of structural and mechanical properties of the dough, increase in its form-holding ability, increase in volume, decrease in blurring of products and slowdown of staling of finished goods. When the dough is enriched with lactic acid bacteria, as well as ultrasonic activation of the dough with power of 60 W and duration of 30 seconds, its fermentation duration is reduced due to mechanical separation and growth intensification of viable yeast colonies. When enriched with lactic acid bacteria by less than 60% and ultrasonic activation of the dough with power less than 60 W physical and chemical indicators of the dough and quality indicators of finished products deteriorate, the specific volume of finished products is reduced. Enrichment of lactic acid bacteria by more than 60% does not lead to an improvement in the physico-chemical indicators and indicators of quality of finished products, and with ultrasonic activation of the test power of more than 60 W deteriorates the physico-chemical indicators of the test and indicators of quality of finished products.

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