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Investigation of Ultrasonic Dough Processing Influence on Bread Quality

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Abstract—**The positive influence of ultrasonic radiation on the fermenting microflora of the semi-finished dough product and the quality of bakery products is determined. The experiments were performed with the help of experimental ultrasonic radiators with a frequency of 100 ± 6 kHz and 20 ± 2 kHz. The ultrasonic effect was performed in the stages of kneading the dough and proofing the dough billets. The properties of the semi-finished dough products were evaluated by the amount of yeast microflora and fermented sugars. The quality of finished products was determined by the indicators of shape stability and volume. The maximum positive effect of the influence of the ultrasonic wave on the semi-finisheddough product has an effect for 30 minutes during the proofing of the doughbillets by an ultrasonic wave of 20 ± 2 kHz. At the same time the amount of fermented sugars in the semi-finished product increases by 29.4%, yeast cells - 3.6 times, the volume of the finished product - 2.7 times, and the form stability is slightly changed in comparison with the control sample.**

Keywords—ultrasound; dough; technological process; bread; quality.

I. INTRODUCTION

In the production of food products, ultrasonic radiators are used for the biorisation, disinfection and preservation of food products. The most common electroacoustic transducers are linear, that is, satisfy the requirement of undistorted signal transmission, and are reversible, that is, they can work as a radiator, and as a receiver, obey the principle of reciprocity [1].

In linear converters, ultrasound radiation is parallel to each other. The main disadvantage of linear converters is the uneven distribution of ultrasonic waves over the entire surface of the processed raw material [2].

Ultrasound emitters can be made in the form of various sensors, which are subsequently attached for a while (or located side by side) or fully embedded in the necessary equipment.

Studies of the influence of ultrasonic vibrations on the processes of manufacturing food products have shown that the quality of the final product varies, and more often for the better [3, 4, 5, 6, 7]. This improvement can be particularly observed in the bakery industry.

The process of making bakery products is extremely difficult and time-consuming. Softness and unpredictability of dough requires special attention. At the time of baking, it can behave differently. In view of this, starting with the kneading operation and further processing, it is necessary to monitor each technological stage.

In production of bakery products it is important to have the knowledge and experience to determine whether the dough is in the right condition at every stage of the process of making bakery products and, if necessary, to make a decision on introducing changes in the process to obtain a quality product [8].

Despite all these difficulties, the production of bakery products is constantly improving. There are new recipes, the technology of preparation of dough is changing, modern equipment is being introduced. One of such implementations can include ultrasonic processing of dough.

When the dough mixes, a homogeneous mixture is formed in the whole mass, proportional to the volume of flour, water, yeast and other components of the recipe. There is a swelling of components of flour - proteins, starch, fiber. Their dispersion, aggregation also take place. Then there is a glutinous carcass formation that binds starch grains. In this case, they are partially ground and covered with protein films. When mixed, the dough produces a gaseous phase. This phenomenon arises due to the capture and retention of air bubbles by the dough (occlusion) and gas release by the fermentation microflora of the dough. It is proved that the volume of gas in the dough during the batch is increased. In the dough with the usual duration of mixing the gaseous phase reaches 10% of the total volume of the dough, and with an increase in the duration of the batch, the volume of the gas phase sometimes increases to 20%. Air enters the dough together with flour and in small amounts - with water [8].

The use of ultrasonic vibrations during the preparation of the dough can have a crushing effect on the raw components, which will lead to an additional grinding effect of the starch fraction of the flour. This will positively affect its amylolysis with the formation of fermentable sugars, which will increase the fermenting activity of the dough [9, 10] and will improve the quality of the semi-finished product at the stage of fermentation of the dough and the proofing of the dough billets. The fermenting energy of baker's yeast increases by about 15% if treated with ultrasound for only one hour. In yeast, there is an increase in ergosterol (provitamin D2) present in the raw material [11]. In addition, an increase in the degree of starch damage may cause retardation of its retrogradation when storing bread, which will have a positive effect on the increase in shelf life.

Ultrasound has a positive effect on processes such as extraction and emulsification [12, 13, 14], which is expected to contribute to a better distribution of the fat component of the formulation, affecting the quality of the dough and finished products.

Under the condition of performing technological operations under ultrasonic radiation, it remains to be assumed that the influence of ultrasound on the quality parameters of bread will have an effect on the size of the bubbles of the gaseous phase and of the raw components - they will become smaller and settle evenly in the dough. Dispersing the solid phase of the dough will improve the gas-forming ability of the dough. The components of the dough will be distributed evenly. It will improve the structural and mechanical properties of the dough and positively affect the quality of the final product.

The purpose of the research was to determine the influence of the force and the duration of the ultrasonic wave action during the kneading and proofing of the semi-finished product on the quality of the baked product.

II. MATERIALS AND METHODS

The research was carried out in the laboratories of the department of "Mechanical Engineering" of the Orel State University, the department "Technology of grain processing, bakery, pasta and confectionery industries" of the Moscow State University of Technology and Management named after K.G. Razumovsky (The First Cossack University), together with the direction "Information Technology" of the All-Russian Research Institute of Meat Industry named after V.M. Gorbatov and the Center for Collective Use "Industrial Biotechnologies" of the Federal Research Center "Fundamental Foundations of Biotechnology" of the Russian Academy of Sciences.

The subject of the research was dough and bakery products, made from wheat flour of the highest grade, bakery pressed yeast, margarine, salt, sugar and water in accordance with the recipe and technology of Stolichnaya bun, weighing 0.1 kg in accordance with GOST 27844-88 [15].

To determine the influence of the impact force, the time of impact of the shock wave, we made two ultrasound emitters with a frequency of ultrasonic oscillations of 100 ± 6 kHz and 20 ± 2 kHz. The principle of their work is as follows. A generator (piezoceramic element) is attached to the body. It is this part that, when passing an electric current, begins to emit ultrasound. A human ear does not hear it, so the work can not provoke a feeling of discomfort. When on, the device generates acoustic waves that are directed to the material being processed (dough and dough billets). Radiation of ultrasound occurs linearly, i.e. rays spread parallel to each other. Such a radiator is shown in Fig. 2.

During the experimental studies, the ultrasonic radiators were attached to the equipment for kneading the dough and proofing the dough billets.

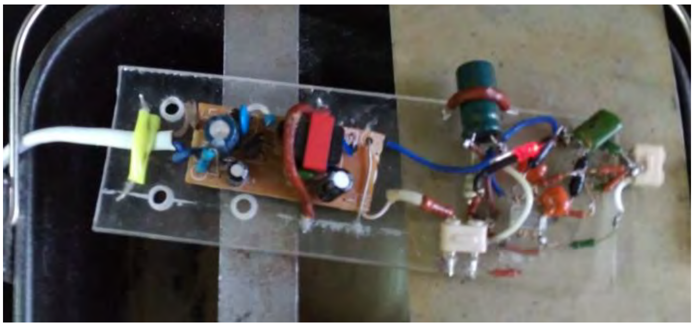

Fig. 1. - Experimental Ultrasound Emitter

To determine the effect of ultrasound on the fermentation microflora of the dough, the amount of yeast microflora at the end of the proofing was examined by microscopy and calculation with a microbiological chamber after preliminary dilution of the sample of the half-finished product with water in a ratio of 1: 1000.The microfloraactivity data was assumed by determining the content of reducing sugars in the semi-finished product in the beginning and the end of fermentation using the Bertrand method [16] based on the ability of the aldehyde group of sugars to reduce copper oxide to cuprous oxide in alkaline solutions, dropping out as a precipitate of red color.

In the finished bakery products (buns), the diameter and height of the product were determined. The shape stability of was evaluated as the ratio of the height of the bun to its diameter. The volume of the product was calculated conditionally taking its shape in the form of a cone according to the formula:

$$V = \frac{\pi \cdot d^2}{4h} \quad (1)$$

where d is the diameter of the bun, mm;
h is the height of the bun, mm.

III. Results and discussion

During the experiment, the semi-finished dough product was processed in three ways. The first method consisted of processing for 100 minutes throughout the whole process cycle before baking: 10 minutes with kneading, 60 minutes with fermentation and 30 minutes with proofing: the second method - for 60 minutes with fermentation; third way for 30 minutes with a proofing. The control sample was not subjected to sonication.

Ultrasonic waves provide great mechanical force and are the source of various processes [17, 18].

The dough contains many microorganisms that determine its quality before and after baking. Undoubtedly, ultrasound affects microorganisms [19]. The results of studies of the effect of ultrasonic radiation on the microflora of the dough are presented in Table 1.

The research data show that the microflora of the dough is subject to the influence of ultrasound. The depth of this influence depends both on the duration of the treatment and on the frequency of oscillation of the ultrasonic wave.

TABLE I. Effect Of The Power And Duration Of Ultrasound Wave Impact During Kneading, Fermentation, And Proofing Of Semi-Finished Bread On The Fermentation Microflora Of The Dough

Ways	Duration of ultrasonic wave impact, min	Frequency of ultrasonic vibrations, kHz	The content of regenerating sugars at the beginning of fermentation,%	Content of regenerating sugars at the end of fermentation,%	The amount of yeast cells, 10^4 in 1 g of dough, pcs.
Control	-	-	2.4±0.1	1.7±0.1	1.2±0.05
Way 1	100	20	2.3±0.1	1.4±0.1	3.2±0.05
		100	2.4±0.1	1.7±0.1	2.7±0.05
Way 2	60	20	2.3±0.1	1.4±0.1	4.0±0.05
		100	2.3±0.1	1.6±0.1	1.9±0.05
Way 3	30	20	2.3±0.1	1.2±0.1	4.3±0.05
		100	2.2±0.1	1.3±0.1	4.0±0.05

An increase in the duration of the exposure has a negative effect on the fermentation microflora, since more unfermented sugars and fewer yeast cells were determined in Method 1 (duration of exposure - 100 minutes) and Method 2 (60 minutes) than in the case of minimal exposure in Method 3 (30 minutes).

When comparing the influence of the frequency of ultrasonic vibrations, it can be noted that the oscillation frequency of the ultrasonic wave of 100 kHz has a greater negative effect on the fermentation microflora than the oscillation frequency of 20 kHz. The difference is the greater, the longer the effect on the semi-finished dough product is. Thus, the maximum positive effect of the influence of the ultrasonic wave on the semi-finished dough product has an effect for 30 minutes during the proofing of the doughbillets by an ultrasonic wave of 20 kHz. At the same time, the amount of fermented sugars in the semi-finished product increases by 29.4%, yeast cells - 3.6 times compared to the control sample.Experimental data on the influence of ultrasonic radiation on the quality of baked bread (Stolichnaya bun) are presented in Table 2.

The conducted studies show that the form stability of test buns samples slightly differed from the control sample. Significant differences were in the volume of buns. The increase in impact time and ultrasound frequency affects the amount of buns negatively. However, all the prototypes were larger in volume than the control sample. The largest volume was measured with samples of buns from the semi-finished dough product subjected to the effect during 30 minutes while proofing of the doughbillets by an ultrasonic wave of 20 kHz. The bunswere 2.7 times higher than the control sample.

TABLE II. TABLE II. EFFECT OF FORCE AND DURATION OF ULTRASOUND WAVE IMPACT DURING KNEADING, FERMENTATION, AND PROOFING OF SEMI-FINISHED PRODUCT ON BREAD QUALITY

Ways	Duration of ultrasonic wave impact, min	Frequency of ultrasonic vibrations, kHz	Diameter of a bun, d, mm	Height of a bun, h, mm	Shape form stability, h / d	Volume of a bun, cm^3
Control	-	-	67±0.5	44±0.5	0.6	51.7
Way 1	100	20	77±0.5	53±0.5	0.7	82.3
		100	69±0.5	49±0.5	0.7	61.1
Way 2	60	20	82±0.5	61±0.5	0.7	107.3
		100	69±0.5	46±0.5	0.7	57.4
Way 3	30	20	90±0.5	68±0.5	0.7	144.2
		100	71±0.5	49±0.5	0.7	93.7

The taste properties of the buns from the semi-finished dough product subjected to ultrasonic treatment did not differ from the control sample. It should also be noted that there appeared large cavities (caverns) in experimental samples that were close to the ultrasound generators. To verify the result, two ultrasound radiators were placed from different edges of the product and cavities on both sides were obtained in the finished product.

IV. Conclusion

The application of ultrasonic dough processing of bakery products changes the quality of the final product. This change depends on the duration of the dough processing and ultrasound frequency. The lower the frequency is, the more significant a positive effect on the microflora of the doughis. When assessing the duration of ultrasound impact, It was determined that the greatest positive effect of ultrasonic treatment was observed with the minimum exposure time taken in the experiment. Thus, the best positive effect on the quality of baked goods is the processing of the semi-finished dough product within 30 minutes by an ultrasonic wave of 20 kHz during the proofing of the dough billets. In this case, the volume of a bun increased 2.7 times in comparison with the control sample. In order to obtain uniform porosity of bakery products, the ultrasonic treatment equipment must cover and evenly process the entire surface of the dough billet.

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