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Enhancing bakery product quality through microwave-activated yeast: an experimental analysis

Tatyana SHEVCHENKO*, Yulia USTINOVA, Evgenia ERMOLAEVA, Gleb UZUNOV and Anton KOLOMEETS

Kemerovo State University, 6 Krasnaya str., Kemerovo, 650043, Russia.
* *Corresponding author; E-mail: tv.shevchenko@bk.ru*

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ABSTRACT

The main indicator of the quality of life is the state of public health, which consists of the safety of food raw materials and foodstuffs. Bread is one of the leading products of mass consumption, and improving its quality by reducing the long stages of dough preparation is essential. This study investigates the use of microwave-activated yeast to enhance the quality of bakery products. The primary aim was to utilize microwave radiation to activate yeast and assess its effect on the quality of the finished product. To achieve this, potato starch was treated with microwave radiation for various durations (5, 10, 20, and 30 seconds) to transfer energy to baking yeast. The rising power of the yeast was then evaluated using an accelerated method involving floating a ball in a salt solution. Various yeast holdup times in potato starch (ranging from 5 to 25 minutes) were tested to determine optimal conditions. The activated yeast was subsequently used in bread production, and the quality of the bread was compared with a control sample made with non-activated yeast. The results showed that microwave-activated yeast positively affected the dough preparation process and the quality of the finished bakery products, demonstrating the feasibility of this method for industrial applications.

Keywords: Quality, Microwave Radiation, Yeast Activation, Energy Transfer, Porosity, Baking Yeast.

INTRODUCTION

The baking industry provides food to all segments of the population and its effectiveness depends on high-quality raw materials and advanced industrial development. The main task of the food industry is to expand the range of competitive products (Legras et al., 2007). Despite the variety and huge range of bakery products, the production of essential products that fully meet the energy needs of the population is an important task (Adegbola et al., 2015). Due to the use of modern technologies, it is possible to obtain a product of high assortment quality at low production costs (Dobrashik and Morgenstern, 2003; Sidibe et al., 2021; Ilyushin & Martirosyan, 2024).

The increase in costs hurts the economic performance of enterprises. This means that further development of bakery production should be carried out based on the introduction and use of intensive technologies (Dougrigue et al., 2023). Therefore, it is necessary to reduce the long stages of dough preparation for

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bakery products (Ollo et al., 2023). The components included in the dough formulation should be improved as much as possible, namely, with the use of high-quality water and the effective activation of yeast (Babeva and Chernov, 2012).

Microwave radiation (MWR) is electromagnetic radiation in the range from 3,000 MHz to 30 GHz, which is one of the physical methods used to activate yeast by mediating energy transfer through potato starch. With the help of MWR, it is possible to quickly transfer energy into the material and positively affect the properties of the finished product. Compared with conventional processes, this energy source significantly reduces the processing time and changes in the physical and chemical properties of potato starch due to the volumetric heating of the product. MWR focuses on the material, which significantly increases the productivity of the processes being implemented; besides, microwave heating is environmentally friendly (Chavan and Chavan, 2010; Devi et al., 2020; Kalla and Devaraju, 2017). Depending on the depth of penetration, the time of exposure, and the power of MWR, structural changes occur in potato starch (Datta and Davidson, 2000; Fernandez et al., 2011; Shahin et al., 2012). Depending on the penetration of microwaves into starch, the dielectric constant changes, and the dielectric loss coefficient determines the ability of starch to accumulate energy (Ahmed and Ramaswamy, 2007; Pan et al., 2017; Reverte-Ors et al., 2017).

The work aimed to use microwave radiation to transfer energy from potato starch to yeast and evaluate the effect of the modified component on the quality of bakery products.

MATERIALS AND METHODS

Study materials

The following items were used for the experiments:

- Potato starch (GOST R 53876-2010) (Rosstandart 2010).
- Baking yeast (Saccharomyces cerevisiae) (GOST R 54731-2011) (Rosstandart 2011).
- Drinking water (GOST 32220-2013) (Rosstandart 2013b).
- Wheat flour for baking (GOST 26574-2017) (Rosstandart 2017).
- Table salt (GOST R 51574-2018) (Rosstandart 2018a).
- Sunflower oil (GOST 1129-2013) (Rosstandart 2013a).

Study methods

Preparation of salt solution

A salt solution was prepared by dissolving 0.5 grams of table salt (GOST R 51574-2018) in 100 milliliters of distilled water. The solution was then heated to a temperature of 35°C before use.

Energy dissipation with starch products

To determine the energy dissipation by starch products, a weighed sample of dry baking yeast was placed in a paper container and lowered into potato starch treated with microwave radiation (MWR) for 5, 10, 20, and 30 seconds at t=18-20°C. The holdup time of yeast in potato starch (the process of microwave energy transfer) ranged from 5 to 25 minutes.

Determination of the yeast rising power (accelerated method)

The method is designed to determine the yeast rising power in an accelerated way by floating a ball. From the average sample, 0.31 grams of yeast was taken, weighed on technical scales, and transferred to a porcelain cup. Then, 4.8 cm^3 of the prepared salt solution heated to 35°C was added to it, and both substances were thoroughly mixed with a spatula. Seven grams of flour was added to the resulting solution, after which the dough was kneaded and shaped into a ball. The ball was then put into a glass of water heated to a temperature of 35°C and placed in a thermostat with the same temperature. The yeast rising power is characterized by the time that has elapsed from the moment the ball is put into the water to the moment it floats back on the surface. The lifting time of the ball in minutes is multiplied by a coefficient of 3.5, obtained empirically, to determine the rising power (Eurasian Council for Standardization Metrology and Certification 2015).

Determination of physical characteristics of the dough

Determination of organoleptic parameters of finished bread samples was performed according to GOST 5667-2022 (Rosstandart 2022a), which outlines the methods for evaluating the sensory characteristics such as taste, smell, and appearance.

Determination of the crumb moisture content was performed according to GOST 21094-2022 (Rosstandart 2022b), specifying the procedure for measuring the moisture level in bread crumbs to ensure optimal texture and shelf life.

Determination of the crumb acidity was done according to GOST 5670-96 (Interstate Council for Standardization Metrology and Certification 1996b), which describes the method for assessing the acidity level in bread to ensure proper fermentation and flavor.

Determination of crumb porosity was performed according to GOST 5669-96 (Interstate Council for Standardization Metrology and Certification 1996a), defining the procedure for measuring the airiness and texture of bread crumbs to ensure a light and fluffy consistency.

RESULTS

The rising power is an indicator of the activity of the yeast microflora in semi-finished products. In this study, the change in yeast activity was examined based on the time of potato starch exposure to microwave radiation (MWR) for 5, 10, 20, and 30 seconds and the yeast holdup time in potato starch, ranging from 5 to 25 minutes. Yeast without holdup in potato starch served as the control variant.

From the obtained results (Table 1), a clear relationship between the yeast holdup time in potato starch and the yeast rising power was observed. The data indicated that as the yeast holdup time in potato starch increased, the rising power of the yeast initially increased with shorter holdup times but decreased with longer holdup times. This finding suggests that optimal activation of yeast by microwave radiation is achieved with a specific combination of exposure time and holdup time, enhancing the yeast's fermentation activity and consequently improving the dough preparation process.

The yeast rising power should not exceed 70; a higher value indicates reduced yeast effectiveness. The greatest improvement in the rising power index compared to the control variant was observed in yeast activated with a potato starch exposure time to MWR of 30 seconds and a holdup time of 5 minutes.

Further studies on the effect of activated yeast on the quality of bakery products were conducted with a potato starch exposure time to MWR of 20 seconds and a yeast holdup time in potato starch of 15 minutes, where the lifting force of yeast was 37%, indicating effective fermentation of glucose and sucrose by yeast enzymes (Sample 3).

Bread made with non-activated yeast was used as the control variant. The general recipe of bread samples is presented in Table 2. A comparative analysis of the quality indicators of bread focused on organoleptic indicators (sensory characteristics) for both the sample made with activated flour (Sample 3) and the control sample made with non-activated flour (Table 3). Sample 3 was prepared with potato starch exposed to MWR for 20 seconds and yeast held in the starch for 15 minutes, while the control sample used flour without any activation.

The analysis revealed that the bread made with activated yeast had a more pronounced taste and aroma compared to the control sample. The crumb of the bread was more elastic and had a superior texture. The surface of the bread baked with activated yeast was smoother, with fewer cracks and breaks. The overall appearance of the bread was improved, displaying a uniform color and well-formed shape.

These results suggest that activating the flour using microwave radiation and optimizing yeast holdup time enhances the sensory qualities of the bread, resulting in a superior final product compared to bread made with non-activated flour. Bread samples baked using activated yeast exhibited a pronounced taste and aroma compared to bread baked using non-activated yeast.

The physical and chemical quality indicators of wheat flour bread are presented in Table 4. A comparative analysis of bread quality indicators showed differences between the two bread samples in humidity, acidity, and porosity. The highest porosity index was found in the sample of bread baked using activated yeast (52.0%), while the lowest was recorded in the bread baked using non-activated yeast (45%).

Table 1: The effect of activated yeast on the yeast rising power.

Time of potato starch exposure to MWR, sec	**Yeast holdup time in potato starch, min**					
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Control sample
	5	10	15	20	25	0
	Yeast rising power					
5	49	42	40	43	40	58
10	50	42	35	45	42	
20	54	43	37	40	45	
30	52	45	38	42	47	

Table 2: General recipe of bread samples.

Raw material name	**Consumption of raw materials per 100 kg of flour, kg**
Wheat flour	100.0
Salt	1.3
Baking yeast	0.4
Sunflower oil	0.15
Water	other
Total raw materials	101.85

Table 3: Comparative analysis of bread quality indicators.

Indicator	**Control sample**	**Sample 3**
Appearance	Corresponding to the bread form where the baking was made	Corresponding to the bread form
Surface	Without major cracks and breaks, with or without punctures or incisions by the specifications	Without cracks and breaks
Color	From light yellow to dark brown	Light yellow
Crumb condition	Baked, not moist to the touch. Elastic, after applying light pressure with fingers, the crumb should take its original shape	Baked, not moist to the touch. Elastic, after applying light pressure with fingers, the crumb takes its original shape
Taste	Characteristic of this type of product, without foreign aftertaste	Pronounced taste, without foreign aftertaste
Smell	Characteristic of this type of product, without foreign smell	Pronounced aroma, without foreign smell

Table 4: Physical and chemical indicators of bread quality.

Indicator	Standard values to GOST 58233-2018 (Rosstandart, 2018b)	Control sample	Sample 3
Crumb moisture content, % max	49.0	45.0	35.0
The acidity of the crumb, deg, max	7.0	6.8	5.4
Porosity of the crumb, % min	54.0	45.0	52.0

DISCUSSION

The results of this study demonstrate the efficacy of using microwave radiation to activate yeast in the production of bakery products, leading to improved dough fermentation and bread quality. These findings align with previous research that explores alternative methods for enhancing yeast activity and improving the quality of bakery products.

One relevant study by Wang et al. (2021) reviewed novel heating technologies, including microwave heating, to improve fermentation efficiency and quality in wheat products. They found that microwave heating significantly enhances the fermentation process, resulting in better dough quality and bread characteristics. This supports our findings that microwave-activated yeast improves the sensory qualities of bread, such as taste, aroma, and texture.

Similarly, Zeng et al. (2014) investigated the effects of microwave irradiation on yeast growth and cell membrane permeability. Their study concluded that controlled microwave exposure could create an optimal environment for yeast activity, leading to enhanced fermentation. This corroborates our observation that shorter holdup times of yeast in microwave-treated potato starch yield higher rising power, thus enhancing the dough preparation process.

Additionally, Guzik et al. (2022) provided an overview of microwave applications in the food industry, highlighting the benefits of microwaves in improving the quality and safety of food products. They noted that microwave treatments could enhance the volume and texture of bakery products, aligning with our findings that microwave-activated yeast produces bread with superior porosity and crumb quality compared to non-activated yeast.

Further supporting evidence comes from Bychkova et al. (2021), who explored the use of microwave radiation in dough processing. Their research demonstrated that microwave-treated dough exhibited improved structural properties and fermentation efficiency, similar to the positive effects observed in our study on yeast activation and bread quality.

In summary, the results of this study are consistent with existing literature on the benefits of microwave radiation in enhancing yeast activity and improving the quality of bakery products. The optimal combination of microwave exposure time and yeast holdup time not only accelerates the dough preparation process but also enhances the sensory and physical properties of the final product. Future research could further explore the mechanistic aspects of microwave-yeast interactions and their potential applications in large-scale bakery production.

Conclusion

The activation of baking yeast is crucial in the preparation of high-quality bakery products. This study identified the optimal technical parameters for microwave processing to activate baking yeast through starch. It was demonstrated that microwave energy could be effectively transferred from irradiated starch to baking yeast, thereby enhancing yeast activity. The feasibility of using microwave energy transfer for the activation of baking yeast was confirmed, which subsequently intensified the dough preparation process. The positive impact of activated yeast on the quality of bakery products was thoroughly examined and established. While the findings of this study are promising, several limitations should be noted. First, the experiments were conducted under controlled laboratory conditions, which may not fully replicate the conditions in commercial bakery environments. Second, the study focused on a specific type of yeast and starch, and the results may vary with different strains of yeast or types of starch. Third, the long-term effects of microwave radiation on the nutritional properties of the yeast and the final bakery products were not explored. Finally, scalability remains a challenge, as the effectiveness of microwave activation needs to be evaluated in large-scale production settings. Future research should address these limitations and explore the broader applicability of this technology. The prospects for the application of microwave-activated yeast in the bakery industry are promising. This technology has the potential to significantly reduce the dough preparation time, leading to increased production efficiency and cost savings. Additionally, the improved sensory qualities of the bread, such as taste, aroma, and texture, could enhance consumer satisfaction and market competitiveness. Future studies could explore the use of microwave activation with different types of yeast and starches, as well as its application in other fermented food products. There is also potential for integrating this technology into automated production lines, further advancing the industrial application of microwave-activated yeast.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

TS, YU, EE, GU, and AK conceptualized and designed the study. TS and GU conducted the experiments and performed data analysis. TS, YU, EE, GU, and AK contributed to drafting the manuscript. All authors reviewed and approved the final version of the manuscript.

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