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Use of food additives in bakery products

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Abstract. The influence of various food additives including emulsifiers (mono- and diglycerides of fatty acids (E471), lecithin (E322), sodium stearoyl-2-lactylate (E481) and preservatives (potassium sorbate (E202), sodium propionate (E281)) on the quality and shelf life of bakery products was investigated. The study was conducted on the basis of the enterprise in Gulistan (Uzbekistan) in order to improve organoleptic characteristics of products and extend their shelf life. To conduct the experiment, test batches of bread with the addition of the specified food additives in various combinations were made. The effect of additives on such parameters as softness and elasticity of crumb, porosity, moisture, as well as resistance to microbiological spoilage (yeast and mould) was analysed. Microbiological analysis showed that the addition of preservatives significantly reduced the number of colony-forming units (CFU) of yeasts and moulds in bakery products. The control group reached 500 CFU/g by day 7, while the combination group had the lowest levels of only 50 CFU/g on day 7, which confirmed the effectiveness of the preservatives. It was also observed that the use of the combination of emulsifiers E471 and E481 resulted in a significant improvement in bread texture, increased bread volume and improved crumb porosity. The addition of lecithin (E322) contributed to moisture retention, which slowed down the staling process. The addition of potassium sorbate and sodium propionate significantly increased the shelf life of the bakery products, preventing

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the development of mould and yeast during 7-10 days of storage in a climate-controlled chamber. Thus, the use of combinations of food additives in conditions of industrial production allowed improving the physical and chemical properties of bakery products, increased their shelf life and ensured microbiological safety of products. The results of the study may be useful for further implementation of these technologies in the bakery industry of the Republic of Uzbekistan

Keywords: lecithin; bread texture; food technology; preservatives; microbiological spoilage

INTRODUCTION

The problem of improving the quality and properties of bakery products remains one of the topical issues in the food industry. Every year consumers' requirements to organoleptic and physical characteristics of bread, such as softness, elasticity, resistance to staling, as well as shelf life of products, are increasing. Modern technologies offer a wide range of solutions related to the use of food additives, in particular emulsifiers and preservatives, which play a key role in improving the quality of bakery products and extending their shelf life.

A. Islam and S. Islam (2024) describe in detail all the pros and cons of this technology. Another interesting solution is the technology of adding honeysuckle powder to the formulation, which was proposed by Chinese scientists in their research work (Çobanoğlu *et al*., 2022; Ran *et al.*, 2023). Another innovative solution is the use of nanomaterials as food additives, but as stated by the authors of the article, such solutions can negatively affect the ecological state of the region (Gerardo-Rodríguez *et al*., 2021). Although these modifications of bakery products are already used in the production of different countries, the risks that may arise in the production processes have not yet been comprehensively studied.

Different types of emulsifiers and their effect on the structure and texture of baked goods have been reported in several studies (Cauvain, 2020; Ardoin *et al*., 2023). Thus, the literature indicates that the use of mono- and diglycerides of fatty acids (E471) contributes to increasing the porosity and softness of the breadcrumb and slows down the staling process (Faccioli *et al*., 2021; Valsalan *et al.*, 2023). This is because emulsifiers enhance the interaction between the fat and water phases in the dough, stabilise the gluten mesh and make the dough more elastic. The study by R.P. Guiné and S.G. Florença (2024) focused on the development and characterisation of functional bakery products, where different additives were used to increase the nutritional value and improve the physicochemical properties of the products. Their results showed that proper selection of food additives such as antioxidants, preservatives, and emulsifiers can significantly improve the quality of finished products and increase their shelf life. An essential part of this study was the introduction of functional components, which not only improved the quality of bakery products, but also gave them additional beneficial properties.

Other studies such as the work of E. Debonne *et al.* (2023) aimed to study the effect of potassium sorbate preservative (E202) on the shelf life of bakery products. They showed that the use of potassium sorbate effectively inhibits the growth of mould fungi and yeast, which can significantly extend the shelf life of bakery products, especially in humid conditions (Yazdanfar *et al.*, 2023; Melin, 2024). This confirms the importance of the choice of preservatives in preserving the freshness of bread. Lecithin (E322) plays an important role in improving the physicochemical characteristics of bread, as shown in the work by A. Kumar and G. Sharma (2018), where it was shown that the addition of lecithin helped to increase the volume of bread and improve its texture. Lecithin stabilizes the dough structure and facilitates moulding, which also improves the economic efficiency of production (Byeon *et al.*, 2024).

Thus, the reviewed studies demonstrate the relevance of the use of additives in the bakery industry to improve the properties of dough and finished products. Considering the relevance of this topic, it is worth noting the work of S. Sadikhov (2024), where it is noted that the Azerbaijani food industry has a significant potential for export, especially if innovative approaches to improving the quality and safety of products are introduced. Nevertheless, despite the large number of studies in this area, the question of the complex effect of various food additives on bakery products under conditions of industrial production remains open. The application of modern technologies and the study of their combined effect require additional attention, especially in the context of developing countries such as Azerbaijan and Uzbekistan, where bread remains one of the key foodstuffs.

This study was aimed at investigating the effect of food additives such as emulsifiers (E471, E322, E481) and preservatives (E202, E281) on organoleptic properties and shelf life of bakery products produced under the conditions of an industrial enterprise in Gulistan (Uzbekistan). The aim of the work was to identify the optimal combinations of these additives to improve the physical and chemical characteristics of the products, as well as to assess their impact on microbiological safety.

MATERIALS AND METHODS

The scientific study was conducted at MPS Rayhon facility in Gulistan city using raw materials and equipment to obtain the most accurate and reproducible results.

Components of samples and reagents for biochemical analysis. For the study, all materials were purchased from certified suppliers and met the standards and requirements for the food industry and laboratory testing. The main suppliers were leading international and local companies accredited to supply food, food additives and laboratory equipment. Mono- and diglycerides of fatty acids (E471), lecithin (E322), sodium stearoyl-2-lactylate (E481), potassium sorbate (E202 and sodium propionate (E281) were purchased from distributors specializing in food ingredients such as Merck, Sigma-Aldrich. The main suppliers of raw materials for the production of samples were local enterprises accredited for the production and supply of ingredients for the baking industry in Uzbekistan. The flour was purchased from local mills that specialize in the production of high-quality wheat flour. The supplier was selected based on the flour's compliance with quality standards and requirements for bakery products, including protein, moisture, and gluten content.

Baker's yeast was used and also purchased from a local producer that meets the requirements of the O'z DSt 950:2011 standard. The manufacturer was selected based on compliance with the requirements for yeast activity and product purity. Sugar, salt and sunflower oil for the manufacture of the samples were purchased from local food suppliers that met health and hygiene standards. These ingredients ensured the flavour characteristics and balance of the bread recipe. All ingredients were thoroughly tested to meet the quality standards adopted in the Republic of Uzbekistan to ensure consistent and high-quality of finished products. Selective nutrient media for microbiological analyses, such as Sabouraud medium and yeast extract medium, were purchased from international suppliers of laboratory materials such as Oxoid and Merck.

Equipment. Laboratory equipment (incubators, shakers, autoclaves and sterile containers) was purchased from manufacturers specializing in equipment for microbiological and chemical laboratories. Companies such as Thermo Fisher Scientific and Eppendorf supplied the necessary equipment for the experiments. The dough mixer was purchased from Kemper through a local distributor in Uzbekistan that provides equipment for the bakery industry. The baking ovens for baking the test batches were purchased from MIWE. A Stable Micro Systems texture meter was also used to measure the physical properties of bakery products such as softness and elasticity. The moisture analyser (Sartorius), microbiological equipment for the analysis of yeast and mould levels in bakery products, which included incubators, autoclaves and PCR analysers (Thermo Fisher Scientific, Eppendorf and Merck), and climate-controlled storage chambers for shelf-life studies (Memmert) met the requirements and standards for research in the food industry and were purchased through certified suppliers who provide support and service in Uzbekistan.

Preparing dough and baking product. For each experiment, the dough was prepared according to the standard recipe, with the addition of appropriate ingredients. Control samples were prepared without food additives. For each sample, different food additives (emulsifiers and preservatives) were selected in the prescribed proportion. After kneading, the dough was fermented and baked under standard conditions in baking ovens at 200°C for 30 minutes. The products were evaluated for several physical and chemical parameters such as: crumb volume and porosity, softness and elasticity (in Newtons), and moisture content. In order to assess the taste and consumer qualities of the products, a tasting was conducted. A group of experts (bakers and specialists of the company) consisting of 20 people evaluated the bakery products according to several criteria, such as taste, texture, and aroma. Each criterion was evaluated on a 10-point scale, where 10 is the maximum score.

Microbiological analysis of bakery products was carried out to evaluate the effectiveness of preservatives. The samples were stored at 20°C for 7 days, after which the content of microorganisms (yeasts and moulds) was analysed. For this purpose, the technique of sowing on selective media was used, followed by counting the number of colony-forming units (CFU). Microbiological analysis of bakery products was carried out to evaluate their microbiological purity and the effectiveness of preservatives in preventing the growth of microorganisms such as mould and yeast during storage. Samples were taken on the 1st, 4th and 7th day of product storage. Each sample weighing about 10 g was taken from the central part of the product to exclude possible external contamination. The samples were chopped with a sterile knife and then placed in sterile containers. The samples were then diluted in sterile physiological solution (0.85% NaCl) at a ratio of 1:10 (1 g of product per 9 ml of solution). The resulting suspensions were stirred vigorously for 2 minutes for uniform distribution of microorganisms. Selective nutrient media were used to evaluate the growth of microorganisms. From each diluted suspension, 0.1 ml was taken and then samples were plated on the surface of agar in Petri dishes by surface seeding method. For each type of medium, 3 cups were used for each time point and experimental group. The seeded Petri dishes were placed in an incubator at 25°C for moulds and at 30°C for yeast. The incubation time was 48 hours for yeast and 5-7 days for mould. After incubation, visual observations of the Petri dishes were made. Yeast and mould colonies were counted using the standard DRE counting method. The number of DREs was counted per sample weight and expressed as DRE/g product.

To study the shelf life, the samples were stored at different temperature conditions (20°C and 5°C) for 7 days. Parameters such as moisture, texture, and mould appearance were monitored at regular intervals. All the

data obtained were processed using descriptive and inferential statistics techniques. To test the significance of differences between the experimental groups and the control group, methods of analysis of variance with a significance level of $p < 0.05$ were used. This allowed us to determine the extent to which the use of food additives influenced the main quality parameters of bakery products. The economic analysis of the cost of products with the addition of emulsifiers and preservatives was carried out. The impact of these additives on the final price of bakery products was studied, and the potential benefits of extending the shelf life of products and improving their quality were evaluated.

RESULTS

In the course of the study on the basis of bakery enterprise "MPS Rayhon" the effects of the use of various food additives, including emulsifiers and preservatives, on the quality of bakery products were studied. The main objective was to evaluate the effect of additives on physicochemical, organoleptic properties and shelf life of the products. Several test batches of bakery products were prepared with the addition of mono- and diglycerides of fatty acids (E471), lecithin (E322), sodium stearoyl-2-lactylate (E481), and preservatives. The control group consisted of products prepared without the use of food additives. The study selected certain food additives based on their functional properties and wide application in the bakery industry. The main objective was to improve the quality, extend shelf life, improve the texture of bakery products, and ensure the microbiological safety of the products.

To achieve these objectives, emulsifiers such as fatty acid mono- and diglycerides (E471), lecithin (E322) and sodium stearoyl-2-lactylate (E481) were used. These emulsifiers played a key role in improving bread texture, and volume and prolonging freshness. Mono- and diglycerides of fatty acids, due to their ability to improve the interaction between fats and water, ensured an even distribution of fats in the dough, which contributed to the formation of a softer and more porous crumb structure. Lecithin, as a natural emulsifier, strengthened the dough structure, improved moisture retention and stabilized the moulding process (Chechitko *et al.*, 2024). Sodium stearoyl-2-lactylate stabilized the gluten mesh, which had a positive effect on increasing the volume of the finished product and improving its texture. These emulsifiers were chosen because of their proven effectiveness in prolonging freshness and improving organoleptic characteristics of bakery products.

Preservatives also played an important role in the study. Potassium sorbate (E202) and sodium propionate (E281) were used to prevent microbiological spoilage of the products. Potassium sorbate, widely used in the food industry, was chosen for its high effectiveness in inhibiting mould and yeast growth, which is particularly important for products with long shelf life in high-humidity environments. Sodium propionate was also found to be effective against microbiological spoilage, inhibiting the growth of mould fungi and bacteria that cause bread spoilage, while not affecting its taste and odour. These preservatives were selected due to their safety, neutral effect on organoleptic properties and high effectiveness in extending shelf life. The combined use of emulsifiers and preservatives allowed achieving a synergetic effect. Together they not only improved physical and organoleptic characteristics of products, but also significantly extended their shelf life. This ensured stable high quality of bakery products during the whole shelf life, reducing the risks of microbiological spoilage and slowing down the processes of staling.

The study showed that the addition of emulsifiers had a significant effect on the volume of the products. Control samples had an average volume of 600 cm^3, whereas products with the addition of mono- and diglycerides of fatty acids (E471) showed a 15% increase in volume (to 690 cm^3). The use of lecithin (E322) also resulted in a significant increase in volume to 670 cm^3, while the combined use of all emulsifiers gave the maximum result of 710 cm^3, which is 18% higher than the control group (Table 1).

***Table 1**. Effect of emulsifiers on physical characteristics of bakery products*

Indicator	Control group	E471 (mono- and diglycerides)	E322 (lecithin)	E481 (sodium stearoyl-2-lactylate)	Combined group
Volume of products (cm^3)	600	690	670	680	710
Crumb porosity (%)	35	42	40	41	45
Softness (H)	10	7	8	7.5	6.5
Elasticity (units)	65	75	70	72	80

***Source:** compiled by the authors*

Measurement of crumb porosity showed that the emulsifiers improved the uniformity of pore distribution in the baked goods. In the control group, the porosity was 35% and the pores were less uniform. In the samples with mono- and diglycerides, the porosity reached 42% and in the products with lecithin it was 40%. The most homogeneous structure was observed in the samples with combined additives (porosity – 45%). This indicated a softer and airier crumb structure when emulsifiers were used. One of the key quality indicators

of bakery products is their texture. According to texture meter testing, the products with emulsifiers had a softer texture compared to the control group. In the control group, the compressive force required to deform the crumb was 10 N, whereas in the samples with the addition of mono- and diglycerides of fatty acids it was reduced to 7 N. Lecithin also contributed to reduce the stiffness of the products, showing a result of 8 N. The highest effect was obtained with the combined use of additives – 6.5 N. When the concentration of emulsifiers was varied from 0.5% to 2%, it was observed that an optimum improvement in softness and texture of bakery products was observed when their content was increased to 1.5%. Higher concentrations (above 2%) resulted in excessive softness, which negatively affected the consumer properties and product perception. These results demonstrated the importance of accurate additive dosage to maximize the improvement effect.

In addition, the effect of food additives on the microstructure of bakery products was studied. Microscopic analysis showed that the addition of emulsifiers improved the structure and even distribution of air bubbles in the dough, which provided a lighter and airier texture of the finished products. This phenomenon was particularly noticeable when lecithin and monoglycerides were used, which contributed to the creation of a more stable foam in the dough, improving its airiness and elasticity. Measurement of the elasticity of the products showed that the emulsifiers contributed to the increase of this index. The elasticity of the control samples was 65 units, while the products with mono- and diglycerides showed a result of 75 units and lecithin 70 units. The combined additives increased this value to 80 units, indicating airier and more elastic crumb structure. This is particularly important for consumer perception, as soft and elastic products are favoured by customers.

In addition, this study evaluated the weight change of the products after baking, which is directly related to moisture loss during heat treatment. The addition of emulsifiers and preservatives reduced the weight loss of the products during baking (Table 2). This is due to the fact that these additives promoted moisture retention in the dough. Products with complex additives showed the lowest weight loss, indicating that the additives were highly effective in preventing the products from drying out during baking.

***Table 2**. Change in weight of bakery products after baking*

Product	Initial dough weight (g)	Weight after baking (g)	Weight loss (%)
Product A (without additives)	1,000	870	13
Product B (with emulsifiers)	1,000	880	12
Product C (with preservatives)	1,000	875	12.5
Product D (with complex additives)	1,000	885	11.5

***Source:** compiled by the authors*

To evaluate the taste characteristics of the modified bakery products, organoleptic analysis by tasting method was carried out to evaluate the taste, aroma, and texture of the bakery products. The control group obtained average taste scores of 7 for flavour, 6.8 for texture and 6.5 for aroma. At the same time, products with added emulsifiers received higher scores. Thus, the flavour of samples with mono- and diglycerides was rated 7.5, and texture – 8 points. Products with lecithin received 7.3 points for flavour and 7.5 for texture, which also indicated an improvement in organoleptic characteristics (Table 3). The highest scores were awarded to products with combined additives: 7.8 for flavour, 8.3 for texture and 7.2 for aroma. This indicated that the use of several types of emulsifiers had a positive effect on the overall evaluation of the products, making them more attractive to consumers. Thus, it can be concluded that the addition of emulsifiers improves the flavour and texture perception of bakery products, making them softer and more aromatic.

***Table 3**. Organoleptic properties of bakery products*

Indicator	Control group	E471 (mono- and diglycerides)	E322 (lecithin)	E481 (sodium stearoyl-2-lactylate)	Combined group
Flavour (points out of 10)	7	7.5	7.3	7.4	7.8
Texture (points out of 10)	6.8	8	7.5	7.7	8.3
Flavour (points out of 10)	6.5	7	7.2	7.1	7.2

***Source:** compiled by the authors*

In addition to organoleptic analysis, studies on the change in colour characteristics of bakery products with the use of food additives were carried out. Colour was measured using a spectrophotometer, where the

parameters L* (lightness), a* (red/green hue) and b* (yellow/blue hue) were evaluated. Products with added nutritional supplements showed a lighter hue (parameter L*) and more intense red and yellow tones (parameters a* and b*, respectively). These changes were particularly pronounced in Product D, where complex food additives were used (Table 4). It can be concluded that such additives can have a positive effect on the appearance of the final product, which can also increase its consumer appeal.

***Table 4**. Colour characteristics of bakery products*

Parameter	Product A (without additives)	Product B (with emulsifiers)	Product C (with preservatives)	Product D (with complex additives)
L*	65.2	68.5	66.8	70.1
a*	1.8	2.1	1.9	2.3
b*	15.4	16.7	16.1	17

***Source:** compiled by the authors*

Interesting results were also obtained in the context of the different types of flour used to create the products. Both traditional wheat flour and alternatives such as rye and maize flours were included in the study. The results showed that the addition of emulsifiers improved the texture of products made from all types of flour, but a particularly noticeable effect was observed when using rye flour, which is characterized by its greater density and tendency to produce a denser texture without additives. When emulsifiers were added, rye products became softer and airier, resulting in a product with similar characteristics to wheat flour-based products. It was also important to determine exactly how long the products would retain their freshness. When determining the shelf life of the samples, important steps were to detect the onset of stale products (assess texture changes and reduction in softness) and to detect the appearance of mould (both visually and by microbiological analysis). In the control group, the products started to stale on day 3, while in the potassium sorbate group the shelf life was 5 days and in the sodium propionate group 6 days. In the combined group, the products remained fresh for 7 days. The moisture content of products with preservatives was preserved significantly better than in the control group, with maximum values in the combined group – 36% on day 7 (Table 5).

***Table 5**. Effect of preservatives on shelf life and moisture content of bakery products*

Indicator	Control group	Potassium sorbate (E202)	Sodium propionate (E281)	Combined group
Shelf life (days)	3	5	6	7
Humidity on day 3 (%)	32	38	37	39
Humidity on day 7 (%)	25	34	33	36

***Source:** compiled by the authors*

For yeast, the colonies had a smooth, shiny surface, with different colouring depending on the strain. For moulds, the colonies were rough and often had the branched structure characteristic of mould fungi. Microbiological results allowed us to evaluate the degree of microbial growth depending on the type of preservative added. Quantitative data on the number of DREs/g were collected for each time interval (days 1, 4 and 7). A comparative analysis was then performed for each group. Microbial growth was significantly higher in the control group than in the preservative groups, especially by day 7. Sodium propionate and potassium sorbate were effective in inhibiting mould and yeast growth, especially in the combined group, where a minimum DRE/g by day 7 was observed (Table 6). The addition of preservatives significantly reduced the amount of yeast and mould DREs in the baked products. The lowest level was in the combined group with only 50 DREs/g on day 7, which confirmed the effectiveness of the preservatives.

***Table 6**. Microbiological analysis of bakery products*

Indicator	Control group	Potassium sorbate (E202)	Sodium propionate (E281)	Combined group
Number of DREs/g (on day 4)	300	120	100	80
Number of DREs/g (on day 7)	500	200	150	50

***Source:** compiled by the authors*

Additionally, the impact of the use of food additives on the cost of production was assessed. Firstly, calculations of the production cost of bakery products with the use of various food additives were carried out.

This included the purchase costs of emulsifiers (E471, E322, E481) and preservatives (E202, E281) as well as basic ingredients (flour, yeast, salt, etc.). The purchase cost of the additives was compared with the costs of conventional production without their use. The use of emulsifiers increased the production cost by 5-7% due to the cost of additives. However, improved product quality increased demand and market expansion, which offset the additive costs (Table 7). The use of preservatives also made it possible to extend the shelf life of the products, which reduced stale losses and increased sales. As a result, the use of additives led to an overall increase in the profitability of the company. Further, the impact of additives on production processes was analysed. For example, the use of emulsifiers improved the textural characteristics of the dough, which in turn reduced raw material losses during kneading and baking. This optimised production costs and increased the yield of finished products.

It was also noted that the addition of preservatives reduced the number of products returned due to premature spoilage. Extending the shelf life of products through the use of preservatives reduced losses from write-offs of unsold products. The longer shelf life also increased the ability to market the products to remote regions, which increased total sales. The analysis process considered data on product returns and their reduction after the introduction of the additives. The impact of new product characteristics on consumer demand was assessed in parallel with production performance. Longer shelf life and improved organoleptic properties of bread resulted in increased customer loyalty and, consequently, increased sales. These data were taken into account when calculating the increase in the company's income. Based on the obtained data, the profitability of the use of food additives was assessed. For this purpose, the following indicators were calculated:

1. Return on sales (profit to revenue ratio), which increased due to a reduction in the cost of writing off spoilt products and an increase in sales volumes.

2. Product profitability (ratio of profit to cost of production), which also increased due to reduced production losses and optimized processes.

3. Return on investment (the period over which the cost of introducing new additives and equipment is recovered).

***Table 7**. Economic evaluation of the impact of food additives on the cost of products*

Indicator	Control group	E471 (mono- and diglycerides)	E322 (lecithin)	E481 (sodium stearoyl-2-lactylate)	Combined group
Cost of product (%)	100	105	104	106	107
Increase in sales (%)	–	10	8	9	12
Reduction of losses (%)	–	20	18	19	25

***Source:** compiled by the authors*

The use of emulsifiers and preservatives in the production of bakery products has significantly improved their physicochemical and organoleptic characteristics. These methods also extended the shelf life of products, ensuring their quality for a longer period of time. The results of this study demonstrated that the use of food additives such as emulsifiers and preservatives significantly improved the quality of bakery products, including their textural characteristics, shelf life and organoleptic properties. These findings are supported by a number of other scientific studies, emphasizing their relevance to applications in manufacturing processes.

DISCUSSION

Baking plays a key role in food security, as bakery products are a staple food for millions of people around the world. Technology in this field is constantly evolving to meet consumer demands for quality, freshness, and variety. Modern production methods, including the use of food additives, improve the texture, flavour, and shelf life of bread, which in turn increases profitability and reduces losses in the production chain. In the course of this study, important aspects were identified which are in agreement with the results of other authoritative studies. Food additives are of great importance in the manufacture of bakery products. The analysis of which can open new perspectives for the modernization of outdated technologies. Food additives can not only improve the physical and chemical properties of products, but also significantly affect their organoleptic characteristics (Melnikova & Gilsanz, 2023).

In the search for effective solutions to improve the physico-chemical performance of bread, firstly, it is worth mentioning the work of R. Dankwa *et al.* (2021), which describes the utilisation of alternative flours such as sorghum, cassava, and beans. In particular, the sorghum and bean data indicated an improvement in the texture and flavour of the products, which converges with the results obtained in this study when emulsifiers were used. These additives promoted uniform moisture distribution in the dough, which improved the quality of the final product. Textural analysis carried out in collaboration with MPS Rayhon bakery showed the positive effect of emulsifiers on the softness and elasticity of dough.

A common but no less interesting alternative is the use of functional foods, such as gluten-free products (Shemet & Hulai, 2023). Thus, in a study by J. Xu *et*

al. (2020), the authors looked at gluten-free products and found a significant effect of emulsifiers in improving the texture and organoleptic characteristics of these products, which correlates with the results obtained in this study, and although it focused on traditional wheat products, the importance of emulsifiers in improving dough texture was noted in both studies. Texturometer measurements showed that products with added emulsifiers had a more uniform and tender texture, contributing to better consumer judgement. Moreover, the data on the use of alternative flours may be important for further research in the context of technology adaptation for gluten-free products.

The safety of the components of future food products plays a major role in formulation development (Tkachuk *et al.*, 2024), where analysing the literature is a particularly important stage of the work. For example, A.V. Herrera-Herrera *et al.* (2019), considered the effects of organophosphorus pesticides on bread and flour, and also emphasized the importance of quality control of raw materials. The importance of factors of possible adverse effects on food can hardly be overestimated, as it is they that require detailed study with the subsequent minimization of health risks for the end consumer. Also, studies on the toxicity of food additives and their effect on the gut microbiota have helped to select the right proportions of food additives (Li *et al.*, 2024).

Microbiological studies have also played an important role in assessing the quality of bakery products. According to studies by D. McCann *et al.* (2007), some food additives may have negative effects on consumer behaviour and health, especially children. This safety requirement was taken into account in this study and the additives used met the safety standards established both for the food industry in Uzbekistan and international norms. Microbiological analyses showed that the level of yeast cultures and moulds in the samples were within the permissible limits even after prolonged storage, indicating the high quality and safety of the product.

In addition, when analysing the articles of different scientific groups, it is possible to identify those that have studied the benefits of food additives, for example in the work by İ. Özhamamcı *et al.* (2019), the authors emphasized the role of emulsifiers in improving the physical and chemical properties of dough. In this work, such an effect was observed through increasing the softness and elasticity of the finished products. The use of modern emulsifiers, such as lecithins and polyglycerol polyricinoleates, allowed for a more uniform distribution of fatty components in the dough, resulting in improved texture and flavour of the products (Moni *et al.*, 2023; Precup *et al.*, 2024). On the other hand, it is not uncommon to find the use of natural additives in the form of various extracts in bread making, but the implementation and scaling up of such technologies cannot always be called a commercially viable solution (Nabiyev *et al.*, 2024).

In addition, it is worth considering the impact of food additives on the profitability of production. In particular, the use of preservatives allowed significantly increasing the shelf life of products, which reduced the volume of returns and reduced losses at all stages of the supply chain. The results of this study showed that by increasing the shelf life of bakery products to 14 days without significantly changing their quality characteristics, manufacturers can significantly optimize logistics and reduce distribution costs. A number of literature sources have highlighted the potential of the food industry in Azerbaijan and Uzbekistan, and studies have shown that improving the technological processes of bakery production through the use of food additives has great prospects for increasing export potential and meeting domestic demand (Amoriello *et al.*, 2020). Extending the shelf life of products and improving their quality opens up new markets in both domestic and foreign markets. This coincides with the research data of J. Swinnen *et al.* (2017), who noted that the regions of Eastern Europe and Central Asia have significant potential for improving productivity in the food industry through the introduction of modern technologies and additives. The results of this paper confirm that the use of food additives can be an important step towards achieving this goal. Thus, it can be concluded that the introduction of these technologies into production not only contributes to increasing competitiveness in the market, but also improves the overall performance of production. The use of food additives opens new opportunities for the Uzbek bakery industry, providing producers with tools to improve product quality and shelf life.

CONCLUSIONS

This study evaluated the effectiveness of various food additives, such as emulsifiers and preservatives, in the production of bakery products. The main attention was paid to their influence on organoleptic characteristics of products, including softness, porosity, texture, and elasticity of crumb, as well as on shelf life and microbiological stability of products. Several important conclusions can be drawn from the data obtained. Firstly, the use of emulsifiers such as mono- and diglycerides of fatty acids (E471), lecithin (E322) and sodium stearoyl-2-lactylate (E481) showed a significant improvement in the textural characteristics of the bread. Products containing these emulsifiers had higher porosity, which had a positive effect on the softness and airiness of the crumb. In particular, the addition of E471 and E481 promoted a more uniform distribution of fat and water in the dough, resulting in a soft, elastic bread structure resistant to deformation. Lecithin (E322) was particularly useful for retaining moisture in the products, which slowed down the staling process and prolonged the freshness of the products.

Secondly, the addition of preservatives such as potassium sorbate (E202) and sodium propionate (E281)

significantly increased the shelf life of bakery products. These preservatives effectively inhibited the growth of mould fungi and yeasts, preventing microbiological spoilage of the products during 7-10 days of storage under controlled conditions. This is particularly important for bakery products with a long shelf life, produced under conditions of high humidity or temperature fluctuations. The inclusion of these preservatives ensured consistent product quality while minimizing the risks of mould growth and undesirable enzymatic processes.

A third important aspect of the study was the combined use of emulsifiers and preservatives, which resulted in a synergistic effect. Products containing both groups of additives showed not only improved textural properties, but also significantly extended shelf life while maintaining microbiological safety. This allows us to recommend the combined use of food additives to improve the quality of bakery products on an industrial scale. In addition, the analysis showed that an important factor in achieving the positive results was the exact compliance with the dosage and technological parameters of production. Changing the proportions of additives could have both positive and negative effects on product characteristics, which confirms the need to carefully control the technological process at each stage. For example, excessive addition of preservatives could affect the organoleptic properties of products, while insufficient amounts of emulsifiers could lead to texture deterioration and rapid staling.

Significant differences in microbiological resistance of products were also found depending on climatic storage conditions. Humidity and temperature-controlled chambers were found to be the most effective in extending product shelf life, which emphasises the importance of creating optimal storage conditions for bakery products, especially in regions with high humidity and temperature fluctuations. Thus, the study has demonstrated that the use of food additives in the industrial production of bakery products allows achieving a significant improvement in product quality and increase its shelf life. The use of emulsifiers improves the textural characteristics of bread, and preservatives provide microbiological safety and extend the shelf life of products. Combined use of these additives proved to be the most effective, which makes them promise for further application in the baking industry of Uzbekistan and other countries with similar production conditions.

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CONFLICT OF INTEREST

None.

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Застосування харчових добавок у хлібобулочних виробах

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Анотація. Було досліджено вплив різних харчових добавок, включно з емульгаторами (моно- і дигліцериди жирних кислот (Е471), лецитином (Е322), стеароіл-2-лактилатом натрію (Е481) і консервантами (сорбат калію (Е202), пропіонат натрію (Е281)), на якість і термін зберігання хлібобулочних виробів. Дослідження проводилося на базі підприємства в Гулістані (Узбекистан) з метою поліпшення органолептичних характеристик продукції та продовження її терміну зберігання. Для проведення експерименту було виготовлено тестові партії хліба з додаванням зазначених харчових добавок у різних комбінаціях. Проводився аналіз впливу добавок на такі показники, як м'якість і еластичність м'якушки, пористість, вологість, а також стійкість до мікробіологічного псування (дріжджі та пліснява). Мікробіологічний аналіз показав, що додавання консервантів значно знижує кількість колонієутворювальних одиниць (КУО) дріжджів і цвілі в хлібобулочних виробах. У контрольній групі рівень КУО досяг 500 КУО/г до 7-го дня, тоді як у комбінованій групі показники були найнижчими – лише 50 КУО/г на 7-й день, що підтвердило ефективність консервантів. Також було відзначено, що використання комбінації емульгаторів Е471 і Е481 призводить до значного поліпшення текстури хліба, збільшення його об'єму і поліпшення пористості м'якушки. Додавання лецитину (Е322) посприяло утриманню вологи, що сповільнило процес черствіння. Додавання сорбату калію і пропіонату натрію істотно збільшило термін зберігання хлібобулочних виробів, запобігаючи розвитку цвілі та дріжджів протягом 7-10 днів зберігання в камері з контрольованим кліматом. Таким чином, застосування комбінацій харчових добавок в умовах промислового виробництва дало змогу поліпшити фізико-хімічні властивості хлібобулочних виробів, збільшити їхній термін зберігання та забезпечити мікробіологічну безпеку продукції. Результати дослідження можуть бути корисними для подальшого впровадження даних технологій у хлібопекарську промисловість Республіки Узбекистан

Ключові слова: лецитин; текстура хліба; харчова технологія; консерванти; мікробіологічне псування