Effect of complex baking improver on prolonging freshness of bakery products with reduced salt content

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Abstract

Introduction. The aim of research was to determine the effect of a complex baking improver on prolonging the freshness of bakery products with a reduced salt content using the principles of lean manufacturing.

Materials and methods. Sociological research on the requirements for the quality of bakery products was conducted. A composition of a complex improver "Mineral Freshness Plus" was developed and its optimal dosage was determined. The effects of the developed improver addition on the quality of bakery products with reduced salt content of 0.5% by weight of flour, and the effect on the processes of staling products during storage were studied.

Results and discussion. According to sociological studies the presence of ingredients of synthetic origin in bakery products and rapid loss of their freshness is undesirable for consumers.

To meet the consumer demands, the use of the principles of lean manufacturing in bakery production is provided, which consists in reducing technological costs and losses due to application of the developed improver.

A recipe for a complex baking improver Mineral Freshness Plus has been developed, which is designed to intensify the technological process, improve consumer properties and time for keeping the freshness of bakery products with low salt content of 0.5%. The composition of the improver includes food additives with Generally Recognized as Safe status. Addition of "Mineral Freshness Plus" improver in quality of 2.0% to flour weight extends freshness of bakery products.

This is confirmed by the higher by 65.2–75.6% content of dextrins in the product with the improver comparшtп with the control, the thinner subcrustal layer on 72 hours of products storage, and changes in the structure of the bread pulp, which consists of interspersed swollen and partially gelatinized grains of starch, wrapped in a continuous mass of coagulated proteins.

Conclusions. The use of the developed improver "Mineral Freshness Plus" in the manufacture of bakery products ensures the high consumer demands.

Introduction

Bakery products being a part of everyday diet consumption have an important role in human nutrition. To increase the competitiveness of bakery products, manufacturers, through the applicaton of accelerated technologies, food additives, non-traditional raw materials, are expanding the range and providing products.

Hovewer, consumers are dissatisfied with the presence of food additives of synthetic origin in the composition of products, the rapid loss of product freshness, namely the loss of aroma and taste, the elasticity of the crumb and the crunch of the crust (Bilyk et. al., 2019). These changes are caused by the components of formulation, the method of dough preparation, the quality of raw materials, the duration and conditions of storage.

Along with this, to increase the competitiveness of food industry enterprises is the active promotion of the system of operational improvement and optimization of business processes in the company's activities.

The world trend in the business processes management is the use of anti-crisis management systems, among which the most famous is "Economical (lean) production" or "Lean-management". The main goal of lean-management is a creation of needed product value to meet an actual customer's demands based on the principle of fewer resources and less waste. Thus, the development of complex improvers, which, along with enhancing of the finished products consumer properties, will improve their nutritional value and ensure their economical production, is the actual direction of scientific research in the technology of bakery products.

The formulations of complex bakery improvers consist of a functional and an active part. Functional part includes such ingredients as flour, starch, dextrenized flour, meanwhile the active part consists from gluten oxidizing and reducing agents, enzymes, emulsifiers and various food additives or ingredients with specific effects.

All components of the complex baking improver are selected according to their activity and synergistic action with each other (Bilyk et al., 2019).

The use of complex bakery improvers allows to intensify the technological process, as well as reduce and cost of production and losses during the storage.

The aim of research was to determine the effect of a complex baking improver "Mineral Freshness Plus" on prolonging the freshness of bakery products with a reduced salt content using the principles of lean manufacturing.

Only Generally Recognized as Safe (GRAS) additives will be included in the composition of proposed improver.

Materials and methods

Materials

Preparation of dough samples

Dough samples were prepared according to the recipe, % by weight of flour: premium wheat flour, 100.0, pressed baker's yeast, 3.0, salt, 0.5, margarine, 2.0, sugar, 2.0. The dough with a moisture content of 44.5% was kneaded using a non-dough method. The dough was kneaded in a two-speed Escher kneading machine (Italy). The dough was processed manually, the test pieces were kept at a temperature of (38 ± 2) °C and relative humidity (78 ± 2)%. The products were baked in a Sveba-Dahlen cabinet oven (Italy) at a temperature of 220–240 °C.

Methods

Determination of bread weight, volume and specific volume

The weight of bread was determined after cooling using a digital balance with accuracy 0.01 g, and the bread volume was determined using grain displacement method. The specific volume of each bread was calculated as (Zhu et al., 2016).

Determination of bread porosity

The porosity of bread was determined as the volume of the pores in a certain volume of the crumb, expressed as a percentage to the total volume (Verheyen et al., 2015).

Determination of Comprehensive Quality Score

Based on the results of the sensory and physico-chemical evaluation of finished products, a complex quality index was calculated. The Comprehensive Quality Score is the total number of points a prototype receives when it is analyzed. For its calculation, each product was evaluated according to the following parameters: specific volume; the correctness of the form; crumb color; characteristics of the surface of the crust; bread staling after 72 hours; the porosity structure; form stability of hearth bread; rheological properties of the pulp; the aroma of bread; taste of bread, and crumb chewing.

These bread properties were evaluated on a five-point scale, taking into account the weighting coefficient, which was established for each parameter by the method of expert evaluation. The number of points provided to the parameter was multiplied by the weighting coefficient. Then, the sum of the obtained values was calculated. The more points the sample receives as a result of the calculation, the better its quality.

The expert commission included seven PhD, three Masters of philosophy, and 15 postgraduate students by the specialty "Food Technologies".

Determination of bread pulp deformation

The time for which bread keeps the freshness was evaluated by changing the structural and mechanical properties of the bread pulp. Its total deformation was determined after 48 h of storage using an AP 4/1 penetrometer (Finemass, Germany) (Drobot et al., 2015).

Determination of aromatic substances content

The content of aromatic substances in finished products was evaluated by the amount of bisulfite-binding compounds (Drobot et al., 2015). The method is based on the ability of aldehydes and some ketones react with sodium bisulfite to form adducts, and consists in the preliminary removal of unreacted bisulfite by iodine, followed by the destruction of the adducts with sodium bicarbonate and the dissolution of the released bisulfite, which is equivalent to the content of carbonyl compounds.

Determination of the staling degree

The staling degree of bread was evaluated by area and stiffness of the subcrustal layer using scanning and graphic editors to determine the average thickness of the subcrustal layer (Petrusha and Niemirich, 2016).

Microscopy of bakery products

Microscopy of bakery products was performed after 72 hours of storage. The samples were stored unpackaged at a temperature of (20±0) °C. The samples were prepared by freezing, freeze-drying, and deposition of carbon in a vacuum chamber on a piece of the dried sample. The samples were examined using an IEOLJSMM-200 (Japan) scanning electron microscope at a magnification of 1000 times and the most visible areas were photographed.

Determination of dextrins content

The content of dextrins was determined by the method of their mass fraction, which is based on the ability of dextrins to precipitate at various concentrations of ethanol in solution. Test samples were treated with enzymes to release the sample from water-soluble carbohydrates and fermentable sugars for better recovery. Precipitation of dextrins was carried out with alcohol solutions of different concentrations. Further dissolution of the extracted dextrins was done in water, and they were hydrolyzed with a 2% hydrochloric acid solution. Determination of the amount of glucose in the hydrolyzate of dextrins of different molecular weights was carried out according to the method of Wiltetter and Schudl. On the basis of a certain content of dextrins, the mass fraction of dextrins was determined by fractions, depending on the mass fraction of dextrins in ethyl alcohol solutions with different concentrations (Drobot et al., 2015).

Statistical analysis

All experiments were performed at least in triplicates. The statistical analysis of the data was performed by sequential regression analysis using the Microsoft Excel XP and Origin Pro8 software calculating correlation coefficients (Hinkle et al., 2003).

Results and discussions

Sociological research to found ways to improve bakery products

The first step of the research using the Kano method (Mezur et at., 2017), the requirements for bakery products that consumers expect to improve were studied.Consumers of bakery products were invited to participate in the study. 79 respondents took part in the sociological survey, namely, 27 men aged from 32 to 39 and 52 women aged from 28 to 39 years.All respondent interviews are working people having families of at least 3 people. An analysis of their preferences and characteristics showed that the vast majority of respondents (88.6%) consume products daily and buy bakery products at least 1 time in 3 days and, and 70.9% of respondents prefer products made from wheat flour. When choosing products, consumers pay special attention to: packaging, 64.6%; quantity of products, 62.0%; labeling (primarily information on recommended consumption periods and product composition), 91.1%; the presence of non-traditional flavoring additives (seeds and nuts), dried tomatoes and olives, 87.3%, and useful ingredients in products, 93.4%.

Questionnaires proposed by Noriaki Kano, which allow to separate product requirements into mandatory, expected, attractive, unimportant and undesirable, were used during the surveys,

According to the results of survey, the properties of products required by the current regulatory documentation and the absence or unsatisfactory level of which indicate a poor-quality product are classified as mandatory attributes. Among the requirements of this

category, the following characteristics are the most valuable for consumers: the shape, taste and aroma, the state of the crust, the elasticity and porosity of the pulp, and the freshness of the product

Expected or one-dimensional requirements include those whose presence or improvement of which has a linear correlation with customer demands. An analysis of the respondents' answers shows that environmental friendliness of packaging, product availability, small volumes of the product in a unit of consumer packaging, the presence of natural flavoring ingredients in the composition of products, and their high staling resistance are related to this category of requirements.

An attractive feature for the majority of respondents, 93.4%, is a wide range of products of one brand, to meet the needs of all family members. Among the product properties, consumers are particularly interested in such as: reduced calorie content, 53.2%, enrichment of finished products with micronutrients of natural origin, 62.0%, and reduction of salt content in the product, 55.7%.

It was found that such characteristics as the color of the crust and crumbling, when they reach the minimum acceptable level, are unimportant properties, since they do not affect the overall impression from finished product and do not reduce the value of the product for consumers. This is due in large part to the fact that most of the bakery products are packaged, making it difficult for the consumer to evaluate the quality of their surface and crumbliness.

It should be noted that the presence of a pronounced aroma of a fresh bakery product at the stage of staleness creates a negative impression and is associated by the overwhelming majority of respondents with the presence of synthetic flavors in the product. Also, undesirable characteristics of bakery products include the presence of other ingredients of synthetic origin and too bright packaging.

Based on the results of the first step of the research, the feasibility to improve the range of bakery products made from wheat flour was found, the requirements for finished products were grouped, and highly valued by the respondents characteristics were determined. All this allowed to make the description of the desirable finished product.

Development of a composition for a complex baking improver

To develop a complex baking improver for bakery products from premium wheat flour with a reduced salt content the medium-strong flour and selected food additives with the status of GRAS Official website of the US government US Foof & Drug (FAD, 2022) was used to crease the composition of the complex improver were used.

These additives included:

- moisture-containing additives: white clay, apple pectin (Zhang et al., 2021), dry wheat gluten, carboxymethyl cellulose (Ammar et al., 2020), maltodextin (Lauren et al., 2018);
- surface-active substance: phosphatide concentrate (Gómez et al., 2004);
- amylolytic enzymes: enzyme preparation Alfamalt 50 (to ensure the intensity of fermentation and volume of products) (Zhang et al., 2019) and enzyme preparation Novamil 1500 MG (to prolong the freshness of products) (Lambert-Meretei et al., 2010);
- a natural oxidizing agent: ascorbic acid.

Based on the results of trial baking of bakery products from premium flour, made with the addition of different components of a baking improver, Comprehensive Quality Scores were calculated (Table 1).

Table 1

Determination of the optimal addition of components in the baking improver by Comprehensive Quality score

Comprehensive Quality Scores					
Control	**Addition, % of the weight of flour**				
	Pharmaceutical white clay				
	0.5	1.0	1.5	2.0	2.5
88.6	89.4	89.8	90.6	91.2	91.2
	Enzyme preparation Novamil 1500 MG				
	0.004	0.008	0.012	0.016	1.25
88.6	88.8	89.8	90.6	91.8	91.3
	Enzyme preparation Alfamalt 50				
	0.005	0.010	0.015	0.020	0.025
88.6	89.8	90.4	91.6	92.7	92.7
	Dry wheat gluten				
	0.05	0.1	0.15	0.20	0.25
88.6	88.6	89.1	89.5	90.1	90.2
	Carboxymethylcellulose				
	0.005	0.010	0.015	0.020	0.025
88.6	88.6	89.4	90.2	91.7	91.8
	Apple pectin				
	0,01	0.02	0.03	0.04	0.05
88.6	88.6	89.1	89.5	90.1	90.2
	Maltodextrin				
	0.1	0.2	0,4	0.6	0.8
88.6	88.6	89.5	90.6	90.8	90.8
	Phosphatide concentrate				
	0.12	0.18	0.24	0.30	0.36
88.6	88.8	89.2	90.2	90.2	90.3
	Ascorbic acid				
	0.004	0.006	0.008	0.01	0.012
88.6	88.8	89.8	90.6	90.8	90.3

According to the Comprehensive Quality Scores, the rational dosages of the components in the baking improver, % of the weight of flour, are: white clay, 2.0%; enzyme preparation Novamil 1500 MG, 0.016%; enzyme preparation Alfamalt 50, 0.020%; dry wheat gluten, 0.2%, carboxymethylcellulose, 0.02%, apple pectin, 0.04%, maltodextrin, 0.4%, phosphatide concentrate, 0.24; ascorbic acid, 0.008% (Table 1). When formulating a baking improver, the found rational dosage of food additives and food ingredients was halved to form an improver recipe.

As a result of the research, a recipe for a complex baking improver (CBI), Mineral Fresh Plus, to intensify the technological process, improve consumer properties and lengthen the freshness of bakery products with low salt content of 0.5% was developed (Table 2).

Table 2

Recipe of complex baking improver (CBI) Mineral Freshness Plus

Additives	Raw materials, kg/ 100 kg of CBI
Pharmaceutical white clay	81.0
Enzyme preparation Novamil 1500 MG	0.3
Enzyme preparation Alfamalt 50	0.4
Dry wheat gluten	4.0
Carboxymethylcellulose	0.4
Apple pectin	0.8
Maltodextrin	8.0
Phosphatide concentrate	4.9
Ascorbic acid	0.2
Total	100

To determine the influence of CBI addition on the quality of finished bakery products with low salt content of 0.5%, laboratory baking with the dosage of CBI 1.0; 1.5; 2.0, and 2.5% by weight of flour were conducted (Table 3).

Table 3

Influence of a complex baking improver on the technological process and product quality

Characteristics	Control (no CBI)	CBI addition, % of the weight of flour			
		1.0	1.5	2.0	2.5
Sensory indicators					
Shape	Oblong, oval, not indistinct, the incisions are clear				
Crust color	Light	Light golden	Golden to brown		
Crust surface condition	Quite smooth, single small bubbles, barely noticeable small short cracks and explosions, glossy			Perfectly smooth, without bubbles and cracks, undermining, glossy	
Porosity structure	The pores are small, thin-walled and medium, distributed fairly evenly				
Aroma	Intensely pronounced, typical for bakery products				
Taste	Peculiar to bakery products, not salty	Intensely pronounced, characteristic of bakery products			
Specific volume, $cm^3/100$ g	328	340	352	368	376
Form stability, h/d	0.51	0.8	0.45	0.45	0.45
Porosity, %	72	82	84	88	90
Acidity, degree	1.2	1.8	2.0	2.0	2.2
Preservation of freshness	42	52	55	70	70

An increase of the specific volume of bakery products with low salt content of 0.5% is due to the introduction of amylolytic enzymes into the test system with CBI, which intensifies the fermentation process due to additional nutrition for yeast, and improved dough elasticity due to the action of phosphatides.

For further studies of the effect of the developed complex baking on the quality of finished bakery products with low content of salt, 0.5% by weight of flour, a dosage of CBI 2.0% by weight of flour was chosen.

Influence of the complex baking improver Mineral freshness Plus on the quality and preservation of freshness of a bakery products with a reduced salt content

The assimilation of bakery products largely depends on their taste and aroma. These indicators are formed during dough preparation and baking. The formation of compounds that affect taste and aroma depends on the composition of the recipe and the products of the interaction of sugars, carbonyl compounds with amino acids and proteins.

The main compounds that form the aroma of bakery products are carbonyl containing substances. A recognized method for studying the aroma of products is the determination of the content of carbonyl compounds (Table 4).

Table 4

Content of bisulfite-binding substances, mg-eq/100 g of a bakery product

Part of bakery product	Control (no CBI)	With CBI
after 4 hours of storage		
Pulp	8.6	15.4
Crust	24.3	28.2
after 24 hours of storage		
Pulp	7.1	13.,2
Crust	20.5	26.1
after 48 hours of storage		
Pulp	5.3	10.4
Crust	17.3	21.1
after 72 hours of storage		
Pulp	4.2	7.5
Crust	13.4	16.8

It was shown that when the developed complex baking improver was added to the dough, the content of carbonyl compounds in the crumb and crust of the bakery product increased by 1.6-4.2 times (Table 4). This is due to the fact that complex baking improver contains an amylolytic enzyme preparations and maltodextrin, which accelerate the process of dough fermentation, maturation of dough pieces and the accumulation of aromatic substances, as well as due to addition of carbonyl containing substances such as apple pectin and phosphatide concentrate.

An increase of the content of carbonyl compounds in finished products with an improver correlates with an enhancement of the crust color and the aroma of bread. Addition of complex baking improver does not change the traditional taste of finished products, despite the reduction in the salt content.

Analysis of the research results showed that the addition of the developed complex baking improver in bakery product has a positive effect on the preservation of the bakery product freshness and the subcrustal layer of bakery product after 72 hours of storage is thinner compared to the subcrustal layer of the control (Figure 1).

a b

Figure 1. The subcrustal layer of bakery product after 72 hours of storage: a, control (no CBI); b, with CBI Mineral Freshness Plus

After scanning and measuring of the thickness of the subcrustal layer of the bakery product, it was found that in the control sample the subcrustal layer after 7 hours of storage was 5.43 mm, and when using the Mineral Freshness Plus, it was 3.02 mm.

The bakery samples were stored unpackaged at a temperature of (20±2)°C. Microstructure of bakery products after 72 hours of storage were studied using scanning electron microscope at a magnification of 1000 times (Figure 2).

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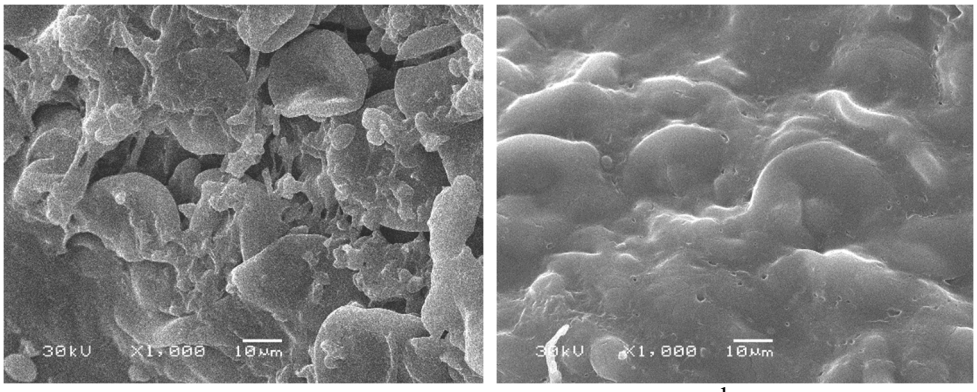


a b

Figure 2. Microstructure of bakery products after 72 hours of storage: a, control (no CBI); b, with CBI Mineral Freshness Plus

The results of the studies showed that in bakery products with the complex baking improver, the crumb of products consists of interspersed swollen and partially gelatinized starch grains, wrapped in a continuous mass of coagulated proteins, and only in some places air layers are visible (Figure 2b). In the control sample, on the contrary, the crumb was characterized by the presence of voids between the pores, which confirms the formation of the starch crystal structure and protein compaction during storage (Figure 2a).

When storing bakery products, the structural and mechanical properties of their crumbs are changed. Changes of the product crumb were determined by its deformation after 4 and 72 hours of storage using a penetrometer. Improving the deformation characteristics of bakery products when using the complex baking improver is due to the introduction of proteins from the CBI into the dough system, which strengthen the structure of the pulp of product because of strengthening of hydration ties and prevention starch from losing moisture during product storage (Table 5).

Table 5

Deformation of bread pulp during product storage

Samples of bread, time of storage	Type of deformation, units of device			Preservation of freshness, %
	total	plastic	elastic	
4 hours of storage				
Control (no additives)	82	53	29	
With CBI Mineral Freshness Plus	114	79	35	
72 hours of storage				
Control (no additives)	34	20	14	**41.5**
With CBI Mineral Freshness Plus	82	51	31	**71.9**

Apple pectin and maltodextrin present in the complex baking improver also possess the moisture-retaining capacity. Along with this, maltodextrin is a water-soluble hydrocolloid that increases the level of moisture retention and forms a three-dimensional network, which inhibits the interaction of gluten and starch resulting in slower retrogradation of starch. When maltogenic α-amylase is added to the dough, the rate of recrystallization of the amylopectin fraction of starch decreases, which delays its retrogradation. This process also prevents complex formation between the polar group of the phosphatide concentrate and the amylose fraction of the starch, which reduces the rate of retrogradation.

It is known that the addition of amylolytic enzymes to the dough increases the rate of fermentation and leads to the formation of a sufficient amount of sugars. Due to additional sugars, the porosity of bakery products becomes more thin-walled, homogeneous, which helps to improve their taste, crust color, and long-term preservation of freshness. The use of dextrins also improves the quality of bakery products and the duration of freshness.

Due to the fact that starch is degraded during the baking process and given that the complex baking improver includes maltogenic α-amylase, carboxymethylcellulose, apple pectin, and maltodextrin, it was advisable to study the change in the amount of dextrins in bakery products.

During baking of bakery products, starch is destroyed with the formation of dextrins. The total amount of dextrins increases by 65.2–75.6% when using CBI compared with the control due to the action of maltogenic α-amylase, which hydrolyzes starch to dextrins, and the direct introduction of maltodextrin (Table 6).

Table 6

Content of dextrins in bakery products

Bakery products	Content of dextrins by fractions, % of DW			Content of total dextrins
		erythro-dextrins	malto- and acro-dextrins	
Control (no CBI)	0.802	0.288	0.701	1.791
With CBI Mineral Freshness Plus	1.127	0.408	1.198	2.733

As a result of the the complex baking improver addition, an increase in low molecular weight dextrins, namely, maltodextrins and achrodextrins, is observed.

So, in the bakery product with CBI, the amount of low molecular weight dextrins increases by 2.5 times. In this regard, the process of staleness of bakery products slows down due to the formation of a three-dimensional network by low molecular weight dextrins, which prevents the interaction of gluten and starch and the release of moisture by starch.

Construction and analysis of the matrix "House of Quality" on the use of the developed improver in the production of a bakery product

In a number of international publications, teams of scientists and practitioners present the results of the successful use of the QFD methodology in order to improve products in accordance with the requirements and expectations of consumers (Lo et al., 2017; Mardar et al., 2016). The deployment of quality functions and the construction of the first-level "House of Quality" matrix ensures the implementation of the "voice of the client" regarding the expected improvements, establishes a close relationship between the wishes of consumers and the technical characteristics of products, determines the priority of their implementation (Chaudha et al., 2011). Therefore, at the next step, during the re-questioning of respondents and ranking the attributes of the experimental product model, we studied their significance for potential consumers (Shrivastava et al., 2016).

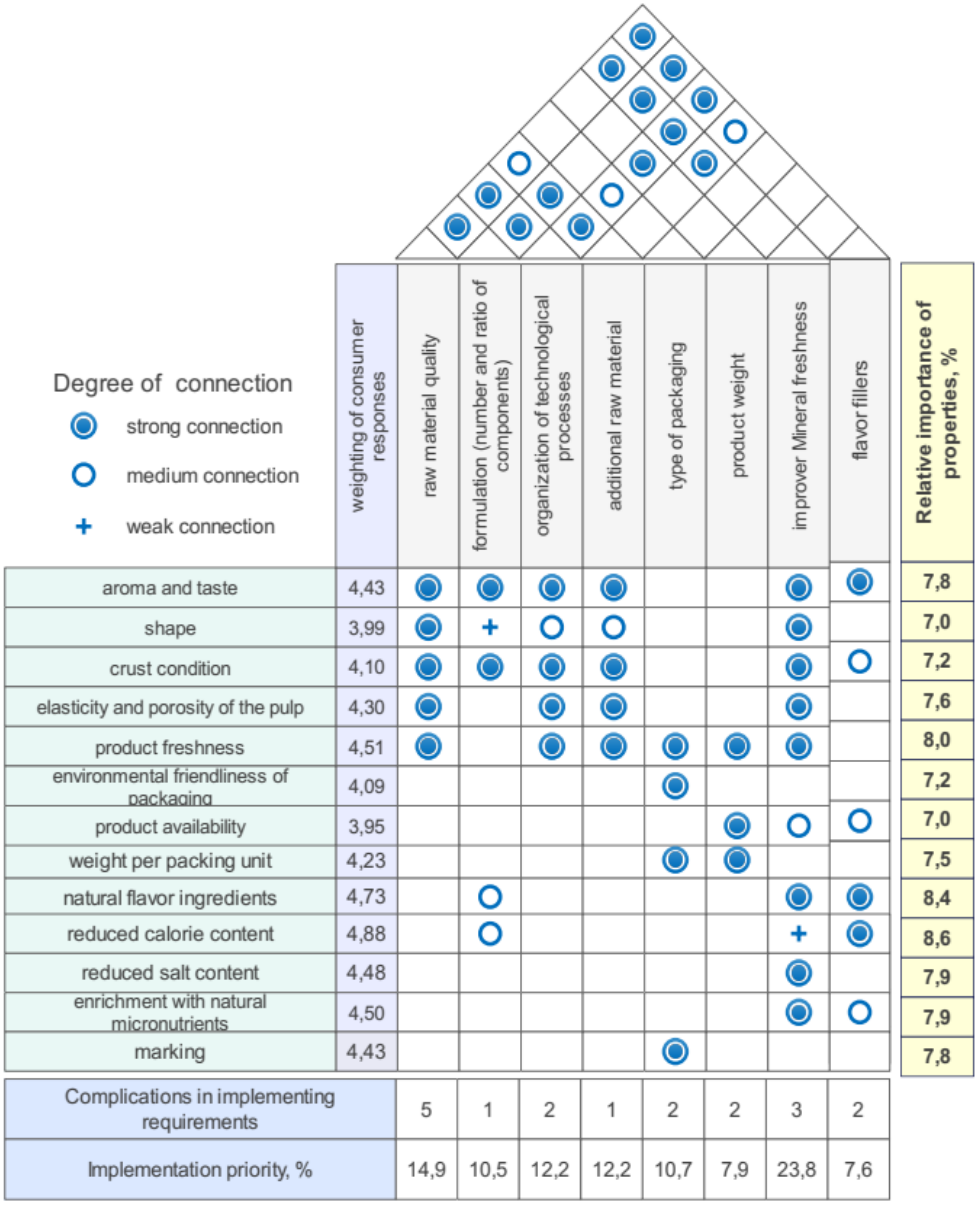
100 people were involved in the survey. The data obtained are given in the part of the requirements of the customers of the "House of Quality" relationship matrix in Figure 3.

Taking into account the importance for consumers of each of the specific requirements and focusing on their achievement at the maximum level, the relative weights of the properties are calculated. The ranking of requirements indicates that the most expected product characteristics for consumers are the reduction of calorie content of bakery products and the expansion of their range through the use of new flavoring ingredients. A group of properties that can be attributed to the unconscious characteristics of products and have a significant impact on the formation of consumer demands is the enrichment of products with natural micronutrients and the reduction of salt in their composition. The high values of the relative weight of such attributes as freshness (8%), taste and aroma during storage (7.8%), and product information shown in the product labeling (7.8%) indicate their decisive role in shaping the overall impression of product quality.

The attributes indicated by consumers are analyzed and their connection with the peculiarities of the formation of sensory and physico-chemical characteristics of finished products, the technical features of production, the complexity of implementing innovations in the production environment are found.

The analysis showed that one of the promising areas for achieving the improvements expected by consumers is the use of the complex baking improver Mineral Freshness Plus. The strong relationship between a number of customer requirements and CBI use determines the feasibility and high priority of this implementation (23.8%).

It should be noted that, according to the production workers, the complexity of implementing the requirements at the enterprise is rated at an average level, namely 3 points. This indicates that the use of the improver will not cause significant efforts to change the technological parameters of the process, special equipment readjustment and long-term training of personnel in its application.



	weighting of consumer responses	raw material quality	formulation (number and ratio of components)	organization of technological processes	additional raw material	type of packaging	product weight	improver Mineral freshness	flavor fillers	Relative importance of properties, %
aroma and taste	4,43	◉	◉	◉	◉			◉	◉	7,8
shape	3,99	◉	+	○	○			◉		7,0
crust condition	4,10	◉	◉	◉	◉			◉	○	7,2
elasticity and porosity of the pulp	4,30	◉		◉	◉			◉		7,6
product freshness	4,51	◉		◉	◉	◉	◉	◉		8,0
environmental friendliness of packaging	4,09					◉				7,2
product availability	3,95						◉	○	○	7,0
weight per packing unit	4,23					◉	◉			7,5
natural flavor ingredients	4,73		○					◉	◉	8,4
reduced calorie content	4,88		○					+	◉	8,6
reduced salt content	4,48							◉		7,9
enrichment with natural micronutrients	4,50							◉	○	7,9
marking	4,43					◉				7,8
Complications in implementing requirements		5	1	2	1	2	2	3	2	
Implementation priority, %		14,9	10,5	12,2	12,2	10,7	7,9	23,8	7,6	

Figure 3. The matrix "House of Quality" on the use of the developed improver in the production of a bakery product

So, based on the results of a survey of consumers using the "House of Quality" matrix, the ranking of product attributes was carried out and their dependence on the technical characteristics of finished products was found, measures were identified to achieve the most significant needs for customers. The priority of using in the bakery technology developed the complex baking improver Mineral Freshness Plus was proved, which will ensure the

achievement of a number of conscious and unconscious needs of consumers, and, accordingly, the formation of high customer satisfaction.

Conclusions

1. A sociological study identified the criteria for the quality of bakery products, the improvement of which is expected by consumers: reducing the calorie content of products, enriching products with micronutrients of natural origin, and reducing the salt content in products. Undesirable characteristics of products by consumers were noted by the presence in the composition of ingredients of synthetic origin and the rapid loss of freshness by products.

2. For the production of a bakery product that meets the expectations of the consumer, the application of the principles of lean-production is provided, which consists in reducing technological losses and costs in the production and storage of products and is achieved by using complex baking improvers.

3. A recipe for the complex baking improver Mineral Fresh Plus has been developed, which is designed to intensify the technological process of production, improve consumer properties and time for keeping the freshness of bakery products with low salt content 0.5%. The composition of the improver includes food additives with GRAS status, that is, safe.

4. In the manufacturing of a bakery product, in the recipe of which the salt content is 0.5% of the weight of flour, it is advisable to use the developed improver Mineral Freshness Plus in the amount of 2.0% by weight of flour. This helps to improve the quality of products and does not change the traditional taste of finished products, despite the reduction of salt content.

5. The use of the developed complex baking improver Mineral Fresh Plus prolongs the time for freshness preservation by bakery products. This is confirmed by the greater content of dextrins in the product with the improver, by 65.2-75.6%, compared to the control, the thinner subcrustal layer after 72 hours of product storage, and changes in the structure of the pulp, consisting of interspersed swollen and partially gelatinized starch grains, which are wrapped with a continuous mass of coagulated proteins.

6. The construction and analysis of the "House of Quality" matrix confirmed that the use of the complex baking improver Mineral Fresh Plus in the manufacturing of bakery products ensures the achievements of high consumer satisfaction.

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References

Ammar Al-F., Siddeeg A., Aqlan F.M., Howladar S. M., Refai M. Y., Afifi M., Ali H.A., Hajjar D., Sulamain M. G. M., Chamba M. V. M., Kimani B. G., Salehh A., Baeshenc M. (2020), Shelf life extension of wheat bread by alhydwan flour and

carboxymethylcellulose and improvement of their quality characteristics, dough rheological and microstructure, *International Journal of Biological Macromolecules*, 156, pp. 851–857, DOI: 10.1016/j.ijbiomac.2020.04.023

Bilyk O., Bondarenko Y., Kochubei-Lytvynenko O., Khalikova E., Fain A. (2019), Studying the effect of the integrated bread baking improver "Mineral Freshness Super" on consumer properties of wheat bread, *Eastern-European Journal of Enterprise Technologies*, *2*(11(98), pp. 65–72, DOI: 10.15587/1729-4061.2019.162671

Chaudha A., Jain R., Singh A. R., Mishra P. K. (2011), Integration of Kano's Model into quality function deployment (QFD), *The International Journal of Advanced Manufacturing Technology, 53,* pp. 689-698, Available at: https://www.semanticscholar.org/paper/Integration-of-Kano%E2%80%99s-Model-into-quality-function-Chaudha-Jain/7e3fd3688a9a79262a56392b8dccd37c6b1b1435

Drobot V., Yurchak V., Bilyk O., Bondarenko Y., Gryshchenko A. (2015), *Technochemical control of raw materials and bakery and pasta*, Condor, Kyiv.

FAD (2022), *US Foof & Drug administration. Generally Recognized as Safe (GRAS)*, Available at: https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras

Gómez M., Silvia del Real, Rosell C. M., Ronda F., Blanco C.A., Caballero P.A. (2004), Functionality of different emulsifiers on the performance of breadmaking and wheat bread quality, *European Food Research and Technology*, 219, pp. 145–150, DOI: 10.1007/s00217-004-0937-y

Hinkle D. E., Wiersma W., Jurs S. G. (2003), *Applied statistics for the behavioral sciences*, Mass: Houghton Mifflin, Boston, DOI: 10.1016/B978-0-12-824135-6.00030-1

Lambert-Meretei A., Szendrei E., Nogula-Nagy M., Fekete A. Methods to evaluate the effects of bread improver additive on bread crumb texture properties, *Acta Alimentaria*, 2010, 39(2), pp. 180–191, DOI: 10.1556/aalim.39.2010.2.10

Lo S. M., Shen H., Chen J. C. (2017), An integrated approach to project management using the Kano model and QFD: an empirical case study, *Total Quality Management & Business Excellence*, 28, pp. 1584–1608, DOI: 10.1080/14783363.2016.1151780

Mardar M., Zhygunov D., Znachek R. (2016), QFD methodology to develop a new healthconducive grain product, *Eastern-European Journal of Enterprise Technologies*, 2/11(80), pp. 15–20, DOI: 10.15587/1729-4061.2016.65725

Mezur G.H. (2017), *Transitioning from JIS Q 9025 to ISO 16355. 23-rd International QFD Symposium, ISQFD 2017*, Tokyo, pp. 20–42, Available online: https://static1.squarespace.com/static/5eb315d2b0e6914ba0419e47/t/5eb9f5795f22c75dffa4fbb8/1589245309034/mazur_2017_transitioning_from_jis_9025_to_iso_16355.pdf

Petrusha O., Niemirich A. (2016), Assessment of color of meat using the method of computer colorimetry, *Eureka: Life Sciences*, 3, pp. 3–7, DOI:10.21303/2504-5695.2016.00141

Shrivastava P. (2016), House of quality: An effective approach to achieve customer satisfaction and business growth in industries, *International Journal of Science and Research*, 5(9), pp. 1365–1371, Avalable at: https://www.ijsr.net/archive/v5i9/ART20161787.pdf

Tebben L., Shen Y., Li Y., (2018), Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality, *Trends in Food Science & Technology*, 81, pp. 10–24, DOI: 10.1016/j.tifs.2018.08.015

Verheyen C., Albrecht A., Elgeti D., Jekle M., Becker T. (2015), Impact of gas formation kinetics on dough development and bread quality, *Food Research International*, 76(3), pp. 860–866, DOI: 10.1016/j.foodres.2015.08.013

Zhang L., Li Z., Qiao Y., Zhang Y., Zheng W., Zhao Y., Huang Y., Cui Z. (2019), Improvement of the quality and shelf life of wheat bread by a maltohexaose producing α-amylase, *Journal of Cereal Science*, 87, pp. 165–171, DOI: 10.1016/j.jcs.2019.03.018

Zhang X., Li J., Zhao J., Mu M., Jia F., Wang Q., Liang Y., Wang J. (2021), Aggregative and structural properties of wheat gluten induced by pectin, *Journal of Cereal Science*, 100, pp. 103247, DOI: 10.1016/j.jcs.2021.103247

Zhu F., Sakulnak R., Wang, S. (2016), Effect of black tea on antioxidant, textural, and sensory properties of Chinese steamed bread, *Food Chemistry*, 194, pp. 1217–1223, DOI: 10.1016/j.foodchem.2015.08.110