ISSN-L 2664-9969; E-ISSN 2706-5448

UDC 664.661.2:005.591.6
DOI: 10.15587/2706-5448.2025.326217

**Olga Gorach,**
**Oksana Dzyundzya,**
**Nataly Novikova,**
**Nina Rezvykh**

# DEVELOPMENT OF GLUTEN-FREE PRODUCTS TECHNOLOGY USING FLAX FLOUR

*The object of research is the production of gluten-free products. 4 samples of dough and finished products with different ratios of corn, rice and flax flour were studied. Organoleptic analysis showed that compared to the assessment of the control sample (4.7 points), sample No. 3 (4.9 points) with a ratio of corn, rice and flax flour 60:20:20 (experiment 3) is rational.*

*Europe and other countries of the world are showing increased interest in the implementation of innovative technologies for the production of special and functional food products. Therefore, the current task is to introduce new technologies and functional formulations into production, taking into account the needs of today, aimed at preserving and increasing the biological value of food products.*

*It was found that the physical and chemical indicators of the finished gluten-free bakery product in terms of porosity, acidity, and crumb moisture exceed the control sample. The results of the studies show that an increase in the amount of rice and flax flour leads to an increase in dough porosity by 2 % compared to the control sample. The acidity of the dough increased from 2.70 degrees to 3.1 degrees and exceeded the control sample by 0.3 degrees. The dimensional stability is almost the same as that of the control sample. The specific volume compared to the control increased by 20 $cm^3$/100 g and amounted to 268 $cm^3$/100 g.*

*Based on the research results, a basic technological scheme of production has been developed and substantiated, parameters and modes of the technological process have been given. The possibility of creating functional technologies and recipes not only with high sensory, physicochemical quality indicators, but also with high nutritional value has been confirmed. This is achieved due to the content of vegetable proteins, unsaturated fatty acids and dietary fiber, minerals and vitamins in flax flour, which have a positive effect on lipid metabolism.*

***Keywords:*** *corn flour, rice flour, flax flour, modeling compositions, gluten-free bakery products.*

*Received: 07.01.2025*
*Received in revised form: 02.03.2025*
*Accepted: 24.03.2025*
*Published: 07.04.2025*



***How to cite***

*Gorach, O., Dzyundzya, O., Novikova, N., Rezvykh, N. (2025). Development of gluten-free products technology using flax flour. Technology Audit and Production Reserves, 2 (3 (82)), 58–63. https://doi.org/10.15587/2706-5448.2025.326217*

## 1. Introduction

More and more countries around the world are showing interest in implementing innovative technologies for the production of special and functional food products. Consumers prefer healthy eating, choosing potentially beneficial products and ingredients for health. Based on extensive world experience, it is possible to conclude that the creation of innovative technologies for functional formulations is possible thanks to the work of domestic scientists and industry specialists involved in the development and production of healthy food products [1].

It is known that the basis of treatment for patients with gluten intolerance [2] is a diet aimed at completely eliminating from the diet all gluten-containing products [3, 4] containing wheat, rye, barley, oats, as well as hybrids of these cereals [5]. Ukraine has its own, annually renewed plant potential, which allows it to be used in the food industry to create functional recipes [6], namely for the production of gluten-free products [7, 8].

It is known that existing gluten-free production technologies are associated with the replacement of traditional wheat and rye flour with gluten-free ones, namely corn, buckwheat, rice, amaranth, etc. [9, 10]. Such technological solutions are aimed at producing new generation food products for certain population groups who voluntarily or due to autoimmune diseases choose a gluten-free diet [11].

However, in the production of gluten-free products, there is a problem of obtaining the correct texture, which is associated with the absence of the main structure-forming component – gluten [12]. Analyzing existing technologies [13, 14], it was found that bread made from gluten-free flour has a mild taste and a pale crust. Therefore, there is a need to introduce additional ingredients into the recipe composition to improve sensory and structural and mechanical properties. For this purpose, studies were conducted to develop a gluten-free dough recipe using a functional ingredient, namely flax flour.

*The aim of research is* to scientifically substantiate the feasibility of adding flaxseed flour to the recipe for gluten-free baking and determine the optimal ratio of corn, rice, and flaxseed flour in the production technology.

## 2. Materials and Methods

*The object of research* is the production of gluten-free products. For the study, 3 experimental samples with different dosages of corn, rice and flax flour were selected:

– the control was manufactured in accordance with the requirements of the current regulatory and technical documentation for organoleptic, physicochemical and microbiological indicators according to DSTU 7517:2014 "Bread from wheat flour. General technical conditions" [15]. The preparation recipe includes the following components: premium wheat flour, granulated sugar, sunflower oil, table salt, pressed yeast, water;
– sample No. 1 – 80 % corn, 10 % rice flour, 10 % flax flour;
– sample No. 2 – 70 % corn, 15 % rice flour, 15 % flax flour;
– sample No. 3 – 60 % corn, 20 % rice flour, 20 % flax flour.

All model compositions were compared with the control version made of wheat flour TM "Khutorok" (Ukraine). Baked samples were examined for organoleptic and physicochemical parameters.

The subject of the study is the technology of gluten-free products. The hypothesis of the study is the possibility of ensuring high quality and increased biological value of gluten-free products by determining the rational ratio of corn, rice and flax flour. The introduction of flax flour into the recipe will allow, due to its moisture-retaining and gelling properties, to improve the rheological properties of gluten-free dough and finished bakery products.

The research selected wheat flour of the highest grade TM "Khutorok", manufactured in accordance with DSTU 46.004-99 "Wheat flour". Finely ground corn flour TM "Skvyryanka" (Ukraine), obtained from corn grain, purified from gluten-containing impurities on a modern optical separator Sortex of the Swiss company "Buhler", recommended for feeding people with special needs and children, manufactured in accordance with GOST 14176-69 "Corn flour. Technical conditions". Rice flour TM "Sto pudiv" (Ukraine) is manufactured in accordance with TU 15.6-00952737-006-2002 "Rice flour. Technical conditions". Flax flour manufactured by FOP Mekh Yu. V. (Ukraine). White sugar is manufactured in accordance with DSTU 4623:2006 "White sugar. Technical conditions". Sunflower oil is manufactured in accordance with DSTU 4492:2017 "Sunflower oil. Technical conditions". DSTU 3583-2015 "Table salt. General technical conditions", DSTU 4812:2007 "Pressed baker's yeast. Technical conditions", DSTU 7525:2014 "Drinking water. Requirements and methods of quality control".

Laboratory studies were conducted in the laboratory of quality control and food safety of the Department of Food Technologies of the Kherson State Agrarian and Economic University.

*The dough was prepared in a safe way.* Control of technological process parameters and product quality indicators was carried out according to generally accepted methods [16].

The organoleptic evaluation of bakery products was carried out on a 5-point scale. When developing the recipe for gluten-free bakery products, the organoleptic evaluation was carried out by a tasting commission consisting of 10 people.

*Acidity* is determined by the presence of lactic and acetic acids in the product, which contribute to the formation of fermentation processes in the dough and during its subsequent baking [16].

To study the ability of dough to ferment, a method based on the rate of rise of a dough ball was used. The activity of yeast cells was determined by an accelerated method [16]. For this, dough was kneaded in laboratory conditions with different ratios of gluten-free flour according to the studied model samples: experiment No. 1 – 80:10:10; experiment No. 2 – 70:15:15; experiment No. 3 – 60:20:20, wheat flour was used as a control.

## 3. Results and Discussion

Based on theoretical and experimental studies on the development of functional gluten-free dough, corn and rice flour were selected. These flour varieties are not inferior to wheat flour in terms of chemical composition, biological and energy value, which is traditionally used in the food industry. Flax flour was selected as a functional ingredient, which is characterized by high biological value and functional properties and contains polyunsaturated fatty acids (PUFA), namely omega-3, soluble dietary fiber, lignans, proteins and carbohydrates [17, 18]. Flax seeds contain 53 % α-linolenic acid (ALA), 17 % linoleic acid (LA), 19 % oleic acid, 3 % stearic acid and 5 % palmitic acid, which indicates an excellent ratio of fatty acids [19]. Using flaxseed flour to produce functional gluten-free baked goods will enrich the finished product with fatty acid composition, amino acids, vitamins, minerals, etc.

To determine the rational ratio of corn, rice, and flax flour, a study was conducted on gluten-free raw materials and their ability to form dough with certain structural and mechanical properties and ensure high quality of finished products.

The first stage was to study the strength of flour, since this is one of the main properties that affects the quality of the finished product. The technological properties of flour allow to predict the behavior of the dough, so it is important to establish the main properties of gluten-free raw materials, which will allow to predict the technological process of production. Table 1 shows the technological properties of the studied types of gluten-free flour.

Analyzing the data presented in Table 1, it is possible to conclude that the moisture absorption capacity (MAC) and moisture holding capacity (MHC) of flax flour are almost twice as high as those of rice and corn. Thus, the MAC of flax flour is on average 261 %, while for rice flour this indicator is 121.6 %, and for corn flour – 117 %. The moisture-holding capacity of flax flour is almost twice as high and averages 308 %, while for rice flour this figure is 142 %, and for corn flour – 166 %. The swelling ability, for rice and corn flour, this figure is almost the same, but compared to flax flour, it is half as low. The fat absorption capacity (FAC) for all studied types of gluten-free raw materials is almost the same, which is consistent with other studies of gluten-free dough [20].

Therefore, the determined technological properties will affect the moisture content, rheological properties of semi-finished dough products and finished bakery products. It was found that the technological indicators of rice and corn flour are almost at the same level. Therefore, taking into account the data obtained, corn flour was chosen as the basis, to which different amounts of rice and flax flour were added. Thus, when developing the technology for the production of gluten-free bakery products, the studied model compositions with different proportional ratios of gluten-free flour were developed, taking into account the technological properties of the studied raw materials.

The research results of the physicochemical characteristics of model compositions for determining the baking properties of gluten-free dough are given in Table 2.

Analyzing the data (Table 2), it is possible to conclude that increasing the dosage of rice and flax flour leads to a change in physicochemical properties, which is explained by the high content of unsaturated fatty acids in rice and flax flour. Thus, the mass fraction of moisture in the studied samples is approximately the same, but in relation to the control sample of wheat dough is higher by 6 %. This can be explained by the fact that the content of vegetable protein in the amount of 20 g/100 g and soluble fiber, which is contained in flax seeds in the amount of 10 g/100 g, provide its binding and gelling properties. These properties are necessary, since they affect the quality characteristics of gluten-free bakery products, which is confirmed by previous studies (Table 1) [21, 22].

**Table 1**

Technological properties of the studied types of gluten-free flour

| No. | Flour Name | Moisture absorption capacity (MAC), % | Fat absorption capacity (FA), % | Swelling ability, % | Moisture holding capacity (MHC), % |
|---|---|---|---|---|---|
| 1 | Rice flour | 121.6±12.8 | 105.6±9.1 | 146±5.4 | 142±3.1 |
| 2 | Corn flour | 117±11.7 | 103.6±5.1 | 156±3.2 | 166±4.4 |
| 3 | Flaxseed flour | 261±13.9 | 109.1±9.7 | 296±14.1 | 308±6.8 |

 ISSN-L 2664-9969; E-ISSN 2706-5448

Table 2

Physico-chemical characteristics of the dough of the studied model samples

| Quality indicators Moisture mass fraction, % | Ratio of corn, rice and flax flour, % | | | Control |
|---|---|---|---|---|
| | Experiment 1 | Experiment 2 | Experiment 3 | wheat flour, h/g |
| | 80:10:10 | 70:15:15 | 60:20:20 | |
| Dough acidity, initial degree | 52.0 | 52.1 | 52.1 | 46.0 |
| Dough acidity, final degree | 1.0±0.1 | 1.1±0.1 | 1.2±0.1 | 1.5±0.1 |
| Duration of proofing, min | 1.2±0.1 | 1.5±0.1 | 1.9±0.1 | 2.5±0.1 |
| Dough specific volume, $cm^3$/100 g | 56 | 56 | 55 | 55 |
| Gas formation in 60 min of fermentation, $cm^3$/100 g | 2.66±0.2 | 2.56±0.2 | 2.51±0.2 | 2.70±0.2 |
| Quality indicators | 230 | 264 | 282 | 280 |

The acidity of the studied model dough compositions allows to conclude that at the beginning of the process there is a gradual increase in the degree of acidity in all test dough samples, which indicates yeast activity. The highest acidity of the dough was observed in the model composition (experiment 3) and was 1.9±0.1 degrees, which is 0.7±0.1 degrees more compared to the model composition (experiment 1), but 0.6±0.1 degrees less than in the control sample, which is explained by the different acidity of the raw materials.

Analyzing the results of the study of specific volume, the dynamics of changes in the volume of control and experimental dough samples were established, namely, a decrease in the specific volume of dough from the amount of added flax flour. A particular decrease in the specific volume of dough is noted when flax flour is increased to 20 %. Thus, the value of this indicator in experiment 1 was 2.66±0.2 $cm^3$/100 g, and in the model sample (experiment 3) this value decreased by 1.5 $cm^3$/100 g and was 2.51±0.2 $cm^3$/100 g and less than the control sample by 1.9±0.2 $cm^3$/100 g. The obtained studies are consistent with the data of the authors [23, 24]. Thus, the obtained experimental data indicate a direct dependence of the specific volume of experimental dough samples on the amount of flax flour. The obtained data must be taken into account when justifying the amount of flax and rice flour for the manufacture of gluten-free bakery products.

It was found that increasing the amount of flax and rice flour has a positive effect on gas formation during 60 min of fermentation, and this indicator in the model composition (experiment 3) exceeds the control by 2 $cm^3$/100 g and is 282 $cm^3$/100 g. It was experimentally established that increasing the amount of flax flour allows it to be used for partial replacement of gluten-free flour in the technology of manufacturing bakery products.

The next stage of research in the development of gluten-free bakery products was the study of the ability of dough to ferment using different proportions of gluten-free flour. It is known that the fermentation process is one of the most important processes that affects the quality of bakery products [23, 24]. As a result, the products of the vital activity of yeast and lactic acid bacteria accumulate, namely alcohol, carbon dioxide, organic acids and other substances that form the structure, taste and aroma of bakery products. Due to the released carbon dioxide, the dough becomes loose. The fermentation process significantly affects the processes of swelling, peptization, dough rheology and enzymatic hydrolysis [25, 26].

Based on the conducted experimental studies, it was found that the best lifting force is possessed by gluten-free dough with the addition of 20 % rice and flax flour (experiment 3), the time of rising of the dough ball was 3.04 min. The lowest lifting force is possessed by dough with the addition of 10 % rice and flax flour (experiment 1), the time of rising of the dough ball was 5.65 min. Therefore, an increase in the amount of rice and flax flour has a positive effect on the lifting force of the dough. This is explained by the favorable nutrient medium for yeast cells due to additional water-soluble proteins and sugars. These substances are contained in rice and flax flour, which is confirmed by previous studies given in Table 1. In connection with the above, the best physicochemical properties and the best lifting force were possessed by model sample 3 with the addition of 20 % rice and 20 % flax flour.

Research on the baking properties of gluten-free bakery products. Further research was aimed at developing the technology and recipe for gluten-free bakery products. To do this, it is possible to determine the effect of the dosage of rice and corn flour of the studied model compositions on the quality of bread. The baking properties of flour can be characterized by bread quality indicators. For this, experimental laboratory samples were baked and the effect of different ratios of gluten-free flour of the studied model compositions on the quality of bread was studied [27, 28]. In the recipe for gluten-free bakery products, egg melange was used to replace gluten and enrich the dough with vegetable protein and nutrients. This allows to improve the organoleptic, physicochemical and structural and mechanical properties. Egg melange is one of the safest and most reliable compared to other correctors, and is also available for use in the food industry [29–33].

When studying the organoleptic indicators of the studied model samples of bakery products, the calculation was carried out on a 5-point scale, assessing: taste, smell, color, shape, surface and appearance.

The scale of assessments according to the obtained indirect data is distributed as follows: 5.0–4.5 – excellent; 4.4–3.7 – good; 3.6–2.6 – satisfactory; less than 2.6 – bad.

The results of the sensory analysis are given in Table 3. Based on the sensory assessment of the main organoleptic indicators, a rational recipe ratio of ingredients was established.

Table 3

Sensory analysis of the studied bakery products

| Experiment variants | Taste, smell | Shape | Color | Surface | Appearance | Average score |
|---|---|---|---|---|---|---|
| | The Value of the Quality Indicator | | | | | |
| | 0.3 | 0.1 | 0.2 | 0.2 | 0.2 | |
| Experiment 1 | 3.7 | 5.0 | 4.4 | 4.0 | 4.0 | 4.2 |
| Experiment 2 | 4.1 | 5.0 | 4.5 | 4.7 | 4.0 | 4.5 |
| Experiment 3 | 5.0 | 5.0 | 5.0 | 4.8 | 5.0 | 4.9 |
| Control | 4.0 | 4.8 | 5.0 | 5.0 | 5.0 | 4.7 |

Sensory analysis (Table 3) confirmed the high organoleptic indicators of the studied samples, which indicates that the combination of the proposed ingredients improves the characteristics of the dough while maintaining the indicators at a high level. As a result of the sensory analysis of the indicators, it was found that the consistency of the bread improved after increasing the amount of rice and flax flour in an amount of 10 to 20 %. This is achieved due to the viscous and gel-forming properties of rice and flax flour, as well as water-soluble carbohydrates and insoluble fibers contained in flax flour. The experimental sample with the addition of 20 % rice and flax flour had a more saturated, harmonious taste, even more than the control sample. The sample with the addition of 10 % rice and flax flour had a pronounced taste and smell of corn flour.

The organoleptic evaluation of the quality indicators of the experimental samples of gluten-free products is presented in Fig. 1. The profilogram shows the results of the sensory evaluation according to various descriptors of samples with different ratios of corn, rice and flax flour.

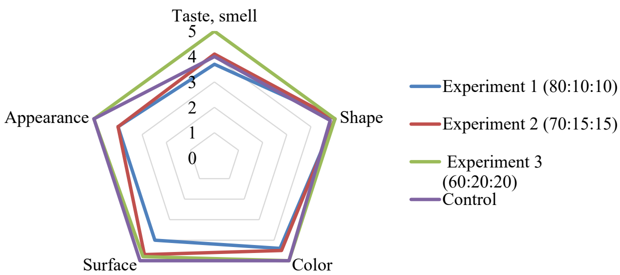


**Fig. 1.** Sensory analysis profile of gluten-free bakery products

According to the results of sensory analysis of bread samples with different ratios of ingredients (Fig. 1), it was found that with an increase in the dosage of rice and flax flour, sensory indicators deteriorate. Tasters noted that when rice and flax flour were increased by more than 20 %, the product had an unattractive appearance and taste indicators. Sample No. 3 was chosen as the best, where the ratio of corn : rice : flax flour is 60 %:20 %:20 %.

After sensory analysis, the samples were examined for physicochemical indicators (Table 4).

Analyzing the data (Table 4), it is possible to conclude that in the studied model compositions, an increase in the amount of rice and flax flour leads to an increase in the porosity of gluten-free bakery products.

In the model composition (experiment 1), the value of this indicator was 67.0 ± 2.0 %, and in the model composition (experiment 3) – 76.0 ± 2.0. Thus, there was an increase of 6 %, which exceeds the control by 2 %. This is explained by the presence of water-soluble proteins and sugars in rice and flax flour, which are a favorable nutrient medium for yeast cells.

The acidity of gluten-free baking also increased from 2.70 degrees (experiment 1) to 3.1 degrees (experiment 3) and exceeded the control sample by 0.2 degrees. This is explained by the fact that rice and flax flour contain sugar and proteins, which positively affect the development of yeast cells in the dough (Table 2) [34].

**Table 4**

Physical and chemical indicators of gluten-free bakery products

| Physicochemical parameters | Experiment options | | | |
|---|---|---|---|---|
| | Control | 1 | 2 | 3 |
| Porosity, % | 74.0 ± 2.0 | 67.0 ± 2.0 | 73.0 ± 2.0 | 76.0 ± 2.0 |
| Acidity, deg | 2.9 ± 0.2 | 2.7 ± 0.2 | 2.9 ± 0.2 | 3.1 ± 0.2 |
| Ability to keep in shape | 0.54 | 0.52 | 0.55 | 0.56 |
| Specific volume, $cm^3$/100 g | 248 | 252 | 259 | 268 |
| Crumb moisture after 48 hours of storage, % | 42.10 | 43.40 | 43.90 | 44.10 |

The dimensional stability of the studied samples was practically the same, the specific volume also had high qualitative indicators and increased compared to the control variant by 20 $cm^3$/100 g and amounted to (experiment 3) 268 $cm^3$/100 g. Characterizing the moisture content of the crumb after 48 hours of storage, it should be noted that an increase in the amount of rice and flax flour allows to maintain the moisture content of the finished product by an average of 1–2 %. Thus, when adding rice and flax flour, an additional amount of insoluble fibers is introduced. Due to their structure, they have the ability to bind free moisture, which is held more firmly by them. Thus, when baking, a larger amount of bound moisture remains in the product. The obtained data are confirmed by previous studies of gluten-free raw materials, which are given in Table 1.

Thus, based on the theoretical and experimental studies conducted, it can be concluded that the rational recipe for experimental sample No. 3 is a recipe of corn, rice and flax flour in a ratio of 60:20:20. Table 5 shows the developed recipe for gluten-free bakery products.

**Table 5**

Gluten-free bakery recipe

| No. | Raw material name | Raw material consumption rates, % | Consumption rates per 1 kg, g | Consumption rates per 100 kg, kg |
|---|---|---|---|---|
| 1 | Corn flour | 29.4 | 294.0 | 29.40 |
| 2 | Rice flour | 9.8 | 98.0 | 9.80 |
| 3 | Flax flour | 9.8 | 98.0 | 9.80 |
| 4 | Pressed yeast | 2.5 | 25.0 | 2.50 |
| 5 | Table salt | 0.4 | 4.0 | 0.40 |
| 6 | Sugar | 12.7 | 127.0 | 12.70 |
| 7 | Egg melange | 6.4 | 64.0 | 6.40 |
| 8 | Sunflower oil | 4.9 | 49.0 | 4.90 |
| 9 | Water | 24.1 | 241.0 | 24.10 |
| Output | | 100 | 1000 | 100 |

When developing the technology for the production of gluten-free bakery products, mixing was carried out on laboratory equipment. To analyze consumer properties, laboratory baking of the studied samples was carried out according to the developed recipe in the conditions of the Department of Food Production Technology of the Kherson State Agrarian and Economic University.

The semi-finished products of the studied samples were baked in a steamless manner. The duration of fermentation was 60 minutes at a temperature of 30–40 °C and a relative humidity of air in a thermostat of 75 %. After the end of the fermentation stage, the dough was kneaded with subsequent proofing of the semi-finished products at $t$ = 35–40 °C for 60 minutes. The studied samples were baked in a laboratory oven at a temperature of 180–215 °C for 40–50 minutes.

Table 6 shows the parameters and technological modes of the technological process.

The general technological scheme for preparing yeast dough is based on the preparation of the main and additional raw materials. The method of making the dough involves mixing all the ingredients according to the recipe at the same time. The basic technological scheme of production involves the following stages of production of the finished product:

1) mixing water, sugar, salt, yeast until smooth; adding melange to the liquid mass, as well as corn, rice and flax flour;

2) the mass is mixed until the ingredients are combined, after which sunflower oil is added; then the mass is kneaded to a homogeneous thick dough that does not stick to the hands;

3) then the fermentation process takes place for 60 minutes;

4) after the fermentation stage is completed, the dough is rolled out, shaped, allowed to rise and baked at 180–215 °C for 45–60 minutes.

**Table 6**

Parameters and modes of the technological process for preparing gluten-free bakery products

| Technological process | Regime |
|---|---|
| Fermentation time, min | 60 |
| Temperature, °C | 30–40 |
| Dough proofing, min | 2–3 |
| Resting of semi-finished products at $t$=35–40 °C, min | 60 |
| Baking temperature, °C | 180–215 |
| Baking time, min | 45–60 |

The proposed technology does not involve significant differences in the stages of production compared to the classical ones. The technological scheme for the production of gluten-free bakery products allows to obtain a product that, in terms of physicochemical and organoleptic indicators, practically does not differ from the traditional one in quality. It should be noted that corn, rice and flax flour are added at one stage of production and do not require additional changes in the production technology, and therefore, additional material costs.

*Impact of martial law conditions.* Under martial law conditions in Ukraine, manufacturers are forced to respond to new challenges. These changes are caused by negative factors associated with the increase in the cost of raw materials, energy sources and fuels and lubricants, disruption of logistics flows, etc. Restrictions are also created to meet the needs of consumers with special needs, taking into account global trends in the formation of an assortment of new types of products.

*Prospects for further research.* Promising areas for further research include monitoring in the baking industry. This will strengthen the position of manufacturers and expand the range of specialty bakery products. This will also help meet the needs of people with special dietary needs related to gluten intolerance.

## 4. Conclusions

The rational ratio of corn, rice and flax flour was determined, it was found that the most rational ratio of corn, rice and flax flour is 60:20:20 (experiment 3).

The physicochemical parameters of gluten-free dough were studied. It was found that an increase in the amount of rice and flax flour leads to an increase in dough porosity by 2 % (experiment 3). The acidity of gluten-free bakery products also increased from 2.70 degrees (experiment 1) to 3.1 degrees (experiment 3) and exceeded the control sample by 0.2 degrees. The dimensional stability of the studied samples was practically the same, the specific volume also had high quality indicators and increased compared to the control variant by 20 cm$^3$/100 g and amounted to (experiment 3) 268 cm$^3$/100 g.

The organoleptic and physicochemical parameters of the finished gluten-free product were determined. It was found that the use of corn, rice and flax flour to create gluten-free bakery products is appropriate, since the average score according to the sensory evaluation corresponded to the control sample.

## Conflict of interest

The authors declare that they have no conflict of interest, financial, personal, authorial or otherwise, in this study that could influence the research and its results presented in this article.

## Financing

The study was conducted without financial support.

## Data availability

The manuscript has no linked data.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the presented work.

### References

1. Marciniak-Łukasiak, K., Dłużewska, E. (2018). Pseudozboża w żywności bezglutenowej. *Przemysł Spożywczy, 72 (9),* 46–50.
2. Cappelli, A., Oliva, N., Cini, E. (2020). A systematic review of gluten-free dough and bread: Dough rheology, bread characteristics, and improvement strategies. *Applied Sciences, 10 (18),* 6559. https://doi.org/10.3390/app10186559
3. Skendi, A., Papageorgiou, M., Varzakas, T. (2021). High protein substitutes for gluten in gluten-free bread. *Foods, 10 (9),* 1997. https://doi.org/10.3390/foods10091997
4. Culetu, A., Duta, D. E., Papageorgiou, M., Varzakas, T. (2021). The role of hydrocolloids in gluten-free bread and pasta; rheology, characteristics, staling and glycemic index. *Foods, 10 (12),* 3121. https://doi.org/10.3390/foods10123121
5. Guimaraes, R. M., Pimentel, T. C., De Rezende, T. A. M., Silva, J. S., Falcao, H. G., Ida, E. I. et al. (2019). Gluten-free bread: Effect of soy and corn co-products on the quality parameters. *European Food Research and Technology, 245 (7),* 1365–1376. https://doi.org/10.1007/s00217-019-03261-9
6. Cederborg, A. C., Hultman, E., Magnusson, K. F. (2012). Living with children who have coeliac disease: a parental perspective. *Child: Care, Health and Development, 38 (4),* 484–489. https://doi.org/10.1111/j.1365-2214.2011.01273.x
7. Makhynko, V. M. (2019). *Scientific substantiation and development of the technology of high-protein bread products for consumers with an increased need for macronutrients.* [Doctoral dissertation].
8. Han, A., Romero, H. M., Nishijima, N., Ichimura, T., Handa, A., Xu, C. et al. (2019). Effect of egg white solids on the rheological properties and bread making performance of gluten-free batter. *Food Hydrocolloids, 87,* 287–296. https://doi.org/10.1016/j.foodhyd.2018.07.041
9. Makhynko, V., Drobot, V., Zemlynska, M. (2018). Crumb briquettes for consumers with the increased protein needs. *Scientific Works of National University of Food Technologies, 24 (3),* 160–169. https://doi.org/10.24263/2225-2924-2018-24-3-19
10. Mykhonik, L. A., Hetman, I. A., Bela, N. I., Bohdan, G. S. (2018). Quality indicators of spontaneous fermentation starters from cereal grain flour in the process of low-temperature canning. *Food Resources, 11,* 116–122. https://doi.org/10.31073/foodresources2018-11-13
11. Păcularu-Burada, B., Turturică, M., Rocha, J. M., Bahrim, G.-E. (2021). Statistical approach to potentially enhance the postbiotication of gluten-free sourdough. *Applied Sciences, 11 (11),* 5306. https://doi.org/10.3390/app11115306
12. Niland, B., Cash, B. D. (2018). Health benefits and adverse effects of a gluten-free diet in non-celiac disease patients. *Gastroenterology & Hepatology, 14,* 82–91.
13. Păcularu-Burada, B., Georgescu, L. A., Vasile, M. A., Rocha, J. M., Bahrim, G.-E. (2020). Selection of wild lactic acid bacteria strains as promoters of postbiotics in gluten-free sourdoughs. *Microorganisms, 8 (5),* 643. https://doi.org/10.3390/microorganisms8050643
14. Horach, O., Mukhalyk, K., Husar, A. (2021). Analiz vyrobnytstva funktsionalnykh bezhliutenovykh produktiv na osnovi vykorystannia vitchyznianoi syrovyny. *Tavriiskyi naukovyi visnyk, 6,* 94–100.
15. *DSTU 7517:2014. Khlib iz pshenychnoho boroshna. Zahalni tekhnichni umovy* (2014). Kyiv.
16. *DSTU 7045:2008. Vyroby khlibobulochni. Metody vyznachennia fizyko-khimichnykh pokaznykiv* (2010). Kyiv.
17. Demirkesen Mert, I., Campanella, O. H., Sumnu, G., Sahin, S. (2016). Gluten-free sourdough bread prepared with chestnut and rice flour. *Foodbalt, 26 (1),* 239–242.
18. Bernacchia, R., Preti, R., Vinci, G. (2014). Chemical composition and health benefits of flaxseed. *Austin Journal of Nutrition and Food Sciences, 2 (8),* 1045.
19. Mercier, S., Villeneuve, S., Moresoli, C., Mondor, M., Marcos, B., Power, K. A. (2014). Flaxseed-enriched cereal-based products: a review of the impact of processing conditions. *Comprehensive Reviews in Food Science and Food Safety, 13,* 400–412. https://doi.org/10.1111/1541-4337.12075

**20.** Lialyk, A., Bejko, L., Kuhtyn, M., Pokotylo, O. (2021). Use of flax oil in food production. *Visnyk Agrarnoi Nauky, 99 (3),* 78–83. https://doi.org/10.31073/agrovisnyk202103-10

**21.** Bartkiene, E., Lele, V., Ruzauskas, M., Mayrhofer, S., Domig, K., Starkute, V. et al. (2020). Lactic acid bacteria isolation from spontaneous sourdough and their characterization including antimicrobial and antifungal properties evaluation. *Microorganisms, 8 (1),* 64. https://doi.org/10.3390/microorganisms8010064

**22.** Singh, K. K., Mridula, D., Rehal, J., Barnwal, P. (2011). Flaxseed: a potential source of food, feed and fiber. *Critical Reviews in Food Science and Nutrition, 51 (3),* 210–222. https://doi.org/10.1080/10408390903537241

**23.** Ahmed, I., Qazi, I. M., Li, Z., Ullah, J. (2016). Approved Methods of American Association of Cereal Chemists. *American Association of Cereal Chemists. Arlington.*

**24.** Bouasla, A., Wójtowicz, A., Zidoune, M. N. (2017). Gluten-free precooked rice pasta enriched with legumes flours: physical properties, texture, sensory attributes and microstructure. *LWT – Food Science and Technology, 75,* 569–577. https://doi.org/10.1016/j.lwt.2016.10.005

**25.** Dupasquier, C. M., Dibrov, E., Kneesh, A. L., Cheung, P. K., Lee, K. G., Alexander, H. K. (2007). Dietary flaxseed inhibits atherosclerosis in the LDL receptor-deficient mouse in part through antiproliferative and anti-inflammatory actions. *American Journal of Physiology-Heart and Circulatory Physiology, 293 (5),* H2394–H2402. https://doi.org/10.1152/ajpheart.00937.2006

**26.** Harper, C. R., Edwards, M. J., DeFilippis, A. P., Jacobson, T. A. (2006). Flaxseed oil increases the plasma concentrations of cardioprotective (n-3) fatty acids in humans. *The Journal of Nutrition, 136 (1),* 83–87. https://doi.org/10.1093/jn/136.1.83

**27.** Oomah, B. D., Berekoff, B., Li-Chan, C., Mazza, G., Kenaschuk, E., Duguid, S. (2007). Cadmium-binding protein components of flaxseed: influence of cultivar and location. *Food Chemistry, 100 (1),* 318–325. https://doi.org/10.1016/j.foodchem.2005.09.054

**28.** Gorach, O. O. (2022). Conceptual basis of the formulation of gluten-free products based on the use of domestic plant raw materials. *Moderní aspekty vědy: XXV. Mezinárodní Ekonomický Institut s.r.o.* Česká republika, 373–388.

**29.** Mykhalyk, K., Husar, A., Horach, O. (2021). Suchasnyi stan vyrobnytstva, yakosti ta bezpeky khlibobulochnykh vyrobiv. *Suchasna nauka: stan ta perspektyvy rozvytku.* Kherson, 315–319.

**30.** Hryshchenko, A. M. (2011). *Udoskonalennia tekhnolohii khliba z bezghliutenovoi syrovyny.* [Extended abstract of PhD thesis; Nats. un-t kharch. tekhnol.].

**31.** Dorokhovych, V. V. (2010). *Naukove obgruntuvannia i rozroblennia tekhnolohii boroshnianykh kondyterskykh vyrobiv spetsialnoho diietychnoho spozhyvannia.* [Doctoral dissertation; KNTEU].

**32.** Lobachova, N. L. (2015). *Tekhnolohiia bezghliutenovykh khlibobulochnykh vyrobiv z vykorystanniam kolahenvmisnykh bilkiv ta transhliutaminazy.* [PhD dissertation; Kharkivskyi derzh. un-t kharch. ta torhivli].

**33.** Hryshchenko, A. M., Drobot, V. I. (2014). Tekhnolohichni vlastyvosti bezghliutenovykh vydiv syrovyny. *Naukovi pratsi, 46 (1),* 162–166.

**34.** Drobot, V. I., Sorochunska, U. S., Bondarenko, U. V., Renkas, O. I. (2019). Vykorystannia shrotu z nasinnia harbuza v tekhnolohii bezghliutenovoho khliba. *Kharchova promyslovist, 26,* 6–13.



✉***Olga Gorach,*** *Doctor of Technical Sciences, Department Food Technology, Kherson State Agrarian and Economic University, Kherson, Ukraine, ORCID: https://orcid.org/0000-0002-8737-5002, e-mail: olga_gorach@ukr.net*

***Oksana Dzyundzya,*** *PhD, Department Food Technology, Kherson State Agrarian and Economic University, Kherson, Ukraine, ORCID: https://orcid.org/0000-0002-1996-7065*

***Nataly Novikova,*** *PhD, Department Food Technology, Kherson State Agrarian and Economic University, Kherson, Ukraine, ORCID: https://orcid.org/0000-0001-5393-688X*

***Nina Rezvykh,*** *PhD, Department Food Technology, Kherson State Agrarian and Economic University, Kherson, Ukraine, ORCID: https://orcid.org/0000-0002-4727-512X*

✉*Corresponding author*