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DEVELOPING A RECIPE AND TECHNOLOGY FOR MAKING GLUTEN-FREE DESSERTS FOR PATIENTS WITH CELIAC DISEASE

Abstract

The article presents the results of an experimental study aimed at developing and optimizing recipes for biscuit desserts adapted for people with celiac disease. The relevance of the topic is due to the growing prevalence of gluten intolerance diseases, including celiac disease, both in Ukraine and around the world. Therefore, it is necessary to create high quality gluten-free food products, which are not inferior to traditional analogues in terms of organoleptic, structural and mechanical properties. The main raw material used is rice flour, the most common gluten-free ingredient, as well as its blends with amaranth and millet flour, which have a higher nutritional value due to the content of proteins, trace elements and biologically active compounds. Potato and tapioca starches were added to the formulations at different concentrations to improve the consistency, structure and moisture retention of the dough. As part of the study, the water absorption capacity of rice, amaranth, and millet flours was determined, the physicochemical parameters of the finished products (moisture content, porosity, specific volume) were evaluated, and organoleptic analysis was performed. The results analysis showed that the addition of 10-20% of amaranth or millet flour to rice flour in combination with 5-10% of tapioca or potato starch allows to obtained products with satisfactory sensory characteristics, soft texture, uniform porosity and stable shape after baking. The introduction of amaranth flour into the gluten-free mix increased the nutritional value of the finished products by increasing the content of complete protein, iron, magnesium, calcium and fiber, and gave the products a characteristic pleasant nutty taste. The addition of tapioca starch to the biscuit recipe contributed to the improvement of such indicators as tenderness and uniformity of structure, aroma and taste characteristics. The results obtained indicate the feasibility of using these ingredients in the formulations of gluten-free confectionery products for functional purposes. The proposed compositions can be used in the industrial and small-scale production of food products for consumers with celiac disease and other forms of gluten enteropathy.

Keywords: gluten-free sponge cake, rice flour, amaranth flour, millet flour, tapioca starch, potato starch, celiac disease

Introduction

This research in the field of food technology focuses on the development of special dietary products for people with autoimmune disorders that require the exclusion of certain foods from the diet. According to epidemiological studies, the overall prevalence of autoimmune diseases has almost doubled over the past three decades [1, 2]. Such diseases include celiac disease, autoimmune thyroiditis, type 1 diabetes mellitus, Crohn's disease, systemic lupus erythematosus and other nosological forms. The vast majority of autoimmune pathologies require strict dietary restrictions with the exclusion of certain food groups, which makes it impossible to consume commonly consumed foods [2].

Among these conditions, celiac disease is a chronic autoimmune enteropathic disorder that occurs in genetically predisposed individuals in response to the consumption of gluten, a protein found in wheat, rye and barley. The main pathogenetic mechanism of celiac disease is damage to the villi of the small intestine, which leads to impaired absorption of nutrients, vitamin and mineral deficiencies, and the development of systemic complications such as osteoporosis, anaemia, growth retardation in children and an increased risk of developing malignant tumours [1]. Currently, the only effective method of controlling the disease is a lifelong strict gluten-free diet. However, adherence to such a diet is fraught with a number of difficulties: a limited range of gluten-free products, their high cost, and limited availability of nutritionally balanced options [3]. In addition, industrially produced gluten-free products often have a higher content of fats and sugars, which increases the risk of developing metabolic disorders among celiac patients [4].

In this context, the development of safe and nutritionally balanced gluten-free products that meet modern dietary requirements and have high consumer appeal is of particular relevance.

Literature review

In response to these challenges, numerous scientific studies focus on improving the formulation of gluten-free products to ensure their high nutritional value and attractive organoleptic properties. Rubio-Tapia et al. highlight the importance of developing products that are not only safe for celiac patients, but also provide adequate intake of macro- and micronutrients [4]. *Lamacchia et al.* have shown the prospects of using pseudocereals (amaranth, quinoa, buckwheat) as a source of protein, dietary fibre and antioxidants to create a balanced gluten-free diet [5].

Pellegrini and Agostoni drew attention to the need to adjust the formulation of gluten-free products to prevent deficiencies in important nutrients and prevent metabolic disorders [6]. *Moreno et al.* found that the addition of dietary fibre, such as inulin or beta-glucans, to gluten-free breads improves its texture and increases its shelf life [7]. Similar findings were confirmed in a study by

Foschia et al. who focused on the use of hydrocolloids and modified starches to optimize the rheological properties of gluten-free products [8].

Mollard et al. demonstrated the clinical benefits of quinoa consumption in a gluten-free diet, which helped to reduce inflammation and improve micronutrient balance in patients with celiac disease [9]. Special attention should be paid to the study by *Calderón de la Barca et al.* that proves the prospects of developing functional gluten-free products enriched with prebiotics and antioxidants for comprehensive dietary support for patients [10].

Despite the progress made, the category of dessert products for people with celiac disease that would simultaneously meet the requirements for safety, high nutritional value and organoleptic quality remains underdeveloped. Development of gluten-free biscuit desserts with improved texture, structural stability and attractive taste characteristics is of particular importance.

Purpose and objectives of the study

Development of a recipe and technology for the preparation of dessert products from gluten-free biscuit dough for people with gluten intolerance, taking into account their nutritional value and organoleptic qualities.

To achieve this goal, the following tasks were set:

1. to develop 3 recipe schemes for gluten-free biscuits;
2. to determine the technological parameters of the preparation of these products;
3. to assess the nutritional value of the finished products;
4. to conduct an organoleptic evaluation of the quality of the developed samples.

Materials and research methods

Characteristics of raw materials and additional ingredients

The following main ingredients were used for the preparation of biscuit products: rice flour, millet flour, amaranth flour, tapioca starch, potato starch, dry egg melange, crystalline white sugar, refined sunflower oil, filtered drinking water, vanilla flavour enhancer (essence).

The choice of ingredients is based on their gluten-free status and technological feasibility in the production of dessert products. All raw materials met the requirements of current standards and specifications.

Equipment

Gluten-free products were prepared in a separate production facility that complied with current sanitary rules and regulations. This is because even a small amount of gluten in the product can cause damage to the small intestinal mucosa in sensitive individuals, which is a pathogenetic mechanism for the development of celiac disease. The following laboratory and processing equipment was used in the study: a kitchen mixer with adjustable speed (Philips HR3745, the Netherlands) was used for whipping the egg-sugar mass; analytical laboratory scales (Radwag AS 220/C/2, Poland) were used for accurate weighing of raw materials; a convection electric oven (UNOX LineMiss, Italy) was used for baking biscuit semi-finished products

Biscuit recipe

Three variants of gluten-free biscuit dough recipes with different proportions of rice, amaranth, millet flour, potato starch and tapioca starch were developed.

To prepare the sponge semi-finished product, the respective types of flour, potato starch and tapioca starch were pre-sifted and mixed until smooth. The egg-sugar mixture was whipped for 30-35 minutes with a gradual increase in the mixer speed. The volume of the mass increased by 2-2.5 times. The resulting whipped mixture was gently combined with the dry ingredients by mixing for no longer than 15s, after which vanilla essence was added. The moisture content of the dough was 36-38%. The resulting dough was poured into moulds pre-greased with edible fat and baked at 190-200 °C for 30-40 minutes. After baking, the semi-finished products were cooled for 20-30 minutes, removed from the moulds and kept for 8-10 hours at 15-20 °C. The calculations, depending on the biscuit composition, are presented in Table 1.

Table 1 - Calculation of the amount of raw materials for the preparation of gluten-free biscuits of different composition in natural terms and in terms of dry matter (per 1000 g of final product)

Raw materials	Calculation of raw materials for rice biscuit		Calculation of raw materials for rice-amaranth sponge cake		Calculation of raw materials for rice-millet sponge cake	
	in natural form, g	in terms of dry matter, g	in natural form, g	in terms of dry matter, g	in natural form, g	in terms of dry matter, g
Rice flour	274.2	240.5	205.7	181.2	137.2	120.8
Amaranth flour	-	-	68.5	60.7	-	-
Millet flour	-	-	-	-	137	124,4
Potato starch	34.7	27.7	34.7	27.7	34.7	27.7
Tapioca starch	34.7	29.1	34.7	29.1	34.7	29.1
Crystalline white sugar	347.1	346.1	347.1	346.1	347.1	346.1
Eggs / melange	578.5	156.2	578.5	156.2	578.5	156.2
Essence	3.4	0	3.4	0	3.4	0
Baked biscuit weight, g	1000		1000		1000	

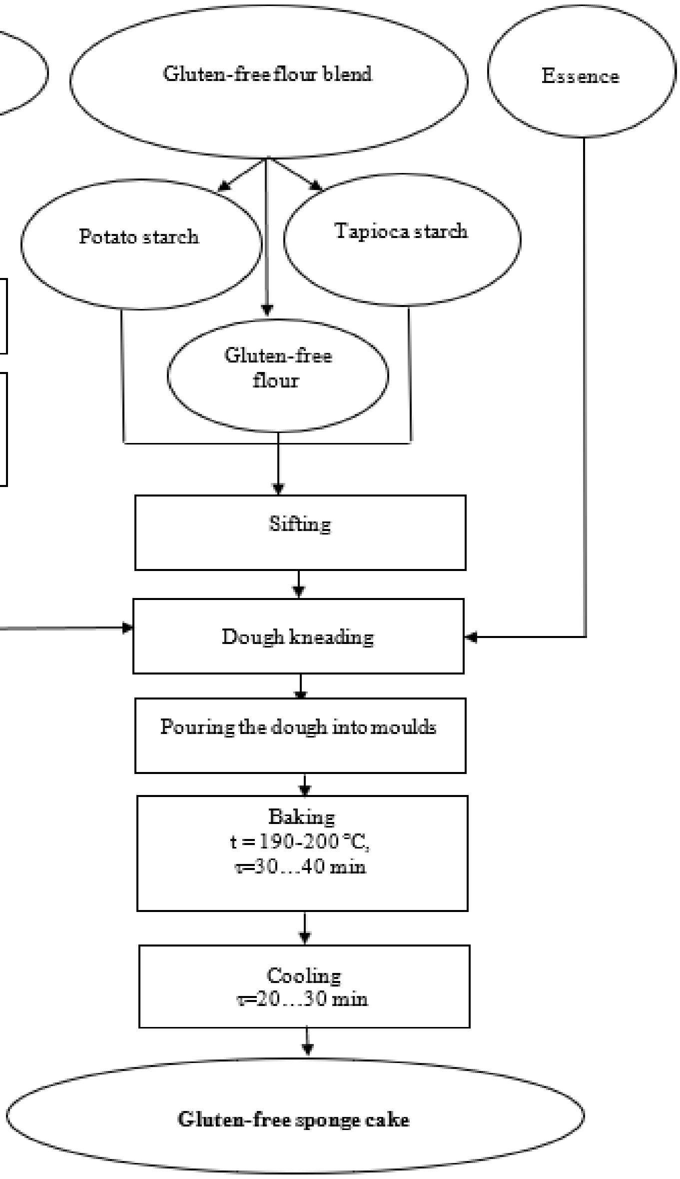


Fig. 1. General flow chart of a gluten-free biscuit

The preparation of a biscuit semi-finished product with a gluten-free flour composition was carried out in accordance with the developed technological scheme of production (Fig. 1).

Quality assessment

The quality of the developed biscuit dough products was studied by trial baking and evaluation of the indicators of the experimental and control samples. Organoleptic evaluation of the finished products was carried out according to the requirements of the State Standard of Ukraine 9188:2022 'Bakery products. Organoleptic evaluation of quality indicators'. The mass fraction of moisture and porosity were determined according to the requirements of the State Standard of Ukraine 7045:2009 'Bakery products. Methods for determining physicochemical parameters'. Protein content was determined by the nephelometric method; fat content by the refractometric method (the State Standard of Ukraine 5060:200 'Confectionery products. Methods for determining the mass fraction of fat'); carbohydrate content by the colourimetric method.

The chemical composition of the control and test samples was also calculated.

Results and discussion

The development of gluten-free biscuits based on alternative flour compositions is one of the leading areas of modern food technology aimed at ensuring the safety of nutrition for people with celiac disease and improving the quality of life. In this study, rice, millet and amaranth flours were tested as gluten-free components, taking into account their functional, sensory and nutritional characteristics.

Sweet white rice flour, which is obtained by milling short grains of 'sticky rice', was chosen as the main structure-forming component. According to a study conducted by *Zhang et al*., rice flour, due to its high content of amylopectin, which is responsible for plasticity and stability, contributes to the formation of a soft and elastic dough texture. This makes it a basic ingredient in gluten-free baking recipes [11]. At the same time, as noted in the study by *Wang et al.,* the exclusive use of rice flour limits the nutritional value of finished products due to a lack of protein, iron and dietary fibre. In this regard, it is recommended to enrich such formulations with protein and mineral-rich ingredients [12].

To increase the nutritional value of the sponge cake, it was decided to use a mixture of rice and millet flour in the recipe of the second sample. In a domestic study conducted by *Petrenko I. M. and Kovalchuk N. Y.*, millet flour was considered an important component of functional food. The authors proved that its introduction into the flour composition improves the trace element composition of products, in particular, increases the content of iron, magnesium and phosphorus [13]. In addition, millet flour helped to improve the flavour profile and gave the product a pleasant yellowish colour.

When developing the recipe for the third sample, it was decided to replace millet flour with amaranth flour. González et al. found that amaranth contains complete protein, including lysine, an amino acid that is present in cereals in minimal or no amount. The authors also noted the high level of squalene, which has an antioxidant effect and helps to increase the body's immune defence [14]. The introduction of amaranth flour into the biscuits in the study significantly increased the content of calcium, iron and magnesium.

The basic model for comparison was the traditional 'Basic sponge cake' made with wheat flour (Table 2).

The chemical composition of the control sample of the biscuit semi-finished product is shown in Table 3.

Since water absorption capacity is a critical factor in the rheological properties of dough, we additionally analysed the moisture retention capacity of alternative flours (Fig. 2).

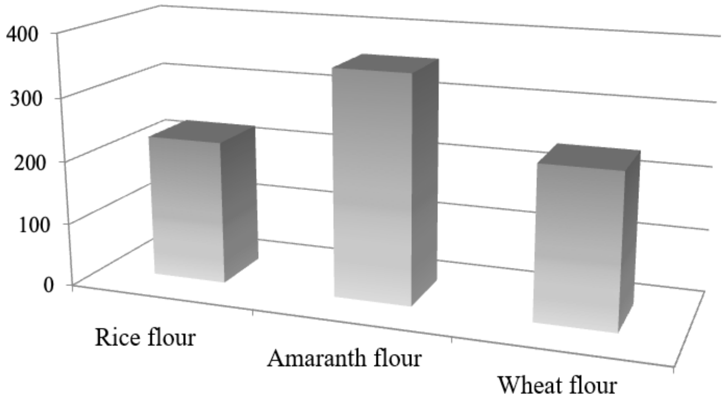


Fig. 2. Water absorption capacity of gluten-free flour, %

Table 2 - Calculation of the amount of raw materials for the preparation of "Basic biscuit" in natural terms and in terms of dry matter (per 1000 g of final product)

Raw materials	Mass fraction of dry substances, %.	Calculation of raw materials	
		in natural form, g	in terms of dry matter, g
Wheat flour of the highest grade	85.50	281.2	240.4
Potato starch	80.00	69.4	55.5
Crystalline white sugar	99.85	347	346
Eggs / melange	27.00	578.5	156.2
Essence	0	3.4	0
Baked biscuit weight, g		1000	750

Table 3 - Chemical composition of 'Basic biscuit' per 100 g

Value	Contains, g/mg	Value	Contains, g/mg
Proteins, g	8.96	Carbohydrates, g	46.81
Fats, g	5.43	including dietary fibre	1.05
Minerals			
Calcium, mg	30.15	Magnesium, mg	10.20
Potassium, mg	99.60	Sodium, mg	60.30
Phosphorus, mg	112.20	Iron, mg	1.49
Selenium, mcg	3.00	Zink, mg	1.32
Vitamins			
B1 (thiamine), mg	0.08	B6 (pyridoxine), mg	0.06
B2 (riboflavin), mg	0.25	B9 (folic acid), mcg	13.35
Vitamin PP, mg	1.97	Vitamin E, mg	0.90

Table 4 - Model compositions of gluten-free flour mixtures, in % by total weight of flour and starch

Product name	Control	Gluten-free composition		
		№1	№2	№3
Wheat flour	80.2	-	-	-
Potato starch	19.8	9.9	9.9	9.9
Rice flour	-	80.2	55.2	40.2
Millet flour	-	-	-	40.0
Amaranth flour	-	-	25.0	-
Tapioca starch	-	9.9	9.9	9.9

It was found that amaranth flour has increased hygroscopicity compared to wheat flour, which led to a change in the ratio of components in the recipe.

Starch components, namely a mixture of potato and tapioca starches, were used to stabilise the dough structure and ensure proper rheological characteristics. The study by *Costa et al.* compared the functional characteristics of these ingredients in gluten-free doughs. It was found that tapioca starch significantly improves the viscosity and stability of the emulsion, and contributes to the formation of an elastic texture after baking [15].

Model compositions of gluten-free flour mixtures are presented in Table 4.

Based on the developed gluten-free compositions 1-3, three variants of gluten-free biscuits were produced:

– rice sponge cake;
– rice-amaranth sponge cake;
– rice-millet sponge cake.

The calculation of the chemical composition of the obtained samples in comparison with the control is presented in Table 5. It was found that gluten was absent in the gluten-free samples, and the content of dietary fibre increased by 1.4-5.8 times. The most enriched was the rice-amaranth biscuit, which showed a 4.3-fold increase in iron, 2.5-fold increase in calcium, and more than 4-fold increase in magnesium.

The analysis of organoleptic and physicochemical parameters (Table 6) confirmed the technological feasibility of the proposed compositions. The gluten-free biscuits had satisfactory indicators of specific volume, porosity, homogeneous texture, with a pleasant taste and characteristic aroma (in particular, rice, millet or amaranth).

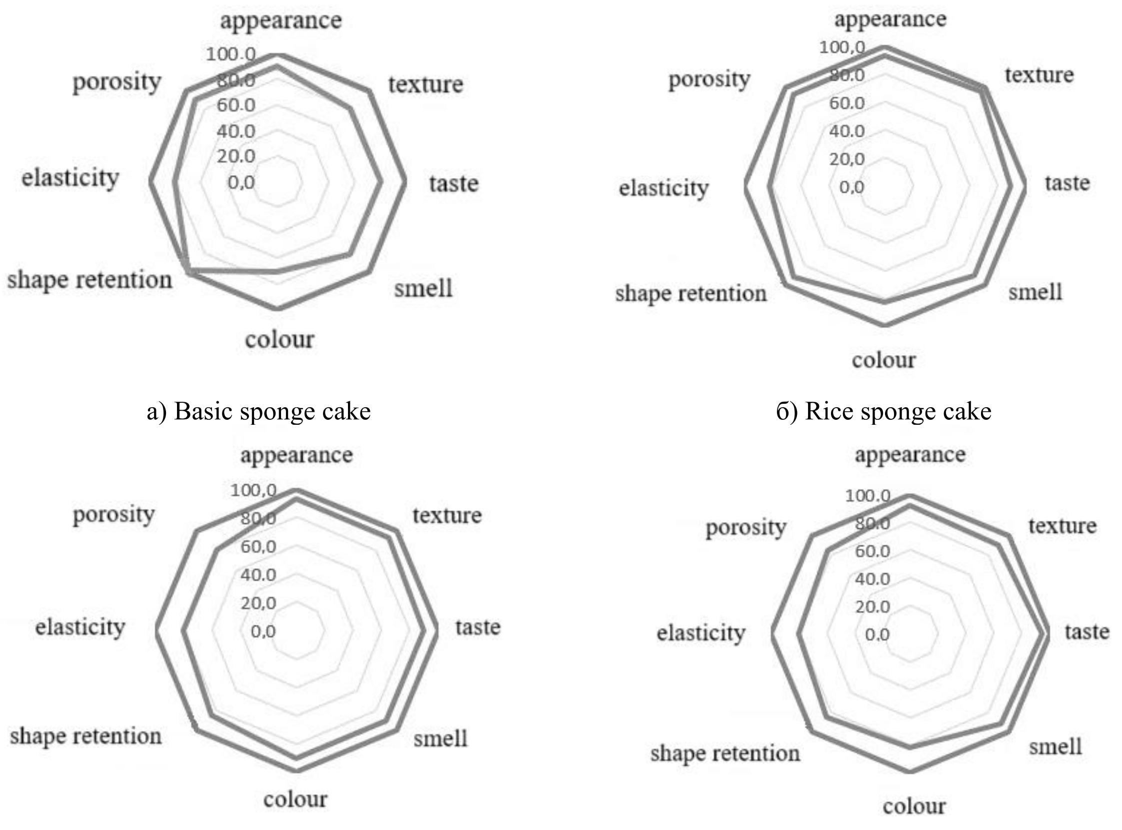
The quality profile (Fig. 3) shows the improved sensory characteristics of the test samples compared to the control.

Table 5 - Chemical composition of biscuit dough products with agglutinating flour composition, (g per 100 g)

Indicators name	Control	Rice sponge cake	Rice-amaranth sponge cake	Rice-millet sponge cake
Proteins, г	8.96	8.06	12.34	10.75
Fat г	5.43	5.33	7.01	6.62
Carbohydrates, g included	46.81	52.3	46.05	47.13
dietary fibre, g	1.05	1.44	5.01	3.02
gluten, g	2.76	0.00	0.00	0.00
Minerals				
Calcium, mg	30.15	30.01	75.77	38.61
Potassium, mg	99.60	89.15	231.4	105.38
Magnesium, mg	10.20	20.12	35.61	41.2
Sodium, mg	9.30	11.2	10.1	9.30
Phosphorus, mg	112.20	132.1	190.5	160.93
Iron, mg	1.49	1.22	6.42	2.5
Selenium, mcg	3.00	6.22	11.12	7.01
Zinc, mg	1.32	1.33	1.35	1.34
Vitamins				
B1 (thiamine), mg	0.08	0.08	0.15	0.12
B2 (riboflavin), mg	0.25	0.23	0.28	0.25
B6 (pyridoxine), mg	0.06	0.05	0.96	0.82
B9 (folic acid), mcg	13.35	13.05	19.44	18.73
Vitamin PP, mg	1.97	1.88	2.67	2.14
Vitamin E, mg	0.90	0.88	1.74	1.55

Table 6 - Organoleptic and physicochemical quality indicators of biscuit products with gluten-free flour composition

Indicators	Basic sponge cake	Rice sponge cake	Rice-amaranth sponge cake	Rice-millet sponge cake
Specific volume, cm3/100g	3.4	3.6	3.3	3.2
Porosity, %	77	79	71	75
Crust colouring	Light brown	Light brown	Light orange	Brown
Crumb colour	Creamy	Milk	Orange	Brown
Texture	Tender, crumbly	Fragile, moist, tender	Fragile, moist, tender	Fragile, moist, tender
Taste and smell	Typical for a sponge cake product	Typical of a biscuit product with a faint rice aroma	Typical for a biscuit product with a faint rice and amaranth aroma	Typical for a biscuit product with a weak aroma of rice and millet
Cutaway view	Medium pores, uniform, without traces of unprocessed product, retains its shape	Medium-porous, elastic, without traces of unprocessed product, uniform, retains its shape	Fine-porous, elastic, without traces of unprocessed products, uniform, retains its shape	Fine-porous, elastic without traces of unprocessed product, uniform, retains its shape



a) Basic sponge cake

б) Rice sponge cake

в) Rice-amaranth sponge cake

г) Rice-millet sponge cake

Fig. 3. Quality profile of biscuit dough products made using gluten-free flour composition

Therefore, the results of our study, in accordance with the above works, confirm the feasibility of using rice, amaranth and millet flour with the addition of starches to create gluten-free biscuits with high nutritional and sensory quality. The proposed compositions can be used in the industrial production of products for special dietary consumption.

Conclusions

The study confirmed the feasibility of using gluten-free flour compositions based on rice, millet and amaranth flour as an alternative to wheat flour in the production of biscuit products. The proposed formulations made it possible to completely eliminate wheat flour containing gluten from the product composition and significantly increase its nutritional value. In particular, the experimental samples showed a 1.4-5.8-fold increase in dietary fibre content, as well as a significant increase in the concentration of minerals: iron - 4.3 times, calcium - 2.5 times, magnesium - more than 4 times, compared to the control sample. The highest nutritional value was found in the biscuit product with the addition of amaranth flour.

The results of the organoleptic analysis showed that the experimental samples are not worse in quality than traditional sponge cake, and in some cases demonstrate better consumer properties, in particular in terms of structure, colour and taste. The addition of potato starch and tapioca starch had a positive effect on the texture of the products, contributing to the formation of a more stable and tender dough structure.

So, the developed recipe solutions can be recommended for implementation in the production of functional dessert products intended for consumers with gluten intolerance, ensuring not only safety but also high nutritional and sensory quality of the finished product.

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РОЗРОБЛЕННЯ РЕЦЕПТУРИ ТА ТЕХНОЛОГІЇ ПРИГОТУВАННЯ БЕЗГЛЮТЕНОВИХ ДЕСЕРТІВ ДЛЯ ХВОРИХ НА ЦЕЛІАКІЮ

Анотація

У статті наведено результати експериментального дослідження, спрямованого на розробку та оптимізацію рецептур бісквітних десертів, адаптованих для осіб із целіакією. Актуальність теми зумовлена зростанням поширеності як в Україні так і в усьому світі захворювань, пов'язаних із непереносимістю глютену, зокрема целіакії. Це потребує створення якісних безглютенових харчових продуктів, які за органолептичними властивостями та структурно-механічними характеристиками не поступаються традиційним аналогам. Як основну сировину було використано рисове борошно – найпоширеніший безглютеновий компонент, а також його суміші з амарантовим і пшоняним борошном, які мають вищу харчову цінність завдяки вмісту білків, мікроелементів та біологічно активних сполук. Для покращення консистенції, структури та вологоутримувальної здатності тіста до складу рецептур вводили крохмалі – картопляний і тапіоковий – у різних концентраціях. У рамках дослідження визначали водопоглинальну здатність рисового, амарантового та пшоняного борошна, оцінювали фізико-хімічні параметри готових виробів (вологість, пористість, питомий об'єм) та проводили органолептичний аналіз. Аналіз результатів показав, що додавання до рисового борошна 10–20% амарантового або пшоняного борошна у поєднанні з 5–10% тапіокового або картопляного крохмалю дозволяє отримати вироби із задовільними сенсорними показниками, м'якою текстурою, рівномірною пористістю та стійкою формою після випікання. Введення амарантового борошна до складу безглютенової суміші підвищило поживну цінність готових виробів за рахунок збільшення вмісту повноцінного білка, заліза, магнію, кальцію та харчових волокон, а також надало виробам характерного приємного горіхового присмаку. Додавання тапіокового крохмалю до рецептури бісквітів сприяло покращенню таких показників, як ніжність і однорідність структури, вираженість аромату та смакових характеристик. Отримані результати свідчать про доцільність застосування вказаних інгредієнтів у рецептурах безглютенових кондитерських виробів функціонального призначення. Запропоновані композиції можуть бути використані у промисловому та малотоннажному виробництві продуктів харчування для споживачів із целіакією та іншими формами глютенової ентеропатії.

Ключові слова: безглютеновий бісквіт, рисове борошно, амарантове борошно, пшоняне борошно, тапіоковий крохмаль, картопляний крохмаль, целіакія

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