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Development of technology and study of properties of gluten-free shortbread biscuits

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Abstract. The number of persons with gluten intolerance is rising in the modern world, which calls for the creation of specialised goods that may satisfy their demands. The aim of the research was to develop a recipe for gluten-free shortbread biscuits with cherry filling. The research was carried out using the expert method, sensory analysis and statistical methods of processing research data. To achieve this goal, it was proposed to use a mixture of almond and coconut flour as a raw material for shortbread buiscits. It had been determined that the development of gluten-free products required the implementation of innovative technologies, the incorporation of alternative ingredients, and the analysis of the properties of raw materials and final products. Various model compositions of shortbread biscuits were developed based on mixtures of almond and coconut flour with different proportions of the mixture components (MC1 – 75:25, MC2 – 50:50, MC3 – 25:75). A sensory analysis of the model compositions of gluten-free shortbread biscuits was carried out, and their organoleptic characteristics were determined. As a result of the studies, a sensory profilogram of model shortbread compositions was obtained, which can be used to determine, which model composition was characterised by the best indicators (it was found that MC1 had the best indicators). The brittleness index of gluten-free shortbread biscuits was also determined depending on the content of almond flour in the mixture. The physicochemical parameters of various model compositions of gluten-free shortbread biscuits were determined and the results of these studies were analysed. The development of gluten-free shortbread biscuits with cherry filling allows expanding the range of flour confectionery products with a healthful orientation

Keywords: gluten; almond flour; coconut flour; moisture; organoleptic evaluation; nutritional value

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Introduction

Over the 2000-2020 years, a growing emphasis on developing new, healthier goods has been placed on flour production. In this aspect, the problem of increased sensitivity of the human body to gluten should be highlighted. Wheat flour, which was a component of confectionery flour products, contained gluten, a substance that belonged to the group of vegetable proteins (gluten). Many consumers are sensitive to gluten. And according to H.F. Hassan *et al.* (2024), up to 1% of people in the world were affected by an autoimmune reaction in the small intestine caused by gluten consumption.

Gluten contained the proteins glutenin and gliadin, which interacted to give the product its viscoelastic properties. Historically, access to gluten-free products had been limited, with few types of gluten-free raw materials available and almost all gluten-free production done in the home. The gluten-free diet, which was becoming increasingly relevant, provided health benefits, helped to lose excess weight, improved digestion, and strengthened the immune system. A. Lerner *et al.* (2019) noted that in conditions, where the human body was dependent on gluten, a gluten-free diet was the cornerstone of treatment, improving health and quality of life, and treating or preventing related complications. M. Tanveer & A. Ahmed (2019) stated that the only available treatment for celiac disease, wheat allergy, was to avoid gluten. Gluten-free products provided relief to people with gluten intolerance, and therefore the need to produce gluten-free products and provide such products to the food market was becoming relevant.

Therefore, the task was to replace wheat flour with alternative types of flour for the preparation of confectionery flour products that do not contain gluten, the natural allergen. In particular, coconut flour can be such an alternative type of flour. Rich in vitamins, minerals, and dietary fiber, coconut flour had a distinct flavour and scent that may find use in baking and human nutrition. M. Raczyk *et al.* (2021) suggested using coconut or chestnut flour as an alternative raw material in the manufacture of bakery products to replace wheat flour, which can give the product an attractive taste and improved nutritional characteristics, in particular, a higher fiber content. Coconut flour, as noted by R. Jiamjariyatam *et al.* (2021), when used for the production of biscuits, gave the product crumbliness, coconut flavour and aroma.

S. Azizi *et al.* (2020) suggested the use of quinoa flour in bread production. The authors noted that the lipase and protease enzymes can had a positive effect on the quality of the product, in particular by slowing down staling. The features of the use of hydrocolloids in gluten-free breads were studied by M. Belorio & M. Gómez (2020). This innovative approach was a strategy to improve bread quality and obtain a product with improved structural and textural properties.

Additionally, confectionery flour items can be made with almond flour. Almonds were gluten-free and almond flour had a high fat content (about 50% of the total weight). This flour also had a sufficient amount of high quality proteins (about 20%). Vegetable fats do not contain cholesterol, and the complex of omega fatty acids contained in almonds had a beneficial effect on blood vessels. Almond flour was also characterised by a high zinc content of 2.12 mg/100 g of product (17.7% of the daily requirement for this micronutrient).

According to B. Sustriawan *et al.* (2021), during manufacturing of biscuits, replacing wheat flour with almond flour and adding vegetable fat can significantly affect the final properties of the product and improve the flavour. In addition to almond flour, they also considered sorghum flour as an alternative to wheat biscuits. R. Gillespie & G.J. Ahlborn (2021) considered about using oat bran and almond flour instead of wheat flour to make gluten-free ketogenic bread. The authors claimed that using these alternatives improved the product's quality metrics. Different fruit fillings can be used to make shortbread cookies. M. Alam *et al.* (2024) claimed that the quality of fillings can be improved by using a variety of hydrocolloids in the formulations of fillings for different types of fruits. According to the authors, the properties of fruit fillings were influenced by factors such as fruit choice, fruit processing methods and hydrocolloid properties.

The aim of the study was to develop a recipe for craft shortbread cookies with fruit filling and to determine the organoleptic, physicochemical characteristics of the new product.

Materials and Methods

Model examples of artisanal shortbread biscuits prepared using the recipe in Table 1 were the subject of a 2024 study at Lutsk National Technical University. Model compositions (MC) of shortbread cookies without gluten were made using varying proportions of almond and coconut flour. During of the research, coconut and almond flour were analysed, and its samples were analysed for the following quality indicators: moisture content, particle size distribution, and organoleptic characteristics. The dough was prepared from a mixture of almond and coconut flours at different ratios. Samples of flour mixtures were prepared by mechanical mixing of flour weights. The dough was made according to the recipe. The mixture of almond and coconut flour was prepared in the proportions: 75:25, 50:50, 25:75.

Table 1. *Model ingredients of shortbread almond-coconut biscuits*

No.	Name of raw material	Raw material consumption per 10 pcs, g		Raw material consumption per 100 pcs, g	
		Gross	Net	Gross	Net
1	Almond flour	128	125	1280	1250
2	Coconut flour	42	42	420	420

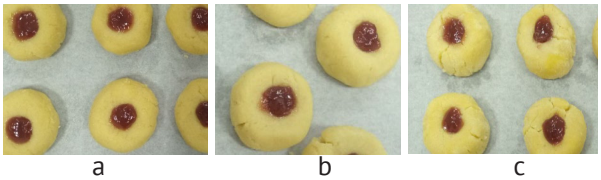
Table 1. Continued

No.	Name of raw material	Raw material consumption per 10 pcs, g		Raw material consumption per 100 pcs, g	
		Gross	Net	Gross	Net
3	Sugar	42	42	420	420
4	Eggs	107	107	1070	1070
5	Honey	13	13	130	130
6	Salt	2	2	20	20
7	Butter	83	83	830	830
8	Amaretto	8	8	80	80
	Weight of n/f dough:		422		4220
9	Cherry	75	75	750	750
10	Starch	1	1	10	10
11	Sugar	11	11	110	110
	Weight of n/f filling:		80		800
	Weight of raw n/f:		502		5020
	Total output of the product:		400		4000

Source: *developed by the authors*

For different flour mixtures, the mass fraction of moisture was by the air-thermal method of determining the mass fraction of moisture using SESh-3M (Ukraine). The moisture content of the cooked dough was determined using the Chizhov machine (Ukraine). From a physicochemical point of view, dough prepared for the production of flour confectionery should be classified as structured masses. By changing the proportions of raw materials or the parameters of the technological process, doughs with different properties and structures can be obtained. The inclusion of new components in the recipe affected the rheological properties of the dough and there was a need to adjust the process parameters, when using new types of raw materials in the dough recipe. The inclusion of new components in the recipe affected the rheological properties of the dough and it was necessary to adjust the process parameters, when using new types of raw materials in the dough recipe. Shortbread biscuits were baked according to a specific mode (baking time – 10...12 min, baking temperature – 180...200℃).

The biscuit samples were tested using physicochemical and organoleptic methods in accordance with the requirements of regulatory documents: DSTU 4683:2006 (2007) and DSTU 3781:2014 (2015). Figure 1 showed samples of semi-finished dough products with different proportions of almond and coconut flour.



a b c

Figure 1. *Model compositions of semi-finished dough products with different proportions of almond and coconut flour*

Note: *a – MC1 (ratio of almond to coconut flour – 75:25); b – MC2 (ratio of almond to coconut flour – 50:50): c – MC3 (ratio of almond to coconut flour – 25:75)*
Source: *developed by the authors*

The experimental samples of shortbread biscuits (Fig. 2) were made according to the recipe given in Table 1. Figure 2 showed the model compositions of gluten-free shortbread biscuits with different ratios of almond and coconut flour (the ratio was 75:25, 50:50 and 25:75).

a b c

Figure 2. *Model compositions of gluten-free shortbread biscuits with different proportions of almond and coconut flour*

Note: *a – MC1 (ratio of almond to coconut flour – 75:25); b – MC2 (ratio of almond to coconut flour – 50:50); c – MC3 (ratio of almond to coconut flour - 25:75)*
Source: *developed by the authors*

The studies monitored the ratio of almond and coconut flour and the moisture content of each type of flour and the mixture. The moisture content was also determined for each sample of semi-finished dough products. The moisture content of various biscuit samples was compared to the data collected. The study was conducted in accordance with the requirements of The Declaration of Helsinki (2013).

Results and Discussion

The study determined the indicators of gluten-free shortbread biscuits with cherry filling made from a mixture of almond and coconut flour. The almond flour used in the biscuits gave the products a better density

and higher moisture content, which helped to reduce the overall brittleness (compared to classic shortbread). Due to the high fat content of this flour, it was possible to achieve a higher crispness and a slight crumbling of the biscuits. The coconut flour, which was part of gluten-free shortbread cookies, had a high ability to absorb moisture, which gave the cookies increased dryness and crumbliness. Figure 3 showed the results of the study of the effect of almond flour content on the brittleness of biscuits.

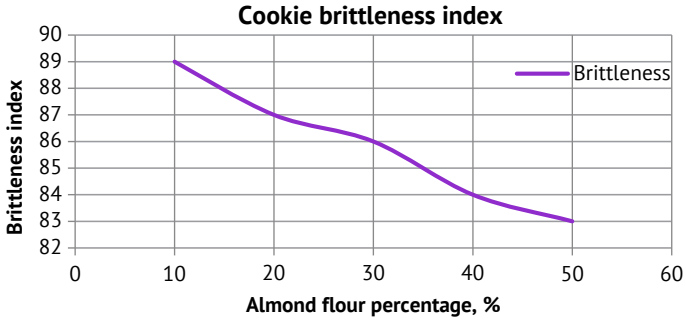


Figure 3. *Dependence of brittleness index on almond flour content*

Source: *developed by the authors*

The brittleness of these gluten-free products primarily depends on the ingredients of the dough (Mushtruk & Mushtruk, 2023). Classic shortbread biscuits made with wheat flour had a brittleness index of 85...95 according to the conventional crumbliness scale. According to the graphical dependence shown in Figure 3, an increase in the content of almond flour in the mixture reduced the fragility of the products. The analysis of physical and chemical parameters of gluten-free shortbread cookies was carried out (three model compositions (MC) of biscuits with a percentage of almond and coconut flour, respectively, 75:25, 50:50, 25:75 were studied). The experiments' findings demonstrated that altering the proportion of almond and coconut flour also altered the goods' moisture content (Table 2).

Table 2. *Results of the study of biscuit moisture content*

No. of MC	Ratio of almond and coconut flour	Moisture content of the finished biscuits
1	75:25	7.5%
2	50:50	9%
3	25:75	10.5%

Source: *developed by the authors*

Table 3 showed the results of determining the physicochemical parameters of biscuits with different contents of almond and coconut flour. In particular, such indicators as the mass fraction of sugar, the mass fraction of fat, and the wettability were determined for model compositions with different ratios of almond and coconut.

Table 3. *Physical and chemical characteristics of gluten-free biscuits*

Indicators	MC1	MC2	MC3
Mass fraction of sugar, %, not more	28.0	26.0	24.0
Mass fraction of fat, %	24.3	21.5	19.2
Wetting capacity, %, not less	170	165	155

Source: *developed by the authors*

DSTU 3781:2014 (2015) specified that the final product must have a moisture content of 5.50 ± 1.5%. The results showed that MC1's moisture content (7.5%) was the most similar to the standard. The final shortbread biscuits from MC2 and MC3 exhibited greater moisture contents (9% and 10.5%, respectively). Products' shelf life was directly impacted by their moisture content; the lower the moisture level, the longer the shelf life. To analyse the organoleptic characteristics of gluten-free shortbread biscuits, a profilogram of organoleptic evaluation of MC1, MC2, MC3 and a control sample of shortbread biscuits made on the basis of wheat flour in accordance with the requirements of DSTU 4683:2006 (2007). Methodology for determination of organoleptic quality indicators, size, net weight and components was obtained (Fig. 4).

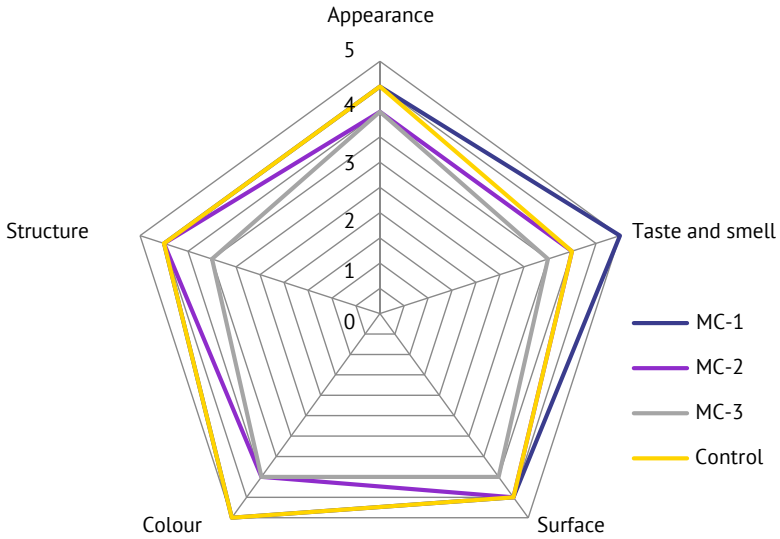


Figure 4. *Profilogram of organoleptic evaluation*

Source: *developed by the authors*

The resulting profilogram of organoleptic evaluation showed that MC1 received the highest scores for organoleptic quality indicators and was the closest in terms of organoleptic indicators to the control sample. Different proportions of coconut and almond flour in the tested samples mainly determine the taste, aroma and texture of gluten-free shortbread biscuits.

In particular, MC3, in which the percentage of coconut flour was 75%, received the lowest organoleptic scores, this sample was characterised by an overly pronounced coconut flavour, as well as a sticky structure and a dense consistency. The low starch and high fat content of coconut flour help to explain this. When developing gluten-free shortbread biscuits made with almond and coconut flour, the filling was selected. The filling was selected – cherry jam. When choosing the filling, consideration was given to the fact that it was best to choose the filling according to the distinct flavour characteristics of the ingredients, when making biscuits using non-standard types of flour. The flavours should be harmoniously combined. For almond and coconut flour, cherry flavour was a compositional match. Cherry jam adds a pleasant sour flavour and a balanced sweet taste. This combination results in good organoleptic characteristics. Table 4 displayed the organoleptic properties of the three almond-coconut shortbread biscuit test samples.

Table 4. *Organoleptic characteristics of gluten-free shortbread biscuits*

Indicators	MC1	MC2	MC3
Surface condition	Smooth, with small cracks in some places	Smooth, with cracks over the entire surface	Uneven, rough, with cracks over the entire surface
Taste and smell	There is a nutty and cherry flavour, the smell is typical for shortbread biscuits	Tangible coconut flavour, cherry flavour, smell typical of shortbread biscuits	Pronounced coconut flavour, smell typical of coconut biscuits
Colour	Light golden over the entire surface	Golden almost over the entire surface, darker at the edges, baked	Dark golden over the entire surface
Shape	Round on the entire surface, without dents and swelling	Round on the entire surface, no damage to the edges	Round, with slight deformations
View in a fracture	The product is baked, the structure is evenly porous, without cavities and signs of unprocessed products	The product is baked, the structure is evenly porous, without cavities and signs of unprocessed products	The product is baked, the structure is dense, without cavities and signs of unprocessed products

Source: *developed by the authors*

The flow chart for the production of gluten-free shortbread biscuits with cherry filling was shown in the Figure 5. The names and order of technological procedures that must be carried out in order to produce a new product were displayed in this figure. The diagram also provided information on the necessary parameters of the technological modes of the operations of the technological process of making gluten-free shortbread biscuits.

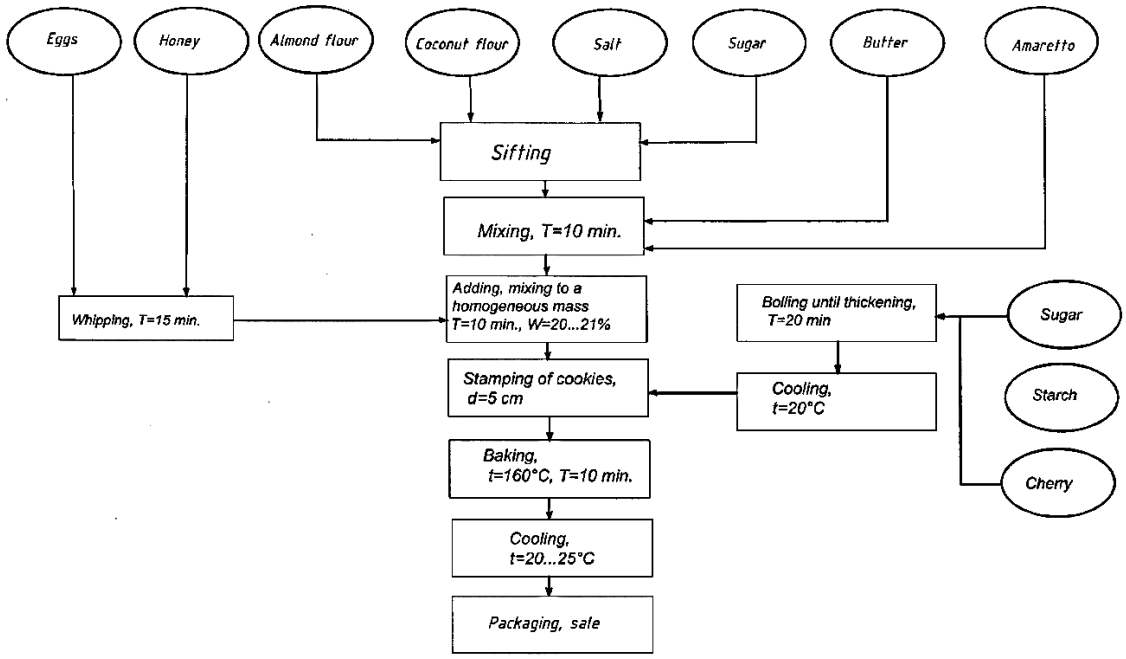


Figure 5. *Process flow diagram of gluten-free shortbread biscuits with cherry filling*
Source: *developed by the authors*

To make biscuits, the first step was to prepare the raw materials. Almond and coconut flour, salt, and sugar were sifted. Next, the eggs and honey were whisked for 15 min until the volume doubles. The jar was filled with a mixture of amaretto, sugar, salt, and almond and coconut flour. After that, the mixture was well combined. The butter was melted and added to the dry mixture and mix for 10 min. The resulting mixture was gradually added to the egg and honey mass and mixed until a homogeneous consistency was obtained. The dough obtained as a result of mixing was rolled out to a 7 mm thick layer and stamped using a round mold with a diameter of d = 5 cm. The cherry filling was obtained by cooking pitted fruit with sugar and starch. The filling was cooked for 20 min until it thickens. After cooking the cherry filling, it was cooled to a temperature of 20℃. Portions of the chilled cherry filling were placed in the center of the dough circle. After that, the dough piece was placed on a tray and baked at 160℃ for 10 min. The finished product was cooled to a temperature of 20...25℃, packaged and sold. It was more acceptable to utilise multiple types of gluten-free flour for shortbread biscuits rather than just one type since the dough and its derivatives had better structural qualities and were more biologically and nutritionally valuable. The mixture of almond and coconut flour used to make shortbread biscuits had a high content of proteins, dietary fiber, healthy fats and minerals, which made the products more nutritious and healthy than cookies made with wheat flour. Almond-coconut biscuits had a lower glycemic index than biscuits made from wheat flour and can therefore be recommended for consumers, who are sugar-conscious. The new product also had an improved flavour profile and texture. The use of almond flour in the recipe results in biscuits with a pleasant nutty flavour, while coconut flour gave the product a special coconut flavour and soft texture.

Research conducted by L. Deinychenko *et al.* (2021) discovered that adding 14.5% by weight of almond flour to the recipe for the doughy semi-finished product "Almond" for cheesecakes increased the product's protein and fat content, while decreasing its carbohydrate content. It also increased the product's zinc, potassium, calcium, magnesium, and phosphorus content. The recipe's use of flaxseed flour and vegetable raw materials allowed for the production of vegetarian-friendly biscuits with 5% more calories than the control sample.

In the study by L. Hopkin *et al.* (2022), ketogenic (low-carbohydrate) gluten-free muffins containing different amounts of almond and coconut flour were investigated for evaluation of textural and sensory properties. It was discovered that the size of the coconut flour particles affected both the product's volume and the muffin crumb's structure; specifically, a smaller flour particle size resulted in a higher product volume and a lower crumb density. It was also found that the particle size of almond flour was not significantly affect the properties of muffins, but an increase in volume was noted in products with a higher content of almond flour, and a higher content of almond flour allowed for a more delicate structure. The studied indicators of adhesion and cohesion for cupcakes showed no statistical difference after 24 hours, and during the subsequent periods of the study, these indicators were insignificant. The authors noted that muffins containing almond flour

contain more moisture and were more tender. Therefore, according to the authors, almond and coconut flours were good substitutes in gluten-free ketogenic muffins, with almond flour providing better results in the parameters evaluated.

The study by A. Bravo-Núñez *et al.* (2019) examined, how protein blends (egg white, whey protein, and pea protein) affected the physical properties of dough and baked gluten-free cakes after substituting 45% of the flour. The addition of new ingredients affected the hardness of the products. The study by H.N. Ramya & S. Anitha (2020) was aimed at investigating the effect of adding honey and different percentages of coconut flour on the quality of cupcakes. In particular, four samples of cupcakes were studied, such as T1 (0% coconut flour content), T2 (5% coconut flour content), T3 (15% coconut flour content) and T4 (25% coconut flour content). Cupcake sample T4 was found to have the finest chemical and physical characteristics. The cupcake samples' sensory qualities were enhanced by adding 25% coconut flour to the batter, which also raised the cupcakes' nutritional content.

In the research by L. Polozhyshnikova *et al.* (2023), rice flour (RF) and coconut flour (CF) were selected as new recipe components for the manufacture of flour confectionery. It was determined that obtaining finished products of the required quality can be achieved by using a composition based on the ratio of RB:CB – 50:50%. The paper by Y. Matsuk *et al.* (2019) scientifically substantiated the recipes and technologies of gluten-free muffins made on the basis of buckwheat and rice flour using chia seeds. The products were characterised by high quality and long shelf life.

The study by Z. Saeidi *et al.* (2018) sought to ascertain, how the physicochemical, sensory, and textural characteristics of a gluten-free rice flour cake were affected by the addition of pomegranate seed powder (0-50%) and transglutaminase enzyme (0-1.2%). The study's findings demonstrated that adding these elements improved the fiber content, ash content, and porosity. The article by O. Shapovalenko *et al.* (2020) discussed the conditions for the use of gluten-free flour obtained from coconuts and brown rice in the technology of gluten-free chocolate muffins. It was found that the complete replacement of wheat flour with the proposed mixture with a ratio of 40:60 (coconut flour to brown rice flour) allowed to achieve the best sensory characteristics.

The authors M. Sahagún *et al.* (2018) examined, how the proteins – rice, peas, egg white, and whey – affected the properties of gluten-free layer cakes. The scientists investigated the qualities of gluten-free cake and examined the dough's density, viscosity, and moisture parameters. Whey protein cakes had the highest acceptance rates among the evaluated samples. M. Kravchenko *et al.* (2021) confirmed the use of a walnut and sesame meal composition to enhance the nutritional qualities of shortbread cookies, which maintained their flavour and odour for 45 days since the higher vitamin E concentration slowed down oxidative processes.

M.H.F. Felisberto *et al.* (2019) evaluated the impact of partial replacement (15%) of wheat flour with young bamboo flour in biscuit recipes. The authors noted positive changes in the characteristics of the new product. Research by M.M. Sanchez-Rivera *et al.* (2019) found a positive effect of plantain flour in the biscuit recipe on the carbohydrate nutritional properties of the product. The study of the properties of fruit fillings was conducted by O. Hrabovska *et al.* (2020). The ability of fillings to maintain the organoleptic, physical, and chemical characteristics of baked goods for the duration of their shelf life was one of the primary needs for flour confectionery items. Therefore, in order to achieve the required properties of heat resistance, viscosity, and harmony of taste, the fruit filling was improved by using stabilising compositions of pectin and modified starch. Thus, the targeted search for innovative solutions for the production of gluten-free flour products in many cases results in a healthy food product with high quality indicators.

Conclusions

A technological plan for making gluten-free shortbread biscuits with cherry filling was created as a result of the study. The resultant biscuits, which had a high protein, dietary fiber, healthy fat, and mineral content, were produced with a blend of almond and coconut flour. The biscuits created by the cutting-edge technology were a result of comprehensive and healthful nourishment because of their qualities.

Model compositions of the new product with different contents of almond and coconut flour in the recipe were studied (for MC1 this ratio was 75:25, for MC2 – 50:50, and for MC3 – 25:75). The physical and chemical parameters for the developed model compositions were determined. Specifically, it was discovered that MC3 had the highest moisture content (10.5%), while MC1 had the lowest and most comparable moisture content (7.5%). The shelf life of biscuits was mostly dictated by their moisture content; the lower the moisture content, the longer the shelf life. The highest fat content was in MC1 (24.3%) and the lowest in MC3 (19.2%), and the wettability index was the highest for MC1 (170) and the lowest for MC3 (155). It was also found that the brittleness of gluten-free shortbread biscuits depended on the content of each type of flour in the biscuit recipe. In particular, with an increase in the content of almond flour from 10% to 50%, the brittleness of the biscuits decreases from 89% to 83%.

According to the results of the expert evaluation, MC1 was characterised by the best organoleptic characteristics (and the closest to those of the control sample), and the lowest scores were given to MC3. Thus, MC1 of gluten-free shortbread biscuits proved to be the

best in terms of its performance, and accordingly, the technology of preparing products according to this recipe was the most promising for recommending the production of nutritious and healthy food products. Fruit fillings using hydrocolloids look promising as a filling for gluten-free shortbread cookies.

So, the growing demand for gluten-free products and the need to expand the range of such products, the development of new innovative ingredients require a wider range of research aimed at developing new technological approaches, the use of which will allow to obtain a new high-quality product for healthy eating. Promising direction for solving the analysed problems is to study the properties of gluten-free flour mixtures in combination with innovative ingredients.

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Conflict of Interest
None.

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Розробка технології та дослідження властивостей безглютенового пісочного печива

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Анотація. Кількість людей з непереносимістю глютену зростає в сучасному світі, що вимагає створення спеціалізованих продуктів, здатних задовольнити їхні потреби. Метою дослідження було розробити рецептуру безглютенового пісочного печива з вишневою начинкою. Дослідження проводилося із застосуванням експертного методу, сенсорного аналізу та статистичних методів обробки дослідницьких даних. Для досягнення цієї мети було запропоновано використовувати суміш мигдального та кокосового борошна як сировину для пісочного печива. Визначено, що розробка безглютенових продуктів вимагає впровадження інноваційних технологій, використання альтернативних інгредієнтів та аналізу властивостей сировини й готової продукції. Було розроблено різні модельні склади пісочного печива на основі сумішей мигдального та кокосового борошна у різних пропорціях (МС1 – 75:25, МС2 – 50:50, МС3 – 25:75). Проведено сенсорний аналіз модельних складів безглютенового пісочного печива та визначено їх органолептичні характеристики. У результаті досліджень отримано сенсорну профілограму модельних складів пісочного печива, яка дозволяє визначити, який склад характеризується найкращими показниками (було встановлено, що МС1 мав найкращі показники). Також визначено індекс крихкості безглютенового пісочного печива залежно від вмісту мигдального борошна у суміші. Визначено фізико-хімічні параметри різних модельних складів безглютенового пісочного печива та проаналізовано результати цих досліджень. Розробка безглютенового пісочного печива з вишневою начинкою дозволяє розширити асортимент борошняних кондитерських виробів оздоровчого спрямування

Ключові слова: глютен; мигдальне борошно; кокосове борошно; вологість; органолептична оцінка; харчова цінність