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Development of flour-based confectionery products with increased nutritional value based on triticale flour

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Abstract. The relevance of the research is in the potential use of triticale with increased protein and mineral content to expand the ingredient base of flour confectionery products technology. The aim of the study was to investigate the quality indicators of flour confectionery products, specifically sponge cakes, in recipes of which wheat flour was replaced with triticale flour and whole milk powder as a protein enricher. Using statistical methods to analyse experimental data, samples of each type of product with different concentrations of whole milk powder (ranging from 5 to 25%) were examined. It was concluded that the developed sponge cake recipes provide a degree of satisfaction for the average daily intake of iron – 29.21%, calcium – 95%, potassium – 40%, magnesium – 50%, phosphorus – 100%, and more; B-group vitamins – 18-80%. Compared to the control sample, the biological value is increased to 71%; the energy value is reduced by 426 kJ. The absence of egg melange in the developed product recipes allows for a 97% reduction in cholesterol content, categorising these products as dietary. The best samples and optimal dosages of whole milk powder were determined: 15% by the weight of flour during sponge cake production. The functional purpose of triticale flour was theoretically and practically confirmed, yielding new results on the dependence of dough structure formation process on technological production parameters and recipe components. A recipe for sponge cakes of increased nutritional and biological value based on triticale flour has been developed, involving the addition of enrichers such as whole milk powder and the exclusion of egg melange from the recipe. The obtained results can be utilised in the confectionery industry to create new products that meet modern trends in nutrition and cater to consumers who value higher nutritional content and healthy food composition

Keywords: sponge cakes; winter triticale; quality; functional product; expert analysis

Introduction

Flour confectionery products (FCPs) are among the most popular items, as they are purchased by nearly the entire population of Ukraine, the majority consume them on a regular basis, often at least once a week. Due to their high demand among the population, FCPs are perspective targets for enrichment with functional ingredients. In the quest to expand the ingredient base in the technology of flour confectionery products, one of the perspective crops is triticale, known for its increased content of complete protein, making the

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product more nutritious, as well as its rich mineral content, including essential elements like iron, magnesium, and zinc, crucial for consumers' health, and its high resistance to fungal diseases.

Studies by S.A. Bazhay-Zhezherun & L.V. Bereza-Kindzerska (2020) and V. Liubych *et al.* (2021) in the food industry are aimed at substituting wheat flour with new alternatives from resilient sources to combat a range of illnesses in the population. Celiac disease, wheat allergy, and gluten sensitivity are among the most common diseases associated with gluten content in wheat. Literature analysis regarding the protein value and amino acid composition of flour products has revealed significant deficiencies in three crucial essential amino acids – lysine, threonine, and methionine – in wheat flour products. According to S.A. Bazhay-Zhezherun *et al.* (2022), alongside the imbalance of essential amino acids in flour products, there is a sharp disproportion in their ratio with non-essential amino acids. Thus, scientific research aimed at finding suitable alternatives by introducing new ingredients is relevant and meets consumers' needs.

Of particular interest is the application of triticale flour instead of wheat flour in FCP technology. Firstly, triticale differs by having a higher content of the essential amino acid lysine per gram of protein, a high content of riboflavin, thiamine, certain macro- and microelements, and secondly, it possesses better technological properties for these types of products, as it contains less weak gluten (Fraś *et al.*, 2021).

Research on triticale grain and its application in processing and food industries has been ongoing in Ukraine and abroad for a long time. However, the use of triticale flour specifically in FCP production has been poorly studied. Despite positive experiences with triticale research as a component of animal feed, flour for bakery products, and its wide application, this crop has not gained traction. Additionally, the most perspective and optimal triticale varieties in terms of technological process management for flour production have not been fully investigated, nor their milling and baking properties (Aprodu *et al.*, 2019; Aragüez *et al.*, 2020).

One of the main factors restraining the growth of triticale grain production volumes of new varieties in Ukraine is the lack of clear recommendations for the final use of its processing products. The advantages of triticale grain as a biologically valuable raw material for the food industry are underestimated. Existing triticale flour production technologies do not fully exploit the potential of the n due to the scarcity and inconsistency of recommendations regarding the organisation and management of its processing technology (Hospodarenko *et al.*, 2019).

The market for flour confectionery products (FCPs) in Ukraine is expanding with each passing year. This development is not only characterised by an increase in the diversity of product offerings but also by an active expansion of assortments, particularly in the case of sponge cakes. Manufacturers are increasingly introducing a rich variety of flour confectionery products to the market. This trend reflects the growing interest of modern consumers in product variety and their desire to explore new tastes and combinations. Such an approach by manufacturers stimulates demand for flour confectionery products and contributes to the overall competitiveness of the Ukrainian market. The aim of this article was to analyse, develop, and scientifically substantiate the technologies for enriched flour confectionery products by refining the technological process of producing sponge cakes from triticale flour and enrichers.

Materials and methods

The object of study in this article was the process of manufacturing high-nutritional-value sponge cakes based on triticale flour with the addition of non-fat dry milk as a protein enricher. The methodological basis of the research, conducted at Lutsk National Technical University during 2022-2023, involved a comprehensive approach to solving tasks related to the development of technology for flour confectionery products based on triticale flour and enrichers to obtain products of increased nutritional value, modern physicochemical methods of raw material, semi-finished product, and product analysis, and mathematical processing of experimental data.

The quality assessment of triticale flour was conducted based on organoleptic and physicochemical parameters (Table 1).

Table 1. *Triticale flour quality indicators*

Indicator	Value of indicators
Organoleptic	
Colour	White with yellowish tint
Taste	Peculiar to triticale flour, without foreign taste
Crispiness	Is not detected
Physical and Chemical	
Moisture, %	13.9
Mass fraction of crude, %	16.4
Falling number, "FN", s	321
Metal and magnetic impurities, mg per 1 kg of flour	Absent
Infection by pests	is not found

Source: *developed by the authors based on the sources of A. Fraś et al. (2018), V. Liubych et al. (2022)*

Scheme for the production of sponge cakes is presented in Figure 1.

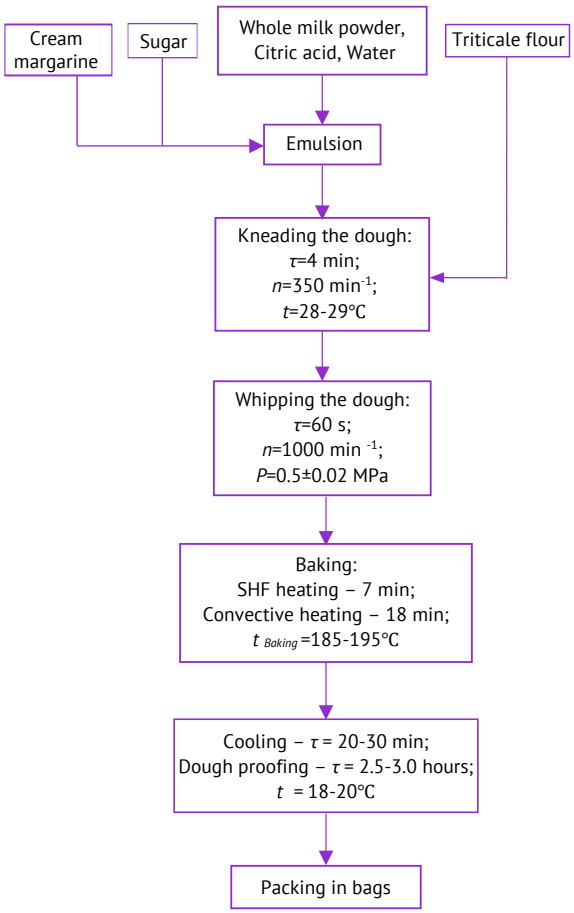

Figure 1. *Structural scheme for the production of sponge cakes from triticale flour*
Source: *developed by the authors*

To prepare the experimental samples of sponge cakes, mixing was carried out with triticale flour and a solution containing reconstituted whole milk powder, citric acid, and water, resulting in a dough with a moisture content of 40% for 2 minutes. Then, sugar was added, and the dough was further mixed for 1 minute. Subsequently, cream margarine was added, and mixing of the dough continued for another 1 minute. The total mixing time amounted to 4 minutes (Table 2).

Table 2. *Sponge cake recipe from triticale flour and whole milk powder*

Name of raw material	Consumption of raw material
Triticale flour, kg	370.0
Sugar, kg	330.0
Cream margarine, kg	150.0
Whole milk powder, kg	150.0
Citric acid, kg	2.0
Flavouring agent-vanillin, kg	0.3
Water, kg	According to calculations
Product output	1000.0

Source: *developed by the authors*

After the mixing process, the dough is unloaded, and dough pieces weighing 300-350 g are formed from it. Then the dough in the molds is heated to 100°C using microwave heating for 7 minutes and baked at a temperature of 185-195°C using convective heating for 20 minutes. After baking, the finished sponge cakes are cooled to a temperature of 30-35°C on a conveyor directly from the oven. This method of cooling prevents product deformation. In the first 3 minutes, the sponge cake cools without forced air circulation, and in the next 3 minutes, with forced air circulation at a speed of 3 m/s. After this, the sponge cake is packaged.

To obtain recommendations regarding the dosage of whole milk powder in this technology, the effect of different dosages of non-fat dry milk on the quality indicators of the dough and finished sponge cakes made from triticale flour was studied. The research included studying the effect of various concentrations of whole milk powder on the texture of the dough, crispiness, structure, and taste of the finished sponge cakes. Various ratios between triticale flour and whole milk powder were used, as well as control samples with different dosages. Based on the research results, optimal dosages of whole milk powder will be recommended to achieve the best quality indicators of the dough and sponge cakes. This approach will improve the production process and ensure stable product quality. During the research, whole milk powder (WMP) was added in dosages ranging from 5 to 25%, and quality indicators of the dough and finished sponge cakes were determined.

Results and discussion

To develop a competitive technology for producing sponge cakes with increased nutritional and biological value, it is necessary to search for new inexpensive raw material sources – enrichers and to improve the processes of dough preparation. The selection of raw materials and enrichers is based on their positive impact on the human body.

WMP is a source of animal proteins and contains all the necessary minerals and vitamins essential for human life, present in an ideally balanced, easily absorbable form. Cream margarine has the best emulsifying ability and is suitable for use in sponge cake recipes. Citric acid acts as an acidity regulator, a preservative for food products, and improves metabolism, which can positively affect weight loss. The justification for the choice of raw materials and enrichers used in sponge cake production confirms their potential for obtaining new products enriched with essential nutrients.

Upon analysing the chemical composition of the raw materials and enrichers, it should be noted that the selection of this type of raw material is expedient for the development of sponge cake technology, as it reduces sugar content and increases nutritional and biological value. The biologically active substances present in the aforementioned raw materials have a favourable effect on human body processes. Considering the presence of

a protein fraction in dry milk, it acts as an emulsifier and accelerates the foaming process. The data from the conducted research are presented in Table 3.

Table 3. *The effect of the introduction of milk powder on the quality of dough from triticale flour*

Name of indicator	Value of indicators in the samples with the introduction of milk powder, %				
	5	10	15	20	25
Bulk weight, g/cm^3	0.65	0.59	0.53	0.56	0.54
Titrated acidity, degrees	1.73	1.72	1.75	1.82	1.80

Source: *developed by the authors*

Adding milk powder in the amount of 5-25% has been found to reduce the volume mass of the dough due to the lactose in milk, which inhibits the foaming process but stabilises the foam. It has been determined that milk powder acts as an adsorbent, binding water and contributing to increased dough viscosity. Experimental samples of biscuits with this enrichment agent differed by having a smooth surface, absence of ruptures and cracks, with uniformly thin porosity. This can be explained by the increase in dough viscosity and the decrease in pressure inside the bubbles. Studies have shown that the application of WMP improves the organoleptic and physicochemical quality indicators of products (Table 4).

Table 4. *The effect of the introduction of whole milk powder on the quality indicators of sponge cake from triticale flour*

Name of indicator	Value of indicators in the samples with the introduction of whole milk powder, %				
	5	10	15	20	25
Organoleptic					
Shape	Corresponds to the form in which baking was carried out				
Surface	Smooth, not burnt				
Colour	Brown				
Crumb condition					
Baked condition	Baked				
Porosity	Fine homogeneous				
Taste and smell	Weakly expressed, peculiar to the given kind of product		Strongly expressed, peculiar to the given kind of product		
Physical and Chemical indicators					
Moisture, %	24	27	29	30	32
Porosity, %	58	74	62	78	82
Specific volume, cm^3/100 g	178	184	188	180	186

Source: *developed by the authors*

Following the conducted research, the optimal dosage of WMP at 15% has been established, leading to an improvement in biscuit quality across all indicators, based on which a recipe for triticale flour biscuits has been developed. In their work, author F. Zhu (2018) summarises the latest achievements in the nutritional composition and diverse utilisation of triticale in food products. The author also identifies that the chemical composition of triticale flour is highly diverse, indicating the potential of triticale as an alternative to whole grain flour in food and beverage production. Schemes for processing triticale grain into high-quality baking flour have been developed and analysed by authors I. Piazza *et al.* (2023) and J. Kaszuba *et al.* (2024), confirming the quality of the final product obtained in this study. Analysis of the chemical composition of grain, flour, and bread of various triticale varieties conducted by S.A. Siddiqui *et al.* (2022) demonstrates that grains of some modern triticale varieties with favourable chemical composition from a technological and nutritional perspective are suitable raw materials for flour and bread production, affirming the potential use of triticale flour in biscuit production. F. Eudes (2015) investigated triticale considering the influence of biotechnological factors crucial for agriculture, feed cultivation, food production, and industrial applications.

Flour-based confectionery products, traditional in many countries, are deficient in micronutrients and vitamins. Enhancing their nutritional and biological value can be achieved by fully or partially replacing wheat flour with triticale, rich in all necessary nutrients, as indicated by the research of S.V. Vasiliev (2018) and A.V. Sachko *et al.* (2020). According to some scientists, its application, due to the low gluten content, is possible for a limited range of confectionery products (sugar, oat, coconut, and chocolate cookies). Particularly, the study by V. Liubych *et al.* (2021) examined the quality formation of cupcakes made with triticale (baking, settling, moisture, volume, porosity), enriched with pumpkin paste. This study confirmed the feasibility of using triticale for the production of gingerbreads, cookies, muffins, and biscuits, as well as the influence of pumpkin paste on product quality. A. Fraś *et al.* (2018) developed a new healthy triticale-oat bread by replacing as much wheat flour as possible with a high-fiber triticale-oat concentrate without compromising the technological quality of the bread, resulting in a food product with high fiber content (over 6 g per 100 g) and increased levels of dietary fiber. A. Torbica *et al.* (2019) investigated the rheological properties of a mixture of whole wheat and whole grain triticale flour for pasta production and provided optimal ratios for obtaining high-quality

flour blends. Authors S. Kalnina *et al.* (2015) studied the rheological characteristics of mixed compositions of wheat and triticale flour for use in pasta production, demonstrating that an increase in whole grain flour deteriorates the rheological properties of the dough. Research by H. Woś & W. Brzeziński (2015) allowed for the identification of biologically activated triticale grain as a source of valuable nutrients and its potential use in creating functional pastry mixtures.

In the works of H. Woś & W. Brzeziński (2015), A.V. Zagrychanska & V.Ya. Golyuk (2021), various plant additives and malt flour are used as enrichments to obtain bakery products with increased nutritional and biological value from triticale flour. Products obtained using plant-based additives are of interest in terms of their chemical composition and may be considered therapeutic and prophylactic products. In this study, the following ingredients were chosen as enrichments for the development of triticale flour biscuits: triticale flour, WMP, cream margarine, and citric acid.

Therefore, the use of WMP in the recipe for triticale flour biscuits resulted in a product of functional purpose with excellent taste quality. This is because milk lactose, which inhibits the growth of harmful bacteria, promotes the maintenance of healthy gut flora and stimulates better absorption of micro- and macro-elements in its walls. The nutritional value of the product was determined based on a combination of properties. Their presence indicates the satisfaction of human physiological needs for necessary substances and energy. The main characteristic of the nutritional value of the product is its chemical composition (proteins, fats, carbohydrates, vitamins, macro- and microelements). At the same time, its consumption in commonly accepted quantities is taken into account, as well as its energy and biological value.

To determine the nutritional and biological value, as well as the degree of satisfaction of the daily human nutrient requirements, the chemical composition of the obtained triticale flour biscuits per 100 g was calculated (Table 5).

Table 5. *Degree of satisfaction of the daily human nutrient requirements*

Name of component	Daily requirement	Value of indicator in finished products per 100 g			
		Sponge cake from wheat flour	Degree of satisfaction, %	Sponge cake from triticale flour	Degree of satisfaction, %
Proteins, g	75	9.9	13.2	11.6	15.5
Fats, g	83	25.1	30.2	20.6	24.8
Carbohydrates, g	365	44.56	12.2	46.1	12.6
Dietary fiber, g	30	11.5	38.3	13.3	44.3
Minerals, mg:					
Potassium	3500	325.5	9.3	1470	42
Calcium	1000	43	4.3	1062	106.2
Magnesium	400	40.8	10.3	206	51.5
Phosphorus	1000	215	21.5	1610	161
Iron	14	4.7	33.6	3.4	24.3
Vitamins:					
E, mg	10	5.21	552.1	0.9	9
C, mg	70	–	–	–	–
B_6, mg	2.0	0.45	22.5	0.73	36.5
B_3, mg	20	0.58	2.9	3.6	18
B_2, mg	1.8	0.5	27.8	1.5	83.3
B_1, mg	1.5	0.4	26.7	0.65	43.3
Amino acids:					
Valine	2500	880	35.2	1822.5	72.9
Isoleucine	2000	690	34.5	1812	90.6
Leucine	4600	1283.4	27.9	2539.2	55.2
Lysine	4100	4679.7	11.7	1836.8	44.8
Methionine	1800	423	23.5	1054.8	58.6
Threonine	2400	508.8	21.2	1567.2	65.3
Tryptophan	800	144.8	18.1	507.2	63.4
Phenylalanine	4400	1130.8	25.7	3291.2	74.8
Biological value, %		57.55		71	
Energy value, kcal/kJ	2500/ 10475	598.8/ 2508.9	23.9	497/ 2079	19.9

Source: *developed by the authors*

Upon analysing the chemical composition of biscuits made from triticale flour, certain differences were observed compared to products made from wheat flour. As evident from the data, the content of B-group vitamins

(B1, B2, B3, and B6) increases compared to control samples, indicating an improvement in their nutritional and biological value. However, vitamin E shows a significant decrease due to the absence of egg melange in the composition. Additionally, an elevated content of mineral elements such as calcium (Ca), phosphorus (P), magnesium (Mg), and potassium (K) was noted in sponge cakes made from triticale flour with the addition of WMP. This indicates an increase in the satisfaction level of human daily nutrient requirements for minerals. Such changes in the composition of sponge cakes may affect their nutritional value and usefulness for the body.

Conclusions

Studying the technologies of using triticale flour, with its increased protein and mineral content, is relevant for expanding raw material ingredients in the production of flour-based confectionery products. The research focused on studying the quality indicators of sponge cakes made from triticale flour with the addition of whole milk powder, which acted as a protein enricher. The conducted studies indicate the feasibility of using triticale flour in the production of flour-based confectionery products, as it allows for obtaining high-quality products with increased protein value and vitamin content, particularly B-group vitamins, macro- and microelements. According to the obtained results, it has been proven that triticale flour can be used to replace higher-grade wheat flour in biscuit production. All samples made from mixtures of triticale flour with varying proportions of whole milk powder, as well as those made from 100% triticale flour, had excellent appearance. The addition of whole milk powder in amounts of 5-25% resulted in a decrease in the volume of dough, and these biscuit samples had a smooth surface and uniform porosity. Using triticale flour instead of wheat flour provides sponge cakes with high sensory characteristics, higher nutritional and biological value due to increased vitamin, macro- and microelement content, protein, and essential amino acids. Protein biological value analysis revealed that sponge cakes made from triticale flour have two times higher scores for threonine and valine, and four times higher scores for isoleucine, lysine, and tryptophan, providing significant consumer advantages to the resulting product.

A priority direction for further development of technological processes in the production of flour-based confectionery products is the search for technologies to produce products with increased nutritional and biological value using non-traditional types of flour and enrichers, which will expand the range of functional food products in general.

Conflict of interest

None.

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None.

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Розроблення борошняних кондитерських виробів підвищеної харчової цінності на основі борошна тритикале

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Анотація. Актуальність дослідження полягає у можливості використання тритикале з підвищеним вмістом білка та мінеральних речовин, для розширення інгредієнтів сировинної бази технології борошняних кондитерських виробів. Метою роботи було дослідження показників якості борошняних кондитерських виробів, зокрема бісквітів, в рецептуру яких було внесено шляхом заміни борошно тритикале та сухе незбиране молоко в ролі білкового збагачувача. За допомогою методів статистичної обробки експериментальних даних було проведено аналіз зразка кожного виду виробу з різною концентрацією сухого незбираного молока (дозування від 5 до 25 %). Зроблено висновок, що розроблені рецептури бісквітів забезпечують ступінь задоволення середньодобової норми споживання заліза – 29,21 %, кальцію – 95 %, калію – 40 %, магнію – 50 %, фосфору – 100 % і більше; вітамінів групи В – 18-80 %. У порівнянні з контрольним зразком біологічна цінність підвищується до 71 %; енергетична цінність знижується на 426 кДж. Відсутність яєчного меланжу в рецептурах виробів, що розробляються, дає можливість знизити частку холестеролу на 97 %, і віднести ці вироби до групи дієтичних продуктів. Було визначено найкращі зразки та оптимальні дозування сухого незбираного молока: 15 % до маси борошна під час виробництва бісквітів. Теоретично та практично підтверджено функціональну спрямованість борошна тритикале, отримано нові результати залежності процесу структуроутворення тіста від технологічних параметрів виробництва та рецептурних компонентів. Розроблено рецептуру бісквітів підвищеної харчової та біологічної цінності, на основі борошна тритикале, що передбачає внесення збагачувачів, зокрема незбираного сухого молока та виключення з рецептури яєчного меланжу. Отримані результати можуть бути використані в кондитерській промисловості для створення нових продуктів, які відповідають сучасним тенденціям у харчуванні та споживачам, що цінують вищу харчову цінність та здоровий харчовий склад

Ключові слова: бісквіти; тритикале озиме; якість; функціональний продукт; експертний аналіз