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STUDY OF THE IMPACT OF CHICKPEA FLOUR BLEND ON BISCUIT SEMI-FINISHED PRODUCTS

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Abstract. *This research is focused on improving the production technology of biscuit semi-finished products by incorporating chickpea flour. The work analyzes improving the nutritional and physicochemical qualities of the products, using mathematical modeling and data analysis in Mathcad to guide the process.*

The aim of the research *is to enhance the quality of biscuit products by substituting some of the wheat flour with chickpea flour, while also identifying the ideal technological parameters that will make the product more attractive to consumers, especially those who prioritize healthy eating.*

Mathematical modeling methods, such as regression analysis, were used in the study to process experimental data. This allowed us to find the optimal combinations of ingredients and improve the technological process to produce high-quality biscuit semi-finished products. The study demonstrates how the use of chickpea flour can not only enhance the product's nutritional value – by increasing its protein, fiber, and mineral content – but also improve its taste, texture, porosity, and longer freshness.

The main ***novelty of the research*** *is the application of modern mathematical modeling methods to refine the recipe and production processes for biscuit semi-finished products, making them competitive in the market, especially for those who choose healthy eating options.*

Analysis of the experimental data shows that the addition of legume flour leads to significant improvements in the organoleptic and nutritional properties of the biscuit product.

The results of the study *show that the optimized recipe provides a product with desirable organoleptic properties, such as taste, texture, and color, while also contributing to overall health improvement. Furthermore, the regression modeling used to determine optimal parameters ensures both economic efficiency and product quality, making it promising for mass production. The conclusions of this study open up new opportunities for the development of healthy and economically efficient food products that align with current dietary trends.*

Key words: *biscuit semi-finished product, legume flour, mathematical modeling, nutritional properties, product optimization.*

Problem Statement. The art of creating flour-based confectionery products has a centuries-old history, with its roots tracing back to ancient times. Archaeological research indicates that more than 10,000 years ago, Neolithic settlements produced flatbreads resembling modern cookies. The first dough-based products began to emerge when humans learned to grind grain into flour. Cakes became widely popular with the discovery of sugar. Historians believe that cane sugar was first produced in India, from where it spread to Arab countries. In these regions, it was harmoniously combined with aromatic spices and seasonings brought from the Far East. In the 17th century, chefs began using whipped egg whites instead of yeast, marking a significant step in the creation of light sponge cakes, which later became part of the culinary heritage of many European countries.

Sponge-based confectionery products are among the most popular types of baked goods due to their delicate texture, pleasant taste, and versatility in use. However, modern trends in the food industry, driven by the growing demand for healthy eating and functional products, encourage advancements in sponge cake production technologies. One promising direction is the use of plant-based raw materials, which not only enhance the nutritional value but also improve the sustainability of production.

Plant-based raw materials, such as cereals, legumes, nuts, fruits, vegetables, and dietary fibers, contribute to the enrichment of sponge-based products with biologically active compounds, including vitamins, minerals, antioxidants, and fiber. This enables the creation of high-value-added products tailored to various consumer categories, including individuals with specific dietary needs.

Domestic scientists continuously identify promising directions for the development and improvement of sponge-based confectionery products. Notable research has been conducted on the assortment and modern production technologies of sponge cakes. According to these studies, the production of confectionery products using advanced sponge cake varieties in Ukraine has reached a new, higher professional level.

An analysis of sponge cake consumption in the diets of Ukrainians [1] and market monitoring of its sales both in Ukraine and abroad [2] indicate the significant production and export potential of Ukraine's confectionery industry, the growing demands of consumers, and the increasing competition in the sponge cake market.

In addition to traditional ingredients (premium wheat flour, chicken eggs, white sugar, table salt, and baking soda), sponge cake formulations include emulsifiers, stabilizers, texture modifiers, as well as flavoring, functional, and other food components. These additives enhance the sensory properties of the products, improve their nutritional and physiological value, and expand the assortment within this category.

In particular, there are technologies for producing sponge cake semi-finished products that involve replacing wheat flour with buckwheat flour and substituting chicken eggs with chickpea broth. Other technologies propose replacing 10 % of wheat flour with starch, semolina, and/or corn semolina, oat flakes, or buckwheat flakes, as well as using gluten-free flours (rice, corn, buckwheat) [3]. Additionally, up to 15 % of dry ingredients can be substituted with carrot purée, and 8–15 % of ground sunflower seeds can be incorporated into the overall formulation, fully replacing butter.

Another popular method for improving sponge cake formulations is the introduction of new unconventional animal-derived ingredients or the partial replacement of traditional ingredients with them. A significant contribution to this field was made by Prof. H. V. Deinichenko and other researchers from Kharkiv State University of Food Technology and Trade (now State Biotechnological University). They proposed replacing 9–11 % of wheat flour with whey protein concentrate obtained through ultrafiltration.

There are also studies by domestic scientists focusing on the technological processes of producing both low-prepared semi-finished products and fully baked sponge cakes. For example, a known method of sponge cake production involves pre-cooling the egg-sugar mixture to (+3…+5) °C and maintaining it at this temperature for 2–3 hours, while the flour is made from wheat grains treated with a pulsed electromagnetic field for 1–2 days [4]. Additionally, there is a technology for cooling sponge cake semi-finished products under vacuum, and research has been conducted on the impact of mixer design parameters on the foaming process. International colleagues have studied the effects of ingredients on dough rheology, the physical and textural properties of sponge cakes, and have also modeled heat and mass transfer processes during baking [5].

Food science also recognizes other methods for improving sponge cake production technology, which involve the use of components derived from advanced technological processing of plant- or animal-based raw materials, such as protein isolates and concentrates, nanopowders, synthetic gluten-free substances, and extracts. For instance, there are technologies where the phytocomposite "Zhemchug" [6] is used as an emulsifier, stevioside serves as a sweetener, and elamin acts as a stabilizer [7].

Dikhtiar A. M. and his colleagues suggest using a fat semi-finished product based on high-oleic sunflower oil, with the addition of beeswax and monoglyceride in the sponge cake formulation [8]. Shidakova-Kamenyuka O. H. and other researchers recommend adding egg shell powder at a ratio of 5–5.5 % of the flour weight [4], while Aarabi F. and Seyedain Ardebili M. propose using acrylamide in the industrial rotational molding process of sponge cake [9]. Xu J. and his colleagues are studying the use of extracts from wild plants in the production of gluten-free sponge cakes [10].

Based on the analysis of the literature, further research in the direction of improving the technology of sponge cake semi-finished products using plant-based raw materials, particularly superfoods, holds scientific and practical significance and is highly relevant. In this regard, we propose the use of a derivative product from chickpea seeds – flour made from this legume.

Based on the analysis of the scientific and technical literature dedicated to theoretical and practical approaches to improving the technology of sponge cake semi-finished products, it has been established that in order to enhance its nutritional and biological value, the search for new types of raw materials with an improved chemical composition is relevant. Additionally, to improve the quality indicators of the product, it is advisable to develop technological measures aimed at optimizing the processes that occur during the stage of ingredient whipping.

Research Results. It is well known that flour from chickpeas is a valuable addition to wheat flour, enhancing the nutritional value and functional properties of food products. Its use enriches baked goods with protein, fiber, vitamins, and minerals, contributing to increased nutritional benefits. The incorporation of flour from chickpeas affects the rheological properties of dough, particularly altering its viscosity, elasticity, and water absorption capacity. The final products acquire a characteristic nutty flavor, a yellowish color, and a more pronounced satiety effect. Due to the presence of flour from chickpeas, the glycemic index of the finished product is reduced, making it more suitable for a healthy diet. However, a high proportion of flour from chickpeas in the formulation may alter the texture and volume of the products, making it essential to optimize the ratio in combination with wheat flour. Therefore, it was decided to study the addition of flour from chickpeas based on gluten ball spread tests, and the

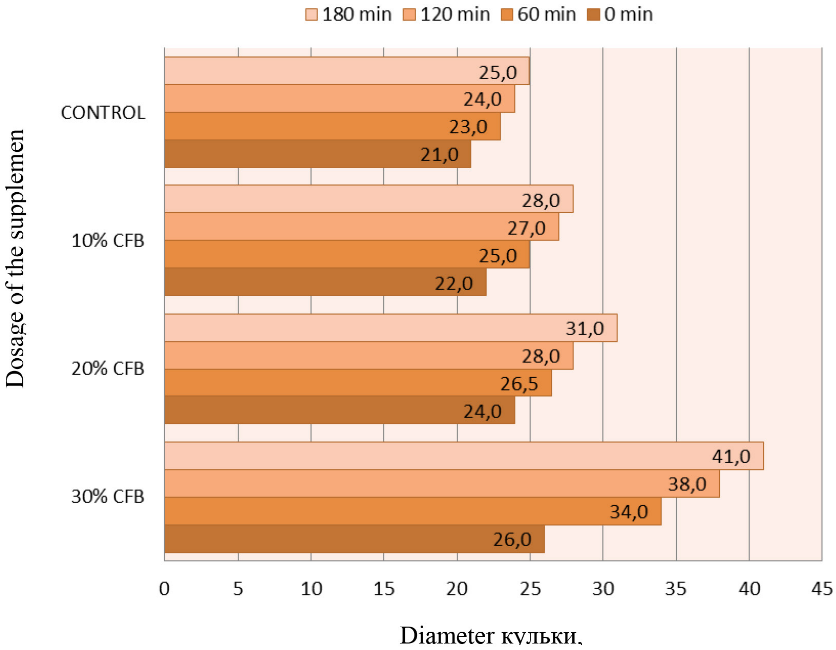

Fig. 1. Kinetics of CFB influence on gluten ball spread

obtained results confirm the findings of the reviewed literature sources.

The extensibility of the samples increases with the higher dosage of chickpea flour blend (CFB), ranging from 20.7 % to 34.2 %. This is due to the disruption of the gluten network integrity as CFB particles distribute between the flour particles.

The study of gluten ball spread (Fig. 1) indicates its relaxation.

Specifically, when CFB is added to the flour mixture in amounts of 10.0–20.0 %, a decrease in gluten elasticity by 6.4–19.3 % is observed compared to the control sample. It was found that the gluten ball spread index after 180 minutes in samples with CFB increased by 1.1–1.4 times and 1.3–1.9 times, respectively, compared to the control.

A deterioration in the water absorption capacity of dough with chickpea flour blend (CFB) is observed, along with an increase in dough formation time, a decrease in stability, and a higher degree of thinning under mechanical processing. This is explained by the competition for moisture absorption between the dietary fibers in the additives and the flour biopolymers, as well as the dehydrating effect of the sugars present in the additives.

The dough moisture content remained practically unchanged, as the functional and technological properties of the additional components were accounted for in advance. During their incorporation into the formulation at the mixing stage, the process of adding liquid ingredients to the dough was simultaneously adjusted.

Chickpea flour is a promising addition for biscuit production due to its high protein content (22.2–22.7 %), minerals (potassium, calcium, iron, and zinc), as well as dietary fibers (10.65–13.95 %) and vitamins. One of the main advantages of chickpea flour is its significantly higher lysine content compared to wheat flour, making it especially beneficial for bakery products. Additionally, chickpea flour contains monosaccharides and disaccharides (3.56–4.35 %), which give it a mild sweet flavor, allowing for a reduction in the amount of sugar in the biscuit formulation.

We propose using flour obtained from chickpea crops, a non-traditional raw material for food science, to improve the chemical composition of biscuit semifinished products. The traditional recipe is presented in Table 1.

Table 1

Traditional Biscuit Semifinished Product Recipe

Raw Material	Dry Matter Content (DM), %	Raw Material Consumption per 1 ton of Semifinished Product, kg	
		In natural form	In dry matter (DM)
Wheat flour (grade 1)	85.5	400.0	340.2
Eggs	27	360.0	90.7
White sugar	99.7	400.0	390.9
Total		1160.0	830.8
Yield		1000	

As is well known today, plant protein serves as an alternative to animal protein in the food industry.

The external appearance results are presented in Figure 2.

The chemical composition of the finished biscuit semifinished products was determined by calculation, using literature data on the chemical composition of ingredients for flour-based confectionery products.

A B C D

Figure 2. External appearance of biscuit semifinished product with the addition of chickpea flour, %: A – 0 (control sample); B – 10; C – 20; D – 30

Table 2

Organoleptic characteristics of the studied samples and control

Indicator	Value for biscuit semifinished product samples, %			
	0 (control)	**10.0**	**20.0**	**30.0**
Shape and surface condition	Correct, fluffy			
Color: – Surface	Light yellow			
Crumb	Light	Light with an intense yellow color		
Aroma	Pronounced taste and aroma of biscuit semifinished product, without foreign odors			
Taste	Sweet, without foreign aftertastes			
Crumb texture: – Porosity	Medium pores, without signs of under-mixing	Fine-pored, retains its shape		Well-developed, dense. Does not retain its shape
–Elasticity	Elastic			

Process control is carried out at all stages of production to ensure the high quality of finished products, particularly bakery confectionery products. During dough kneading, the specific chemical composition of plant-based additives of natural origin is taken into account, allowing for recipe adjustments or close monitoring of structural changes in the dough. Plant-based raw materials typically contain an increased amount of dietary fiber, which contributes to strengthening the gluten framework and forming additional air bubbles. This requires prolonged mixing of additives with other ingredients until a homogeneous mass is obtained. During baking, these bubbles create cavities, ensuring the spongy texture of the biscuit semifinished product in the final product. A standardized biscuit recipe was used as a control stage.

At the next stage of research, mathematical methods of scientific experiment planning were used to optimize the recipe composition of the biscuit semifinished product with plant-based raw materials, based on the chickpea flour content (Table 3.3). For this purpose, an incomplete factorial experiment design (PFE 3²) was developed.

Table 3

Factors and levels of PFE 3²

Experiment Factors	Experiment Levels		
	Minimum (–1)	**Medium (0)**	**Maximum (1)**
X_1 (sugar content, % of chickpea flour mass)	5	10	15
X_2 (chickpea flour content, % of total recipe components mass)	10	20	30

Table 4

PFE 3² Plan in Coded Values

Experiment	X_1	X_2
1	1	1
2	1	–1
3	–1	1
4	–1	–1
5	1	0
6	–1	0
7	0	1
8	0	–1
9	0	0

In general form, the regression equation is presented below:

$$Y = a_0 + a_1 \cdot X_1 + a_2 \cdot X_2 + a_3 \cdot X_1^2 + a_4 \cdot X_2^2 + a_5 \cdot X_1 \cdot X_2. \quad (1)$$

In the laboratory conditions, the values of the output parameter were obtained through the results of implementing the PFE 3² (Fig. 3).

Using the MathCAD Prime 7.0 software package, the initial data were processed, and the result of the processing is the regression equation (2), which adequately describes the dependence of the output parameter on the varying factors, as well as the response surface (Fig.4).

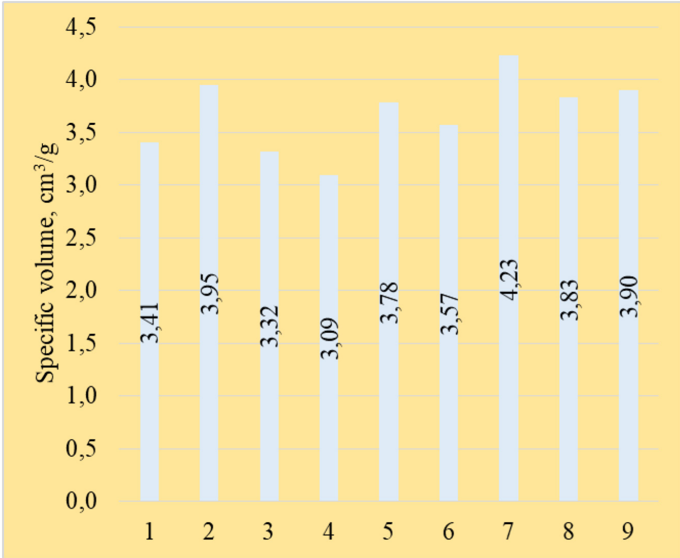

Fig. 3. Specific volume of CFB No. 1–9

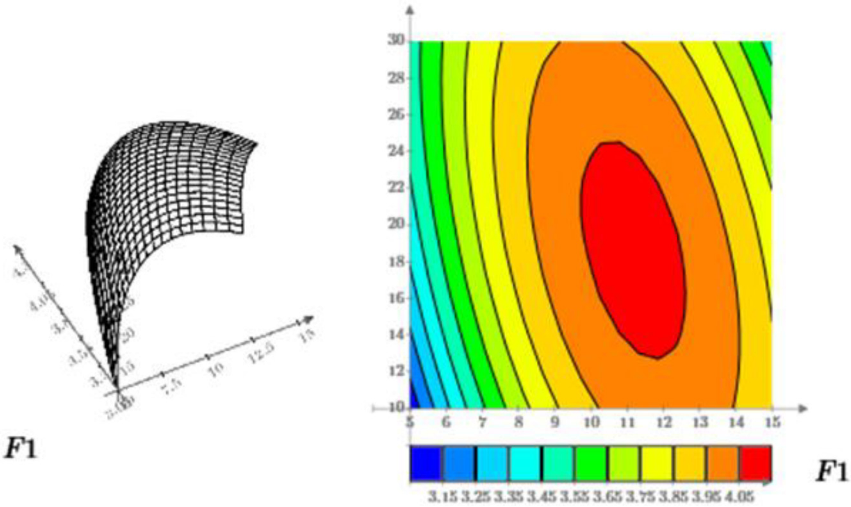

Fig. 4. Response surface of the output parameter from the varying factors

$$Y1(X1, X2) = \frac{\begin{array}{c}((20 \cdot X1 - 350) \cdot X2 + \\ +(7000 - 400 \cdot X1)) \cdot a_5 + \\ +(25 \cdot X2^2 - 1000 \cdot X2 + 10{,}000) \cdot a_4 + \\ +(16 \cdot X1^2 - 560 \cdot X1 + 4900) \cdot a_3 + \\ +(250 \cdot X2 - 5000) \cdot a_2 + \\ +(200 \cdot X1 - 3500) \cdot a_1 + 2500 \cdot a_0\end{array}}{2500}.$$

Analysis of the data presented in Fig. 4 allows us to establish that the best values of the output parameter (about 4.05 cm³/g) can be obtained by dosing chickpea flour in the range of (14.8–23.6) % of the flour mass and sugar (sand) in the range of (11–13) % of the recipe components' mass. According to the results of processing experimental data, the optimal dosing of chicken eggs and sugar (sand) in the biscuit semi-finished product recipe is 11.1 % and 18.6 % of the flour weight in the recipe, respectively. The results of the comparative quality assessment of the biscuit semi-finished product based on organoleptic indicators and specific volume, produced with and without the addition of 15 % chickpea flour replacing wheat flour, according to the optimized recipe, are presented in Table 5.

Organoleptic quality indicators of the developed biscuit products with the addition of plant protein raw materials are presented in Table 6 and in Figure 6.

The sponge semi-finished product containing chickpea flour, optimized through mathematical modeling and data analysis in Mathcad, exhibits improved nutritional and physicochemical properties. The product is characterized by an increased content of proteins, dietary fibers, minerals, a delicate texture, uniform porosity, and prolonged freshness retention. Regression modeling has been used to determine the optimal composition and technological parameters, ensuring both economic efficiency and product appeal

Table 5

Recipe for biscuit semi-finished product using chickpea flour

Raw Material Name	Dry Matter Content (DM), %	Raw material usage per 1000 kg of semi-finished product, kg			
		Biscuit semi-finished product control		Biscuit semi-finished product “Chickpea-based”	
		In natural form	In dry matter (DM)	In natural form	In dry matter (DM)
Wheat Flour (grade 1)	85.5	400.0	342.0	325.6	278.4
Chickpea Flour	84.5	0.0	0.0	73.6	62.2
Eggs	27	360.0	97.2	360.0	97.2
White Sugar	99.7	400.0	398.8	355.6	354.5
Total		1160.0	838.0	1114.8	792.3
Yield		1000		1000	

Table 6

Organoleptic quality indicators of biscuit semi-finished products

Indicator	Indicator values for the samples of biscuit semi-finished products with the addition of chickpea flour	
	Control	Experimental Sample
Shape and surface condition	Correct, surface convex, without cracks or splits	
Color: – Surface	Light	Brown
– Crumb	Light to yellow	Light yellow
Smell	Typical for traditional products	Typical for biscuit products, without foreign odors
Taste	Typical for biscuit products, sweet, pleasant aftertaste	Typical for biscuit products, sweet, without foreign aftertastes
Crumb condition: – Porosity	Even, developed, fine-pored	Even, less developed, fine-pored, with inclusions of chickpea flour
– Elasticity	Elastic	

Fig. 5 Sponge semi-finished product with the addition of chickpea flour

to consumers, particularly those interested in healthy eating.

Conclusions. The application of chickpea flour in the technology of sponge cake production has been justified as a promising approach to improving its chemical composition, characterized by a high content of protein-carbohydrate fractions.

It should be noted that when chickpea flour (CFB) is added to the flour mixture in the amount of 10.0–20.0 %, a decrease in the gluten elasticity value by 6.4–19.3 % is observed compared to the control sample. However, this reduction is not significant for the production of sponge cake semifinished products, as weak flour is preferable for sponge cakes. As a result of recipe optimization, it has been determined that 15 % of wheat flour can be replaced with chickpea flour. Additionally, adjustments to the recipe include changes in the ratio of sugar to egg mass due to the increased density of the sponge cake semifinished product. Consequently, the amount of sugar relative to flour has been reduced by 1.65 % compared to the traditional recipe.

It is summarized that short-term storage of flour confectionery products leads to deterioration of the crumb and moisture loss. This is caused by complex physicochemical processes, including starch retrogradation, protein denaturation, and moisture loss.

Therefore, the research results show that the optimal recipe for biscuit semifinished products using chickpea flour demonstrates high organoleptic properties and increases the shelf life of the products during storage compared to those made using the traditional recipe.

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Вивчення впливу борошна нутових культур на бісквітний напівфабрикат

Анотація. *Це дослідження спрямоване на вдосконалення технології виробництва бісквітних напівфабрикатів шляхом додавання нутового борошна. Особливу увагу приділено покращенню їхніх харчових та фізико-хімічних властивостей, використовуючи методи математичного моделювання та аналізу даних у Mathcad.*

Мета дослідження *– підвищити якість бісквітних виробів, частково замінивши пшеничне борошно борошном із нуту, а також визначити оптимальні технологічні параметри, які зроблять продукт привабливим для споживачів, зокрема тих, хто дотримується принципів здорового харчування.*

У ході роботи застосовувалися ***методи*** *математичного моделювання, зокрема регресійний аналіз, для обробки експериментальних даних. Це дозволило визначити найкраще поєднання інгредієнтів та оптимізувати технологічний процес, щоб отримати бісквітні напівфабрикати високої якості.*

Дослідження підкреслює використання борошна з нутових культур як інгредієнта, що не тільки покращує харчову цінність продукту, збільшуючи вміст білка, харчових волокон та мінералів, а й покращує текстуру, пористість та тривале збереження свіжості.

Наукова новизна *роботи полягає в застосуванні сучасних методів математичного моделювання для оптимізації рецептури та виробничого процесу бісквітних напівфабрикатів, що забезпечує їх конкурентоспроможність на ринку, особливо серед споживачів, зацікавлених у здоровому харчуванні.*

Аналіз експериментальних даних показує, що додавання борошна з нутових культур призводить до значного покращення органолептичних та харчових властивостей бісквітного продукту.

Висновки *дослідження свідчать, що оптимізована рецептура забезпечує продукт з бажаними органолептичними властивостями, такими як смак, текстура та колір, одночасно сприяючи покращенню загальних здоров'я. Крім того, регресійне моделювання, яке використовувалося для визначення оптимальних параметрів, забезпечує як економічну ефективність, так і якість продукту, роблячи його перспективним для масового виробництва. Це дослідження дає цінні відомості для розробки здорових та економічно ефективних продуктів харчування, що відповідають сучасним дієтичним тенденціям.*

Ключові слова: *бісквітний напівфабрикат, борошно з нутових культур, математичне моделювання, харчові властивості, оптимізація продукту.*