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OPTIMIZATION OF THE RECIPE COMPOSITION FOR SAVOIARDI TYPE SPONGE BISCUITS

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Abstract. The results of mathematical modeling and optimization of the recipe composition of Savoiardi type sponge biscuits with the incorporation of waxy wheat flour are presented. The experimental flour was obtained from the spring waxy wheat variety *Biskvitna*, regionalized in the Kharkiv region of Ukraine. A set of distinctive physicochemical and technological properties of the investigated flour was identified. In particular, the flour is characterized by a reduced content of raw gluten of light gray color, which allows classification into the second quality group; a significantly increased water-holding capacity; a reduced starch gelatinization temperature; a markedly increased starch paste viscosity; and an abnormally low falling number compared with conventional baking wheat flour. Using methods of experimental design and statistical analysis, a central composite design at three levels for two factors was developed. Laboratory trials of sponge biscuit production were conducted, and the values of the response parameter, namely moisture uptake of Savoiardi type sponge biscuits, were determined. The influence of two varying factors, namely the proportion of waxy wheat flour (10.0…50.0% of the wheat flour weight) and potato starch (0…25.0% of the wheat flour weight), was evaluated. The regression coefficients were calculated, and a quadratic model was obtained, which adequately describes the dependence of the response parameter on the selected factors. The adequacy of the model was confirmed using the Fisher criterion at a significance level of α=0.05, while the statistical significance of coefficients was tested using Student's *t*-test. Cross-validation confirmed the predictive validity of the model. Based on the optimization performed in the MathCAD environment, the optimal dosages of waxy wheat flour and potato starch in the Savoiardi type sponge biscuit formulation were established as 26.8% and 10.6% of the wheat flour weight, respectively. This combination ensures a moisture uptake index of 257.8%, which is close to the maximum achievable value under the tested conditions. Sensory evaluation confirmed that Savoiardi type sponge biscuits produced according to the optimized formulation differ favorably from the reference sample. In particular, the optimized products demonstrated improved appearance in cross-section due to a higher number of smaller pores, which created the impression of increased volume and enhanced crispness. At the same time, the overall quality of the optimized biscuits was not inferior to the reference samples, thereby confirming the technological feasibility of using waxy wheat flour of the *Biskvitna* variety in sponge biscuit production. The obtained results provide a scientific basis for the rational use of waxy wheat flour in flour-based confectionery technology and may contribute to the development of high-quality competitive domestic products.

Keywords: sponge biscuits, waxy wheat flour, optimization.

Introduction. Formulation of the problem

One of the most popular desserts among visitors of food service establishments is tiramisu, a traditional Italian confection consisting of crispy Savoiardi sponge biscuits soaked in coffee syrup and a delicate egg-cream filling. Since the ingredients of the classic tiramisu are predominantly imported and relatively expensive, many producers seek to identify domestic alternatives. A key formulation component of tiramisu is Savoiardi sponge biscuits, the recipe and production technology of which are typically proprietary and closely guarded by manufacturers. Although numerous formulations of Savoiardi type sponge biscuits have been proposed, most of them fail to yield products that adequately replicate the original characteristics. To address this issue, we proposed the use of waxy wheat flour from the spring variety Biskvitna, developed by researchers of the V. Ya. Yuriev Institute of Plant Production of the National Academy of Agrarian Sciences of Ukraine (Kharkiv), in the preparation of Savoiardi type sponge biscuits.

Analysis of recent research and publications

The unique line of spring waxy wheat *Biskvitna* was developed on the basis of the spring soft wheat cultivar *Kharkivska 30* and waxy wheat lines IR 13640 S, IR 13641 S, and IR 13642 S by irradiation of grain gamma rays. The main feature of waxy wheat is that it has null alleles in three loci that encode granule-bound starch synthetase (EC 2.4.1.21) [1]. This enzyme is responsible for amylose synthesis in the endosperm starch. Consequently, the starch of waxy wheat is composed predominantly of amylopectin, which is why this type of wheat is often referred to as amylose-free [1, 2]. Flour obtained from waxy wheat is characterized by increased water absorption capacity and extended dough development time, with the resulting dough being considerably less stable compared to that made from conventional baking flour. Additional properties include a low falling number, reduced starch gelatinization temperature, and increased paste viscosity [1–4]. It is generally accepted that waxy wheat starch is more susceptible to hydrolysis by amylases, therefore, food products made with waxy wheat flour are more easily digested and can be recommended for the diets of children, athletes, military personnel, and individuals engaged in heavy physical labor. Numerous studies have demonstrated the impracticality of using waxy wheat flour alone in the production of bread and pasta. Nevertheless, blending waxy wheat flour with conventional baking flour typically results in products of improved technological and sensory quality [2, 5–8]. Furthermore, a substantial body of literature supports the feasibility of applying waxy wheat flour in the manufacture of flour-based confectionery products [9–11].

Contemporary scientific literature devotes significant attention to the properties of waxy wheat flour and its potential applications in food technologies. Compared with conventional baking wheat flour, waxy wheat flour is generally characterized by a smaller particle size, slightly lower protein content, and a higher proportion of arabinoxylans. It also contains more damaged starch granules [1, 3, 4], which is attributed to the lower resistance of waxy wheat starch to mechanical stress relative to that of soft or durum wheat [2, 12], as well as slightly higher α-amylase activity [4, 13]. A distinctive feature of waxy wheat flour is its abnormally low falling number, which, according to various studies, typically ranges from 72 to 75 s [3, 9, 13]. In addition, researchers have reported a lower gelatinization temperature of waxy wheat starch and a higher viscosity of its paste, properties associated with the structural characteristics of amylopectin [1, 2, 4, 13, 14]. In a series of studies, Iorgachova K. and co-authors [9–11] demonstrated that waxy wheat flour exhibits greater sugar- and gas-forming capacity than conventional baking flour. Farinograph analyses indicate that waxy wheat flour shows 10…15% higher water absorption, a 30…50% longer dough development time, nearly two-fold lower elasticity and stability, and approximately 30% higher softening compared with baking flour [2, 3]. Consequently, most researchers do not recommend the use of waxy wheat flour alone in bakery production. However, supplementation of baking flour with 10…20% waxy wheat flour generally yields bakery products of improved quality [2, 5–7, 9, 14, 15]. The use of waxy wheat flour has been reported to increase the specific volume of bakery products and to promote the development of a more open crumb porosity, while the crumb retains freshness for a longer period during storage [2, 5–7, 15]. Takata K. and co-authors observed that the incorporation of waxy wheat flour into bakery formulations leads to the formation of large, unevenly distributed pores throughout the product, which is attributed to its enhanced gas-forming capacity and higher dough viscosity [2].

Our previous investigations of waxy wheat flour derived from the *Biskvitna* variety [16, 17] demonstrated that it contains 26.2±0.4% raw gluten of a light grayish color, with tenacity of 76±1 units and extensibility of 17±1 cm, which corresponds to the second quality group. The flour exhibits higher water absorption capacity (193%) compared with conventional wheat flour, as well as an abnormally low falling number of 68 s. It was also previously established that the starch of waxy wheat flour begins gelatinization slightly earlier and at a somewhat lower temperature than that of bread-making wheat flour. At the same time, the maximum viscosity of waxy wheat flour paste (920 units) is nearly 1.6 times higher than that of bread-making wheat flour and approaches the critical measurement values during the experiment.

The results of our previous assessment of the sensory quality indicators of sponge products prepared with partial substitution of wheat flour by waxy wheat flour of the *Biskvitna* variety at levels of 25.0, 50.0, 75.0, and 100.0% [16, 17] demonstrated that all samples retained a proper shape and a smooth surface without ruptures. However, samples containing 50.0 and 75.0% waxy wheat flour exhibited a slightly greater number of microcracks on the surface compared with the other samples. The crust color was light brown, the crumb color light yellow, the aroma was typical for sponge products, and the taste sweet without foreign notes. The crumb structure was airy with fine, uniform porosity, while in samples containing 50.0 and 75.0% waxy wheat flour the crumb was slightly moister, although not sticky. According to the results of determining the specific volume and porosity of sponge products, the incorporation of 25.0% waxy wheat flour increased these parameters by 11.1% and 9.3%, respectively, compared with the reference sample. With higher substitution levels, both specific volume and porosity decreased slightly relative to the best result, though the values did not differ significantly from the reference sample. Since sponge products made with the addition of waxy wheat flour exhibited consistently high quality indicators, the experimental flour was recommended for use in sponge production at substitution levels of up to 75% relative to conventional baking wheat flour [16].

In this regard, both scientific and practical significance lies in establishing the optimal level of substitution with waxy wheat flour of the *Biskvitna* variety in the production of Savoiardi type sponge biscuits in order to obtain high-quality domestic products.

Purpose and objectives of the study

The purpose of this study is to optimize the formulation of Savoiardi sponge biscuits with the incorporation of waxy wheat flour of the *Biskvitna* variety. To achieve this goal, the following objectives were set:

– to develop a central composite experimental design for two factors and construct a mathematical model describing the dependence of Savoiardi sponge biscuit quality, in terms of moisture uptake, on the contents of waxy wheat flour and starch;

– to obtain the optimal formulation of Savoiardi sponge biscuits according to moisture uptake index;

– to assess the quality of products obtained with the optimized formulation based on sensory characteristics.

Research materials and methods

The study utilized waxy wheat flour with a 70% extraction rate, obtained from the *Biskvitna* spring waxy wheat harvested in 2021 and milled using a Bühler laboratory mill. The properties of Savoiardi sponge biscuits prepared with the experimental waxy wheat flour were compared with those of products made from commercial premium-grade wheat flour marketed under the TM *Pokrovchanka* brand (SE *Novopokrovka Bread Products Plant*, Novopokrovka, Kharkiv region). As the reference sample, wheat flour most commonly used in the production of bakery and flour-based confectionery products by food service establishments and industrial enterprises in the Kharkiv region was selected. Experimental research was carried out in 2021 in the laboratories of the Department of Innovative Food and Restaurant Technologies at the Kharkiv Institute of Trade and Economics of Kyiv National University of Trade and Economics.

The water-holding capacity of the flour was determined according to the method described in [18]. A 1.0 g sample was mixed with 30 cm³ of distilled water for 1 min at a stirring speed of 1000 rpm using an electronic mixer, allowed to stand for 30 min, and then centrifuged for 15 min at 4000 rpm. The unabsorbed water was decanted, and the test tube was placed in an inclined position for 10 min to remove residual moisture. The water-holding capacity was calculated using the following formula:

$$X = ((a–b) / c) \cdot 100, \quad (1)$$

where a is a mass of the test tube with the sample and bound water, g; b is a mass of the test tube with the dry sample, g; c is a mass of the sample, g.

The starch properties of the experimental flour samples were analyzed using a Brabender amylograph.

Savoiardi type sponge cakes were prepared as follows. Egg whites were whipped at minimum speed using a Braun MR-530 hand blender (type 4199, power 500…600 W, whisk attachment) until a faint “beer foam” appeared, corresponding to a whipping time of 1…2 min. Half of the sugar was then added, and whipping continued in turbo mode until a stable foam was obtained (5…7 min). Egg yolks were whipped with the remaining sugar in turbo mode until a white foam formed (3…5 min). The whipped yolks were gradually combined with the whipped egg whites, followed by the addition of sifted wheat flour or a mixture of sifted wheat flour and potato starch, and gently mixed to obtain a homogeneous batter. The batter was portioned with a pastry bag into 10 cm sticks weighing 15±1 g, dusted with powdered sugar, and baked at 160°C for 12 min in an UNOX combi oven (Italy). The ingredient proportions are presented in table 1.

Table 1 – Dosages of ingredients for preparing Savoiardi type sponge cakes (n=3; P≥0.95)

Raw material	Weight of raw material, g	
	Gross	Net
Wheat flour	70	70
Chicken eggs, including: egg white egg yolk	2 pcs. - -	110 67 43
Sugar	50	50
Powdered sugar (for dusting dough pieces)	20	20

Experimental sponge cake samples were prepared by substituting 0 to 100.0% of wheat flour with waxy wheat flour and 0…25.0% with potato starch. Sponge cake biscuits prepared according to the recipe in table 1 were used as the reference sample.

Product quality was evaluated according to sensory indicators in compliance with DSTU 3781:2014 requirements for shortbread biscuits and by moisture uptake determining. Moisture uptake index was measured as follows: a stainless-steel mesh container (1 mm² opening size) was immersed in water for 30 s, blotted, and weighed (accuracy 0.001 g). Pre-weighed biscuit samples were then placed in the container, immersed for 3 min, blotted again, and weighed. Moisture uptake was calculated according to formula (2):

$$W = \frac{(m_w - m_n)\cdot 100}{m_d - m_n}, \qquad (2)$$

where W is moisture uptake index of products, %; m_n is mass of the empty mesh after immersion and blotting, g; m_d is mass of the mesh with dry biscuits, g; m_w is mass of the mesh with soaked biscuits, g.

Experimental data were processed using the MS Office Excel package and MathCAD software.

The parameters of the quadratic model were evaluated by the least squares method [19, 20] in natural units of the factors. The normality of the distribution of the obtained results was tested using the Shapiro–Wilk test [21]. Model adequacy was assessed by the Fisher criterion [20] at α=0.05, and the significance of coefficients by the two-tailed Student's t-test [20, 21] at α=0.05, f=2. Predictive validity was evaluated by cross-validation [22, 23].

Results of the research and their discussion

At the first stage of the research, technological properties of waxy wheat flour were compared with wheat flour, in particular water-holding capacity (Fig. 1) and starch gelatinization parameters (Table 2).

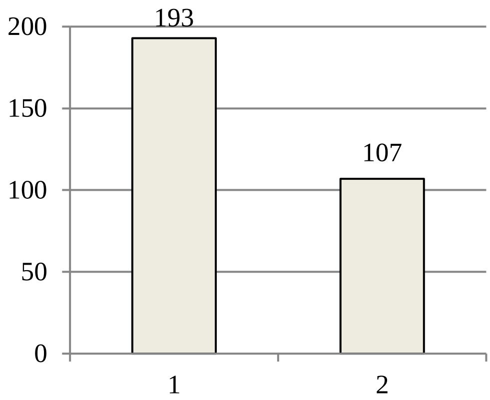


Fig. 1. Water-holding capacity of: 1 – waxy wheat flor; 2 – wheat flour

Table 2 – Starch gelatinization parameters of flour (n=3; P≥0.95)

Indicator	Experimental flour samples	
	Waxy wheat flour	Wheat flour
Temperature of starch gelatinization onset, °C	57±1	60±1
Time to starch gelatinization onset, min	21±1	23±1
Maximum viscosity of starch paste, units	920±10	580±10

It was established that waxy wheat flour has a 1.8 times higher water-holding capacity, attributable to the high amylopectin content in its starch and its strong hydrophilicity. This may also be explained by the higher proportion of damaged starch granules produced during milling and by the smaller flour particle size [1–4, 12]. Similar findings were reported for waxy flours of other varieties using farinogram, mixogram [1-4], and differential scanning calorimetry analyses [5, 24].

The starch of waxy wheat flour gelatinized slightly earlier and at a somewhat lower temperature compared to wheat baking flour. This may be attributed both to the structural characteristics of starch granules and to the absence of amylose in waxy wheat starch, since amylose is primarily associated with flour lipid complexes, which raise the starch gelatinization temperature due to reduced swelling of these complexes [4, 9, 14]. At the same time, it should be noted that data published by other researchers regarding the absolute values of the onset temperature of waxy wheat starch gelatinization vary and fall within the range of 67…71°C [3, 13]. The maximum viscosity of waxy wheat flour starch paste is nearly 1.6 times higher than that of wheat baking flour and approaches the critical measurement limits during the experiment. The high viscosity values of waxy wheat flour starch paste are most likely associated with the predominant amylopectin content in the experimental flour, as amylopectin has a significantly higher molecular weight compared with amylose and a strong hydration capacity. This finding correlates with the results obtained in determining the water-holding capacity of the experimental flour samples (Fig. 1), as well as with data reported by other researchers from corresponding amylograph and mixograph tests [1-3, 13]. Similar results were obtained when studying the properties of isolated starch from waxy durum wheat in comparison with isolated starch from conventional durum wheat [4]. It should be noted, however, that when starch gelatinization temperatures are determined by differential scanning calorimetry, the measurement results are the opposite: waxy wheat starch samples exhibit higher gelatinization onset temperatures, as well as higher temperatures corresponding to maximum viscosity and the onset of paste breakdown, compared to conventional wheat starch [3, 5, 24].

The results of amylogram analysis, particularly the maximum viscosity index of starch paste, may indicate the feasibility of using waxy wheat flour in combination with wheat baking flour with abnormally strong gluten for the preparation of flour-based products, with the aim of balancing the properties of both types of flour and achieving improved quality of the final products.

At the next stage of the study, trial baking of Savoiardi type sponge cake biscuits was carried out with the addition of waxy wheat flour in amounts of 25.0, 50.0, 75.0, and 100.0% as a replacement for wheat flour in the recipe. As a reference sample, biscuits prepared without the addition of waxy wheat flour were used. The results of the quality evaluation of the products according to sensory indicators are presented in table 3.

Table 3 – Sensory quality indicators of Savoiardi type sponge biscuits (n=3; P≥0.95)

Indicator	Quality characteristics of biscuits produced				
	without additives (reference sample)	with waxy wheat flour dosage, %			
		25.0	50.0	75.0	100.0
Shape	Proper, stick-shaped, without damage		Proper, stick-shaped, defect-free, slightly spread, with insufficient volume		
Surface	Not burnt, without blisters, burst bubbles, or crumb inclusions; decorated with an even layer of powdered sugar				
Color	Light yellow, uniform				
Taste and aroma	Typical of sponge biscuits, without foreign odors or flavors				
Cross-sectional appearance	Evenly porous, without cavities, properly baked	Evenly porous, without cavities, properly baked, with a greater number of smaller pores compared with the control sample		Evenly porous, with a small number of cavities, properly baked	

Data analysis (Table 3) shows that increasing the proportion of *Biskvitna* waxy wheat flour in the Savoiardi type sponge biscuit formulation above 50.0% leads to a deterioration in product quality compared with the reference sample in terms of shape. This finding is consistent with results obtained during the evaluation of sponge semi-finished products containing the same proportion of waxy wheat flour [3]. This result may be attributed to the pronounced hydrophilic properties of waxy wheat flour, which cause dough tightening and deterioration of product quality. Given the relatively large substitution step (25.0%), further investigation was directed at the 10.0–50.0% range. Moreover, it is well known that partial substitution of wheat flour with starch in sponge product formulations has a beneficial effect on the quality characteristics of the final products. Therefore, at the next stage of the study, the possibility of optimizing the recipe composition of Savoiardi type sponge biscuits with the addition of waxy wheat flour and potato starch was investigated.

To obtain a quadratic model, a central composite design was used [19], with waxy wheat flour dosage (X_1) and potato starch dosage (X_2) as factors (Table 4). The optimization parameter was moisture uptake (Y), selected as it integrates textural characteristics and permits objective measurement. The design matrix in coded values, average responses, and calculated responses are shown in Table 5.

To obtain a quadratic model of the recipe composition of Savoiardi type sponge biscuits with the use of waxy wheat flour, a central composite design for two factors [19] was developed according to equation:

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

where Y is moisture uptake index of products, %; $a_0 \ldots a_5$ are equation coefficients; X_1 is dosage of waxy wheat flour, % of wheat flour weight; X_2 is dosage of potato starch, % of wheat flour weigh.

The factors selected for variation were the dosage of waxy wheat flour in the formulation (X_1) and the dosage of potato starch (X_2), the values of which are presented in table 4.

When selecting the factors for variation, the hypothesis was based on the assumption that with a stable content of sugar and eggs in the sponge biscuit formulation, as well as constant technological process parameters (in particular, the parameters of whipping the egg and sugar mixture), the greatest influence on the formation of sponge product quality indicators is exerted by the content and properties of flour and starch.

Table 4 – Factors and levels of the central composite design (n=3; P≥0.95)

Experimental factors	Experimental levels		
	minimum (-1)	central (0)	maximum (1)
X_1 (waxy wheat flour content, % of wheat flour weigh)	10	30	50
X_2 (starch content, % of wheat flour weigh)	0	12.5	25

Moisture uptake index of the sponge biscuits (Y) was taken as the response parameter for optimization. This parameter was selected because moisture uptake index provides a comprehensive characterization of biscuit quality, indirectly reflecting the features of pore structure and crispness, while also allowing quantitative instrumental measurement. The design of the central composite experiment in coded values, the averaged values of the response parameter, and the calculated values of the response parameter according to equation (4) are presented in table 5.

The obtained data were processed by the least squares method using MathCAD software. It yielded the regression equation (4):

$$Y(X_1, X_2) = 128.182 + 7.875 \cdot X_1 + 4.527 \cdot X_2 - 0.152 \cdot X_1^2 - 0.245 \cdot X_2^2 + 0.026 \cdot X_1 \cdot X_2 \quad (4)$$

The Shapiro–Wilk test confirmed normal distribution of moisture uptake values (W=0.94, p=0.44), which allowed the application of the Fisher criterion to assess the adequacy of the proposed model and the Student's t-test (Table 6) to evaluate the significance of the coefficients in equation (4). According to the calculated Fisher criterion value ($F_{exp}(5,3)=47.3$, $\alpha=0.05$), it was established that the proposed model (4) explains approximately 98.8% of the variation in moisture uptake index and is statistically significant according to the Fisher criterion. The mean prediction error of 6.87% is moderate compared with the levels of the response parameter in the range of 130…250% and is likely associated with measurement error of the moisture uptake index during the experiment.

Analysis of the data presented in Table 6 shows that at $\alpha=0.05$, the response parameter is significantly influenced by the linear and quadratic coefficients of equation (4), whereas coefficient a_5, which characterizes the interaction of the selected factors (flour and starch dosage), appears statistically weak. At the same time, it should be noted that at $\alpha=0.10$ this interaction becomes nearly significant. The presence of substantial negative quadratic terms indicates a concave response surface with a maximum in the interior of the design space, which is consistent with the result shown in Fig. 2.

Analysis of the data presented in Fig. 2 shows that the best response values (250…258%) can be obtained when the dosage of waxy wheat flour is within the range of 20…34% of wheat flour weigh and starch within the range of 5…16% of wheat flour weigh. According to the results of experimental data processing, the optimal dosages of waxy wheat flour and starch in the Savoiardi type sponge biscuit formulation, which ensure products with a moisture uptake value of 257.8%, are 26.8% and 10.6% of wheat flour weigh, respectively.

The optimized recipe of Savoiardi type sponge biscuits is presented in table 7.

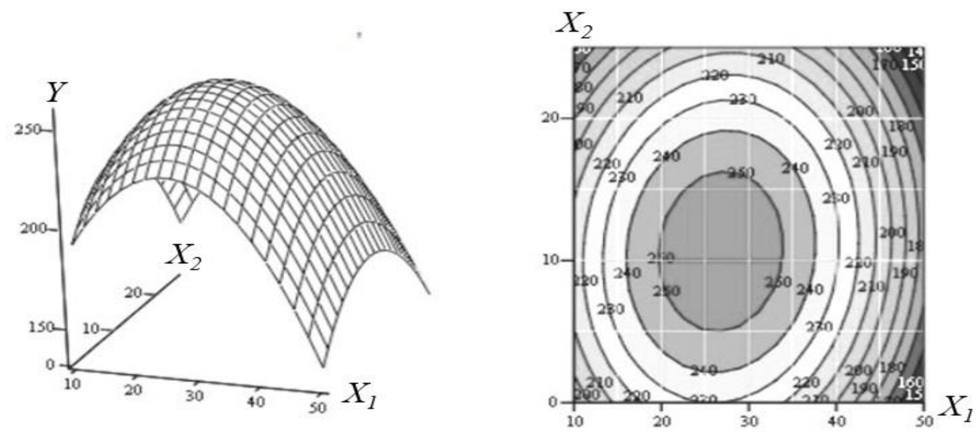
Table 5 – Central composite design in coded values, averaged experimental result, and calculated response parameter values (n=3; P≥0.95)

Run	X_1	X_2	Y	Ŷ
1	1	1	132	134.056
2	1	-1	140	141.722
3	-1	1	157	158.056
4	-1	-1	191	191.722
5	1	0	180	176.222
6	-1	0	215	213.222
7	0	1	210	206.889
8	0	-1	230	227.556
9	0	0	250	255.556

At the next stage of the study, the sensory quality indicators of Savoiardi type sponge biscuits produced according to the optimized recipe were evaluated in comparison with sponge biscuits made without the addition of waxy wheat flour and starch. The results of the quality evaluation of Savoiardi type sponge biscuits prepared using the optimized recipe are presented in table 8.

Table 6 – Results of determining the significance of the coefficients of equation (4) using Student's t-test

Equation term (4)	Coefficient value a_j	SE	t	p
a_0	128.182	5.779	22.18	0.0002
$a_1(X^1)$	7.875	0.546	14.42	0.0009
$a_2(X^2)$	4.527	0.584	7.76	0.0045
$a_3(X_1^2)$	-0.152	0.009	-17.52	0.0006
$a_4(X_2^2)$	-0.245	0.020	-12.14	0.0015
$a_5(X_1X_2)$	0.026	0.008	3.18	0.0780



a b

Fig. 2. Response surface for moisture uptake: a – 3D model; b – 2D model (X_1 is waxy wheat flour dosage, %; X_2 is potato starch dosage, %; Y is moisture uptake, %).

Table 7 – Optimized recipe of Savoiardi type sponge biscuits (n=3; P≥0.95)

Raw material	Raw material weight, g	
	Gross	Net
Wheat flour	2 244.0	2 244.0
Waxy wheat flour of the *Biskvitna* variety	961.0	961.0
Potato starch	380.0	380.0
Chicken eggs, including egg white egg yolk	112 шт. - -	5 630.0 3 428.0 2 202.0
White sugar	2 560.0	2 560.0
Powdered sugar (for dusting dough pieces)	1 040.0	1 040.0
Yield	-	10 000

Table 8 – Sensory quality indicators of Savoiardi type sponge biscuits (n=3; P≥0.95)

Indicator	Quality characteristic for the Savoiardi type sponge biscuit sample produced:	
	according to the standard recipe (reference sample)	according to the optimized recipe
Shape	Proper, stick-shaped, free from defects	
Surface	Not burnt, without blisters, burst bubbles, or crumb inclusions; coated with an even layer of powdered sugar	
Color	Light yellow, uniform	
Taste and aroma	Typical of sponge biscuits, without foreign odors or flavors	
Cross-sectional appearance	Evenly porous, without cavities, properly baked	Evenly porous, without cavities, properly baked, with a greater number of smaller pores compared with the reference sample

Analysis of the data presented in table 9 shows that Savoiardi type sponge biscuits produced according to the optimized recipe differ favorably from the reference sample in terms of cross-sectional appearance, namely by the presence of a greater number of smaller pores, which contribute to a greater perceived volume and crispness of the sponge biscuits. Products prepared according to the optimized recipe are not inferior in quality to the reference samples.

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Conclusion

As a result of the conducted research, the recipe composition of Savoiardi type sponge biscuits with the use of waxy wheat flour of the *Biskvitna* variety was optimized. A central composite design for two factors was developed, and a mathematical model was obtained to describe the dependence of Savoiardi type sponge biscuit quality on the content of waxy wheat flour. This model makes it possible to predict sponge biscuit quality in terms of moisture uptake depending on such varying parameters as waxy wheat flour dosage in the range of 10.0…50.0% of wheat flour weigh and potato starch dosage in the range of 0…25.0% of wheat flour weigh. Using mathematical modeling, an optimized recipe for Savoiardi type sponge biscuits was determined, which involves 26.8% waxy wheat flour and 10.6% potato starch. It was established that Savoiardi type sponge biscuits produced according to the optimized recipe differ favorably from the prototype in terms of cross-sectional appearance, namely by the presence of a greater number of smaller pores, which provide a greater perceived volume and crispness. Products made according to the optimized recipe are not inferior in quality to the reference samples.

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ОПТИМІЗАЦІЯ РЕЦЕПТУРНОГО СКЛАДУ БІСКВІТНОГО ПЕЧИВА ТИПУ САВОЯРДІ

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Анотація. Подано результати математичного моделювання та оптимізації рецептурного складу бісквітного печива типу савоярді з використанням борошна пшениці ваксі, отриманого із зерна пшениці ваксі ярого сорту *Бісквітна*, районованого в Харківській області. Відмінними особливостями дослідного борошна є знижений вміст сирої клейковини, що має світлий із сірим відтінком колір та може бути віднесена до другої групи якості; підвищена водоутримуюча здатність, знижена температура клейстеризації крохмалю, підвищена в'язкість крохмального клейстеру та аномально низький показник «число падіння» порівняно з борошном пшеничним хлібопекарським. З використанням методів експериментально-статистичного планування розроблено матрицю центрально-композиційного плану для трьох рівнів. За результатами реалізації експерименту в лабораторних умовах отримано значення вихідного параметра – намочуваності бісквітного печива від зміни таких факторів, як дозування борошна пшениці ваксі та дозування крохмалю картопляного в рецептурі печива відносно маси борошна пшеничного. Обчислено коефіцієнти рівняння регресії, що адекватно описує залежність вихідного параметра від обраних факторів варіювання у діапазоні дозування борошна пшениці ваксі в межах 10.0…50.0% маси борошна пшеничного та крохмалю картопляного в межах 0…25.0% маси борошна пшеничного. Адекватність отриманої моделі була перевірена за критерієм Фішера на рівні значущості α=0.05; статистична значущість коефіцієнтів рівняння регресії – за критерієм Стьюдента. Прогностичну придатність моделі оцінено шляхом перехресного затверджування. За результатами розв’язання задачі оптимізації в програмі MathCAD отримано оптимальні дозування борошна пшениці ваксі та крохмалю картопляного в рецептурі бісквітного печива типу савоярді, що становлять відповідно 26.8% та 10.6% маси борошна пшеничного та дозволяють отримати печиво з показником намочуваності 257.8%. Бісквітне печиво типу савоярді, виготовлене за оптимізованою рецептурою, вигідно відрізняється від прототипу за показником вигляду в розломі, а саме наявністю більшої кількості дрібніших пор, які забезпечують відчуття більшого об’єму печива та його хрусткості. Вироби, виготовлені за оптимізованою рецептурою не поступається якістю зразкам порівняння.

Ключові слова: бісквітне печиво, борошно пшениці ваксі, оптимізація