 ISSN 2226-3780

12. Musembi, M. N. Design and Analysis of Solar Dryer for Mid-Latitude Region [Text] / M. N. Musembi, K. S. Kiptoo, N. Yuichi // Energy Procedia. – 2016. – Vol. 100. – P. 98–110. doi:10.1016/j.egypro.2016.10.145
13. Hebbar, H. U. Development of combined infrared and hot air dryer for vegetables [Text] / H. U. Hebbar, K. H. Vishwanathan, M. N. Ramesh // Journal of Food Engineering. – 2004. – Vol. 65, № 4. – P. 557–563. doi:10.1016/j.jfoodeng.2004.02.020
14. Kiranoudis, C. T. Design of tray dryers for food dehydration [Text] / C. T. Kiranoudis, Z. B. Maroulis, D. Marinos-Kouris, M. Tsamparlis // Journal of Food Engineering. – 1997. – Vol. 32, № 3. – P. 269–291. doi:10.1016/s0260-8774(97)00010-1
15. Pan, Z. Infrared Processing of Foods [Text] / Z. Pan, C. Venkitasamy, X. Li // Reference Module in Food Science. – Elsevier BV, 2016. – 12 p. doi:10.1016/b978-0-08-100596-5.03105-x
16. ICh-susharka dlia sushinnia orhanichnoi roslynnoi syrovyny [Electronic resource]: Patent UA 106461 C2, MPK A23N 12/08 V01D 1/00 / Cherevko O. I., Kiptela L. V.; assignee: Kharkiv State University of Food Technology and Trade. – № a201314949; filed 20.12.2013; published 26.08.2014, Bull. № 16. – 5 p. – Available at: \www/URL: http://uapatents.com/6-106461-ich-susharka-dlya-sushinnya-organichno-roslinno-sirovini.html
17. OWEN LLC [Electronic resource]. – Available at: \www/URL: http://www.owen.ru/en
18. Hnuchkyi plivkovyi rezystyvnyi elektronahrivach vyprominiuiuchoho typu [Electronic resource]: Patent UA 108041 U, MPK G05D 23/19, B01D 1/22, H05B 3/36 / Zagorulko A. M., Zagorulko O. Ye.; assignee: Kharkiv State University of Food Technology and Trade. – № u201600827; filed 02.02.2016; published 24.06.2016, Bull. № 12. – 4 p. – Available at: \www/URL: http://uapatents.com/5-108041-gnuchkijj-plivkovijj-rezistivnijj-elektronagrivach-viprominyuyuchogo-tipu.html
19. Oborudovanie [Electronic resource] // Royal Walnuts. – Available at: \www/URL: http://www.royal-walnuts.com.ua/oborudovanie
20. EL-A VERFAHRENSTECHNIK GMBH [Electronic resource] // EUROPAGES. – Available at: \www/URL: http://www.europages.com.ru/ELA-VERFAHRENSTECHNIK-GMBH/DEU287468-00101.html

УСОВЕРШЕНСТВОВАНИЕ ИК-ИЗЛУЧАТЕЛЯ ДЛЯ СОЗДАНИЯ БЕЗРЕФЛЕКТОРНОЙ СУШИЛКИ РАСТИТЕЛЬНОГО СЫРЬЯ

Усовершенствован ИК-излучатель на основе гибкого пленочного резистивного электронагревателя излучающего типа для создания безрефлекторных ИК-сушилок растительного сырья. Это обеспечит уменьшение металлоемкости оборудования, равномерность распределения тепловых потоков на приемных поверхностях (сетчатых поддонах с сырьем) и повысит качество получаемых сушеных полуфабрикатов. Исследована поглощающая способность растительного сырья для подтверждения эффективности использования усовершенствованного ИК-излучателя.

Ключевые слова: гибкий пленочный резистивный электронагреватель, безрефлекторные ИК-сушилки растительного сырья, качество сушеных полуфабрикатов.

Kiptelaya Lyudmila, *Doctor of Technical Sciences, Professor, Department of Processes, Devices and Automation of Food Production, Kharkiv State University of Food Technology and Trade, Ukraine, ORCID: http://orcid.org/0000-0002-8593-9142*

Zahorulko Andrii, *PhD, Assistant, Department of Processes, Devices and Automation of Food Production, Kharkiv State University of Food Technology and Trade, Ukraine, e-mail: match_andrey@mail.ru, ORCID: http://orcid.org/0000-0002-7182-1733*

Zagorulko Aleksey, *PhD, Associate Professor, Department of Processes, Devices and Automation of Food Production, Kharkiv State University of Food Technology and Trade, Ukraine, ORCID: http://orcid.org/0000-0003-1186-3832*

Liashenko Bogdan, *PhD, Associate Professor, Department of Processes, Devices and Automation of Food Production, Kharkiv State University of Food Technology and Trade, Ukraine, ORCID: https://orcid.org/0000-0001-7228-8814*

UDC [664.696–026.787:633.88]–048.34
DOI: 10.15587/2312-8372.2017.99941

Mardar M., Tkachenko N., Znachek R., Leonardi C.

OPTIMIZATION OF FORMULATION COMPOSITION OF THE CRISPBREAD WITH IMPROVED CONSUMER PROPERTIES

Розглянуто питання оптимізації рецептурного складу зернових хлібців з поліпшеними споживними властивостями. Обґрунтовано оптимальні масові частки порошку розторопші та кухонної солі – 5,27 та 0,92 % відповідно як компонентів цільових продуктів. Доведено, що зернові хлібці з оптимальним складом характеризуються поліпшеними органолептичними, нормованими фізико-хімічними показниками, високою харчовою, біологічною цінністю, є безпечними.

Ключові слова: *зернові хлібці, спельта, цільнозернові продукти, оптимізація рецептурного складу, комплексний показник якості.*

1. Introduction

A promising direction in the development of the food industry is the creation of safe and, at the same time, high-grade food and consumer properties. Such products are able to maintain the health of consumers at the proper level, as well as reduce the risks of a number of diseases [1].

The imbalance of modern nutrition, the inability to provide the body with the necessary amount of essential nutrients and biologically active substances (BAS) is a global problem in both developed and developing countries. Unfortunately, in recent years, nutrition quality of the population has significantly worsened and this trend continues. Consequences of such nutrition is a violation of the nutritional status of modern humans, the occurrence of hypovitaminosis, decreased immunity, deterioration in physical development, diseases of the gastrointestinal tract and other non-infectious diseases of nutritional character [2, 3]. One of the reasons for this imbalance is the production of products that do not meet the recommended standards of rational nutrition in terms of nutritional and biological values.

One of the most important tasks in improving the structure of the population's nutrition is to increase the production of mass consumption products with improved consumer properties. Modern food should not only meet the physiological needs of the human body in nutritional, BAS and energy, but also perform preventive and/or therapeutic functions and, of course, be absolutely safe. The solution of these problems is possible due to the development of new generation food products, which meet the requirements and realities of today. To the creation of such products, enriched with vitamins, minerals, food fibers, beneficial bacteria and other additives, manufacturers are prompted by a growing number of fans of healthy nutrition [1, 4].

A promising direction in the development of prophylactic food production is the creation of enriched cereal-based products. Due to the relatively low cost of raw materials, they are available to a wide range of people and are able to compensate for the lack of BAS in the diet, increase the body's resistance to unfavorable environmental factors, and, consequently, increase the life expectancy of the population [1, 5].

2. The object of research and its technological audit

The object of research is crispbread with the inclusion of milk thistle powder, vitamin-mineral supplement and table salt.

Spelt, milk thistle powder, salt and vitamin-mineral supplement were used as raw materials for experimental studies.

The most suitable raw material for the production of bread is cereals (wheat, rye, buckwheat, rice, etc.). This is due to the fact that the grain is a starch raw material, and starch is the main component, which affects the processing conditions of processing and the quality of finished products [6]. Taking into account consumer properties, technological capabilities, as well as on the basis of market research and application of QFD methodology [7], it is decided to use spelt as the main raw material for production of crispbread. Spelt is a kind of soft wheat, which unlike traditional wheat is characterized by a high content of proteins, dietary fibers, minerals and vitamins [8].

The goal of developing nutritional foods is to fill a deficit of essential nutrients and BAS in the human body using them. To achieve this goal, the analysis of the actual nutrition of Ukraine is carried out, its disadvantages are identified and it is determined which nutrient deficiency and BAS is observed in the population nutrition. It is established [1–3] that in the diet of the population of Ukraine, first of all, there is a shortage of minerals, B vitamins and other components. Therefore, it is decided to add a powder of milk thistle into the crispbread, as well as a complex of vitamins and minerals in the form of a vitamin-mineral mixture. In order to provide a pleasant taste of crispbread, it is decided to add salt into their composition.

The optimal composition of new crispbread is calculated in the environment of the software package Statistica 10 (StatSoft, Inc., USA).

Basically, existing formulation optimization models are reduced to the task of linear programming. The objective function is to require the maximum value of the organoleptic evaluation and the output of one component, the need for the content of the component not less than the planned value, and some additive criterion that takes into account the cumulative effect of several criteria with different weight coefficients.

3. The aim and objectives of research

The conducted researches *aimed* to optimize the component composition of crispbread using the milk thistle powder, vitamin-mineral mixture, table salt and grain raw materials.

To achieve this goal, the following tasks were solved:

1. To establish the optimum ratio of grain raw materials, powder of milk thistle concentrate, vitamin-mineral mixture and table salt in the formulation of crispbread.
2. To determine the quality indicators of the enriched crispbread produced using the raw components in the optimal ratio.

4. Research of existing solutions of the problem

Traditional cereal products (bakery products, cereals, pasta, cereal breakfasts) are available to low-income groups of the population, often the basis of their diet. Recommended by the Ukrainian Research Institute of Food Hygiene for the consumption of grain products per person is 101 kg/year [1, 9]. But in recent years, actual consumption was slightly higher [10], which is due to the imbalance in nutrition structure in the direction of cheap grain products due to the low living standards of the country's population. At the same time, this group of people is most affected by the deficit of BAS, which is caused by one-sidedness, imbalance and inadequate nutrition.

Particular interest among cereal-based products has ready-to-eat foods – grain bread. They have a long shelf life, are convenient for transportation and consumption, and are in demand among various segments of the population. Crispbread are made by special technology, do not contain residual fermentation products, completely ready for use. In addition, when consuming such breads, the human body becomes healthier. The effect of recovery is due to both the features of the manufacturing technology, and the high food and biological value of finished products. Based on biomedical research, it has been established that they are capable of removing radionuclides, heavy metal salts, and toxins from the body due to the presence of a large amount of BAS in them [11].

Researches of foreign scientists indicate that consumers are now more concerned about their health and prefer products based on whole grains. So the American scientists [12] carried out analytical researches, which showed that due to changes in the basic principles of nutrition and increased attention of this media, the demand for products that were made from whole grains is increased. At the same time products based on high-quality flour consumed less attention of consumers. In order to meet the demand in

ISSN 2226-3780

healthy nutrition, scientists from different countries conduct numerous studies in the field of formulation development, production technology and quality evaluation of products based on whole grains. They develop, first of all, bakery products; a lot of research is being done in the field of the development of food concentrates based on whole grains. Thus, Polish scientists [13] developed extruded products based on whole grains with the inclusion of corn chips, rice flour, cocoa and sugar. Scientists of Greece [14] proposed bread, where a part of wheat flour was replaced by whole-grain flour of rye, barley and oat flakes. The developed products were characterized by increased food and biological value, high content of dietary fiber, β-glucans, total content of phenols and other BAS. American scientists [15] carried out research on the production of breakfast cereals based on whole grains or corn, wheat, rice, and oats. According to the researches of scientists in Pakistan and Sweden [16], the use of bread with an increased content of dietary fiber can solve the problem of unbalanced nutrition of modern man. According to studies, regular consumption of such bread improves the functioning of the intestines, reduces the risk of obesity, constipation, diabetes, hypertension, cardiac and vascular diseases. Therefore, today, whole wheat crispbread is recommended by nutritionists as a product of adequate nutrition for health improvement of the population. This indicates that foreign scientists are conducting numerous product development on the basis of whole grains with a view to their further use for healthy human nutrition. In Ukraine, researches are underway in this area, but the range of domestic whole grain products is minimal and needs to be expanded and optimized for component composition [17]. Researches aimed at formation of the quality of a new food product using the example of crispbread for healthy food are promising, taking into account the requirements of consumers and its promotion to the consumer market in Ukraine.

5. Methods of research

To optimize the formulation composition of crispbread, the method of the response surface is used [18]. This method is a set of mathematical and statistical techniques aimed at modeling processes and finding combinations of experimental predictor series in order to optimize the response function $\hat{y}(x,b)$, which is generally described by the following polynomial:

$$\hat{y}(x,b)=b_0+\sum_{l=1}^{n}b_l x_l+\sum_{k=1}^{n}b_k x_k^2+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}b_{ij}x_i x_j, \quad (1)$$

where $x\in R^n$ – vector of variables, b – vector of parameters

Simulation and processing of the experimental data was performed in the environment of the software package Statistica 10 (StatSoft, Inc.).

In the formulations of enriched crispbread, the mass fraction of the milk thistle powder and table salt varied. All components were screened, magnetic cleaned and dosed. To the prepared dry ingredients, water was added and mixed for 5 minutes until a homogeneous mass and redistribution of the surface-bound moisture were obtained. The resulting mixture was sent to a special device for the production of whole-grain expanded grain grades УВХ-80х8 (Ukraine), where its thermal and mechanical treatment took place under the conditions recommended for this equipment: duration 8 s, P = 2.5...5 MPa. As a result, whole crispbread were obtained with a vegetable additive in the form of round briquettes. Bulk mass (BM, kg/m^3), swelling degree (*SD*, cm^3/g), and also the organoleptic evaluation (*OE*, points) were determined in the crispbread.

The optimum ratio of components in crispbread was determined using a complex quality index (*CQI*), which takes into account the cumulative effect of bulk weight, organoleptic parameters, swelling degree and weight coefficients of the specified unit indicators.

Based on the developed formulations of cereal loaves made on the basis of raw materials in optimal proportions, the chemical composition and the main quality indicators were determined, which resulted in conclusions about the possibility of producing new crispbread with specified consumer properties.

When performing the studies, the organoleptic parameters of the enriched crispbread were determined from the 20 points of the assessment scale, which was developed by the authors and described in [19]; bulk mass – according to [20]; swelling degree – according to [21].

6. Research results

The bulk mass (*BM*, kg/m^3), swelling degree (*SD*, cm^3/g), organoleptic evaluation (*OE*, points) and complex quality index (*CQI*) are chosen as criteria for optimizing the formulation of cereal loaves. *CQI* is an indicator that takes into account the cumulative influence of bulk mass, organoleptic evaluation, swelling degree and weight coefficient (*WC*) of the indicated unit indicators [22, 23]. Independent varied factors in the experiment are the mass fraction of table salt (C_{ts}, %) and the mass fraction of the powder of milk thistle (C_t, %). The content of vitamin-mineral mixture in breads is 1 %. The mass fraction of the grain is set such that the mixture of all the raw ingredients is 100 %.

For the modeling of the bulk mass (*BM*, kg/m^3), swelling degree (*SD*, cm^3/g), organoleptic evaluation (*OE*, points) and complex quality index (*CQI*) the response value is chosen, which has the form of a polynomial of the second degree:

$$BM=b_0+b_1\cdot C_{ts}+b_{11}\cdot C_{ts}^2+b_2\cdot C_t+b_{22}\cdot C_t^2+b_{12}\cdot C_{ts}\cdot C_t, \quad (2)$$

$$SD=b_0+b_1\cdot C_{ts}+b_{11}\cdot C_{ts}^2+b_2\cdot C_t+b_{22}\cdot C_t^2+b_{12}\cdot C_{ts}\cdot C_t, \quad (3)$$

$$OE=b_0+b_1\cdot C_{ts}+b_{11}\cdot C_{ts}^2+b_2\cdot C_t+b_{22}\cdot C_t^2+b_{12}\cdot C_{ts}\cdot C_t, \quad (4)$$

$$CQI=b_0+b_1\cdot C_{ts}+b_{11}\cdot C_{ts}^2+b_2\cdot C_t+b_{22}\cdot C_t^2+b_{12}\cdot C_{ts}\cdot C_t, \quad (5)$$

where *BM* – bulk mass, kg/m^3; *SD* – swelling degree, cm^3/g; *OE* – organoleptic evaluation, points; *CQI* – complex quality index; b_0 – constant; C_{ts} – mass fraction of table salt, %; C_t – mass fraction of milk thistle powder, %; b_1, b_{11}, b_2, b_{22}, b_{12} – coefficients for each element of the polynomial.

In studies, the central composite rotational plan is used [18]. The choice of levels and intervals of variation of factors are carried out according to the results of previous experiments [7, 11]:

– mass fraction of table salt varied within 0.5–1.5 %;
– mass fraction of the milk thistle powder – within 2.5–7.5 %.

The planning matrix and the experimental values of the response functions are presented in Table 1. To reduce the influence of systematic errors caused by external conditions, the sequence of experiments is randomized.

Table 1

Planning Matrix and Response Functions

Number of experiment	Mass fraction of table salt, (C_{ts})		Mass fraction of the milk thistle powder, (C_t)		Bulk mass (BM, kg/m^3)	Swelling degree (SD, cm^3/g)	Organoleptic evaluation (OE, points)
	Coded level	%	Coded level	%			
1	–1	0.65	–1	3.23	586	6.45	3.60
2	–1	0.65	+1	6.77	641	6.18	4.40
3	+1	1.35	–1	3.23	580	6.41	3.90
4	+1	1.35	+1	6.77	645	6.15	4.40
5	$-\sqrt{2}$	0.50	0	5.00	620	6.29	4.58
6	$+\sqrt{2}$	1.50	0	5.00	625	6.26	4.28
7	0	1.00	$-\sqrt{2}$	2.50	558	6.53	3.20
8	0	1.00	$+\sqrt{2}$	7.50	662	6.04	3.55
9	0	1.00	0	5.00	619	6.24	4.80
10	0	1.00	0	5.00	618	6.22	4.70
11	0	1.00	0	5.00	615	6.24	4.90
12	0	1.00	0	5.00	620	6.25	4.88

To test the significance of the regression coefficients (2), (3) and (4), the Pareto charts are constructing. They are shown in Fig. 1 (L – linear effect, Q – quadratic effect).

The Pareto charts (Fig. 1) show standardized coefficients, sorted by absolute values.

Analysis of the data in Fig. 1, *a*, indicates that the mass fraction of the common salt is linear (Ct, L) and quadratic (Ct, Q), as well as the interaction effect of the investigated parameters (1Lon2L) for regression (2) is insignificant (the evaluation columns of these effects do not intersect the vertical line, which is a 95 % confidence level). With this in mind, these regression members are eliminated from the model (2).

For regression (3), according to the data shown in Fig. 1, *b*, only the effect of the interaction of the mass fractions of the table salt and the milk thistle powder – (1Lon2L) is insignificant, therefore this regression member is eliminated from the model (3).

As for regression (4), two members are eliminated from it: the mass fraction of the table salt (C_{ts}, L) and the interaction of mass fractions (1Lon2L), since, according to Fig. 1, *c*, they are insignificant.

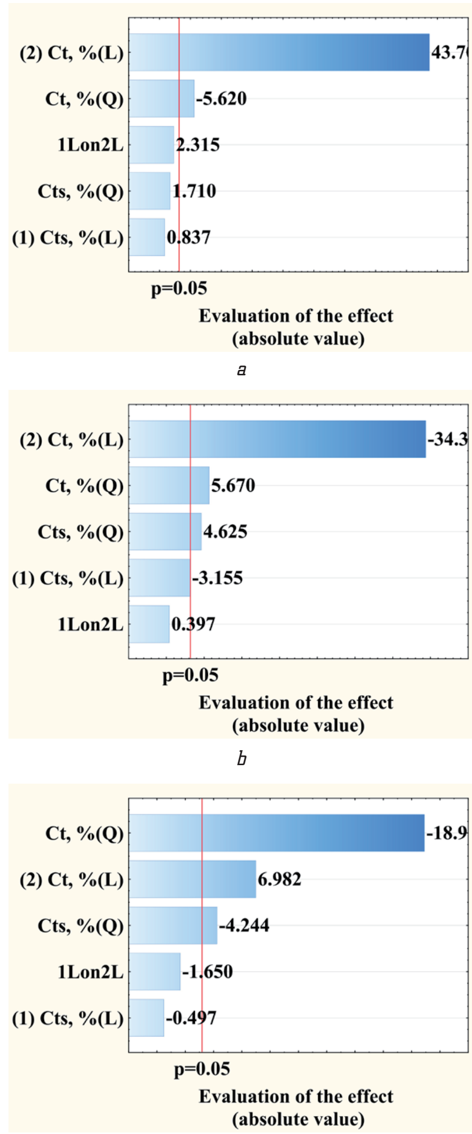
The obtained equations with the calculated coefficients have the form:

$$BM = 484{,}0 + 35{,}189 \cdot C_t - 1{,}632 \cdot C_t^2, \quad (6)$$

$$SD = 7{,}120 - 0{,}410 \cdot C_{ts} + 0{,}185 \cdot C_{ts}^2 - 0{,}177 \cdot C_t + 0{,}009 \cdot C_t^2, \quad (7)$$

$$OE = -1{,}078 - 0{,}052 \cdot C_{ts}^2 + 2{,}207 \cdot C_t - 0{,}208 \cdot C_t^2. \quad (8)$$

The adequacy of the developed models (6), (7) and (8) is checked by the method of variance analysis. The significance level of consistency loss for all three models is $p > 0.05$. The values of the determination coefficients for all models are close to 1: for model (6) $R^2 = 0.985$ and $R^2_{adj} = 0.972$; for model (7), $R^2 = 0.977$ and $R^2_{adj} = 0.958$; For model (8), $R^2 = 0.936$ and $R^2_{adj} = 0.884$. Thus, presented results indicate that the models adequately describe the experiment.



c

Fig. 1. The Pareto chart for testing the significance of the coefficients: *a* – regression (2); *b* – regression (3); *c* – regression (4)

The combined effect of the mass fraction of table salt (C_{ts}, %) and the milk thistle powder (S_t, %) on the bulk mass (BM, kg/m^3), swelling degree (SD, cm^3/g) and organoleptic evaluation (OE, points) of crispbread in a graphical form are shown in Fig. 2, *a*, *b*, *c*, respectively.

The increase of the mass fraction of the milk thistle powder (SD, %) in the formulation of crispbread contributes to a significant increase in the bulk mass (by 19.7...19.9 %). The increase in the mass fraction of table salt practically does not affect this indicator (Fig. 2, *a*). The maximum value of the bulk weight has crispbread, which contain 7.5 % powder of the milk thistle concentrate and 1.5 % of table salt. An increase in the mass fraction

ISSN 2226-3780

of the milk thistle powder (S_t, %) in the formulation of crispbread leads to decrease in the swelling degree (SD, cm^3/g) – Fig. 2, *b*, which is explained by a significant decrease of the grain component in the plant-grain mixture. The maximum values of swelling degree are noted for products that contain a minimum mass fraction of the milk thistle powder. The increase in the mass fraction of table salt (S_{ts}, %) from 0.5 to 1.0 % contributes to an insignificant decrease in swelling degree of crispbread that is also probably due to a decrease in the content of the grain ingredient in the initial mixture. Further increase in the content of table salt from 1.0 to 1.5 % causes an insignificant increase in the studied indicator, which is explained by the hygroscopic properties of the salt. The highest swelling degree has the samples of crispbread, in which the mass fraction of the milk powder is 2.5 %, and table salt – 1.5 %.

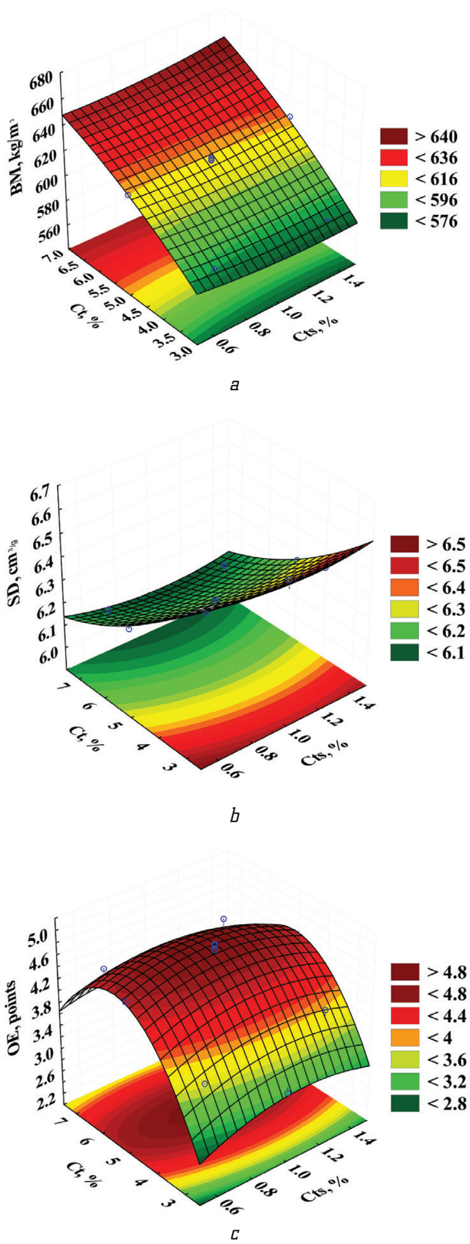


Fig. 2. Dependence: *a* – bulk mass (*BM*); *b* – swelling degree (*SD*); *c* – organoleptic evaluation (*OE*); mass fraction of the milk thistle powder (C_t, %) and mass fraction of the table salt (C_{ts}, %)

Organoleptic parameters of crispbread are more significantly affected by the increase in the mass fraction of milk thistle powder (S_t, %) than the increase in the content of table salt (S_{ts}, %) – Fig. 2, *c*.

An increase in the mass fraction of the milk thistle powder from 2.5 to 5.3 % contributes to the improvement of the organoleptic characteristics of the target products. Further increase in the content of this raw ingredient to 7.5 % negatively affects the organoleptic characteristics of the crispbread. The products are slightly deformed, with minor cracks and fractures along the edges, there are darkish patches on the surface, the smell and taste of used additives are too pronounced.

The highest organoleptic evaluation – 4.88 points (Fig. 2, *c*) have crispbread samples, which contain 0.97 % table salt and 5.30 % powder of milk thistle concentrate.

The obtained results do not allow to determine the optimal mass fractions of raw ingredients. To optimize the formulation of crispbread, a complex quality index (CQI) is used. It is defined as a function of evaluation of single quality indices – bulk mass, swelling degree and organoleptic evaluation (Table 2), converted into a scaled value, taking into account the weight coefficients of individual indicators (M_i) [22, 23]:

$$CQI = M_1 \cdot BM_s + M_2 \cdot SD_s + M_3 \cdot OE_s, \quad (9)$$

where BM_s, SD_s, OE_s – bulk mass, swelling degree, organoleptic evaluation of crispbread, respectively, converted into scaled values; M_1, M_2, M_3 – the weight coefficients of unit indicators-bulk mass, swelling degree and organoleptic evaluation of the products, respectively. In this case [22, 23]:

$$\sum_{i=1}^{n} M_i = 1{,}0. \quad (10)$$

To convert single indicators into the range (1...10), the initial data given in Table 1, are scaled by expression (11) [22, 23]:

$$y = \frac{(y_{\max} - y_{\min}) \cdot (x - x_{\min})}{x_{\max} - x_{\min}} + y_{\min}, \quad (11)$$

where y – the scaled data; x – output data given in Table 1; $x_{\min}$ and $x_{\max}$ – the minimum and maximum values of the output data (for the bulk mass $x_{\min}$ and $x_{\max}$ are calculated according to the model (6).

For swelling degree – according to the model (7).

For an organoleptic evaluation $x_{\min} = 1$ point, $x_{\max} = 5$ points (according to 5-point evaluation).

$Y_{\min}$ and $y_{\max}$ – the minimum and maximum values of the new range (1 and 10, respectively).

The scaled values of the single indicators and the values of the complex quality index (CQI) calculated according to the expression (9) are given in Table 2 (the following values of the weight coefficients are adopted for the calculation of the CQI: according to the recommendations of the expert commission: $M_1 = 0.10$; $M_2 = 0.15$; $M_3 = 0.75$).

To test the significance of the regression coefficients (5), the Pareto chart is constructed, which is shown in Fig. 3 (L – linear effect, Q – quadratic effect).

Table 2

The scaled values of the single indicators and the values of the complex quality index

Number of experiment	Scaled bulk mass (BM_s)	Scaled swelling degree (SD_s)	Scaled organoleptic evaluation (OE_s)	Complex quality index (CQI)
1	8.53	3.42	6.85	6.325
2	3.57	8.18	8.65	6.985
3	7.80	2.90	7.53	6.222
4	3.02	8.53	8.65	6.925
5	5.59	6.37	9.06	7.212
6	5.04	6.80	8.38	6.904
7	10.00	1.00	5.95	5.68
8	1.00	10.00	6.74	5.996
9	4.67	6.28	9.55	7.105
10	4.31	6.19	9.33	6.882
11	4.67	5.93	9.78	7.092
12	4.86	6.37	9.73	7.261

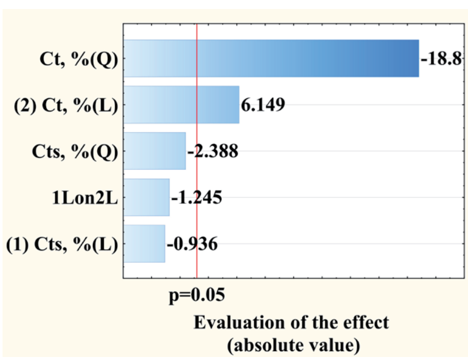


Fig. 3. The Pareto chart for testing the significance of regression coefficients (5)

Mass fraction of table salt is linear (S_{ts}, L) and quadratic (S_{ts}, Q), the interaction effect of the investigated parameters (1Lon2L) for regression (5) is insignificant (Fig. 3). With this in mind, these regression members are eliminated from this model. The equation obtained with the calculated coefficients of regression has the form:

$$CQI = -3.487 + 4.058 \cdot C_t - 0.385 \cdot C_t^2. \qquad (12)$$

The adequacy of the developed model (12) is tested by the method of variance analysis. The obtained data, in particular, the absence of consistency loss (significance level $p > 0.05$) and the values of the determination coefficients ($R^2 = 0.942$ and $R^2_{adj} = 0.893$), close to 1, allow to conclude that the model (12) adequately describes the responce.

The combined effect of the mass particles of the milk powder (S_t, %) and table salt (S_{ts}, %) on the complex quality index (CQI) of crispbread described by the polynomial (12) is shown graphically in Fig. 4.

The increase of a mass fraction of milk thistle powder (DM, %) from 2.50 to 5.27 % in the formulation of crispbread causes an increase in CQI. With a further increase in the content of this raw ingredient in the crispbread recipes, CQI value decreases (Fig. 4). With an increase in the mass fraction of table salt from 0.50 to 0.92 %, CQI increases, and with a further increase in C_{ts}, CQI decreases (Fig. 4). The change in the mass fraction of the milk powder has a more significant influence on CQI change, which is due to the significant influence of this optimization criterion on all the investigated response functions (Fig. 2, *a–c*).

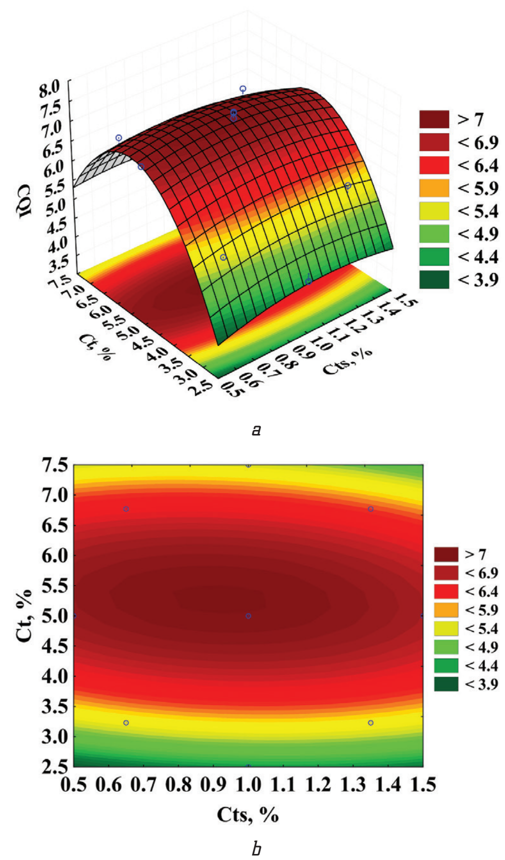


Fig. 4. Dependence of the complex quality index (CQI) on the mass fraction of table salt (S_{ts}, %) and the mass fraction of milk powder (S_t, %): *a* – response surface; *b* – contour plot

Processing of the polynomial (12) in the Statistica 10 allows to determine the optimal values of the mass fractions of the milk thistle powder and table salt – 5.27 and 0.92 %, at which the maximum CQI value is reached (7.195).

The main quality indicators of enriched crispbread, obtained with the use of raw materials in optimal proportions, are given in Table 3.

Researches of experimental samples of crispbread have proved that the target products with the optimum content of the enriched additives are characterized by improved consumer properties:

- good organoleptic characteristics;
- normalized physicochemical parameters;
- high food and biological value;
- absolute safety.

Table 3

Organoleptic, physical, chemical and microbiological parameters of enriched crispbread

Indicator	Characteristic of an indicator
Organoleptic indicators	
Color	Uniform, light cream with minor impregnations of used additives
Smell	A pleasant, pronounced smell of plant components
Appearance	The shape is correct, the dimensions are correspondingly rounded, rough, without deformations
Taste	Pleasant, pronounced flavor of used additives
Structure	Sufficiently crispy, with developed porosity, without signs of impurity
Physical and chemical indicators	
Mass fraction of protein, %	12.19±0.23
Mass fraction of starch, %	52.19±0.57
Mass fraction of cellulose, %	11.41±0.21
Mass fraction of fat, %	2.71±0.07
Bulk weight, kg/dm^3	624.0±1.0
Swelling degree, cm^3/g	6.21±0.01
Microbiological indicators	
Bacteria of the coliform group (coliforms), in 0.1 g	Absent
Pathogenic microorganisms, including C. Bacteria of the genus Salmonella, in 50 g	Absent

7. SWOT analysis of research results

Strengths. Strengths of the developed product include: the consumer's interest in the new product, high nutritional value, natural ingredients and improved organoleptic indicators.

Weaknesses. The weaknesses of the developed product include: a higher price compared to similar products and a weak awareness of consumers about the new product, its advantages.

Opportunities. As for the possibilities of the new product, it is: low food value of analog products from competitors, the presence of unsaturated segments of markets, a narrow range of products for healthy nutrition.

Threats. Threats when a new product is released to the consumer market include:

– possibility of new products and alternative products;
– growing competitive pressure, as a result of the emergence of new competitors;
– decline in the purchasing power of the population;
– consumer conservatism.

Based on the SWOT analysis, the following strategic solutions are proposed:

– access to new markets or market segments. This is a flexible pricing policy, as well as an active role of marketing. At marketing activities, it is necessary to focus on the consumer properties of the product, its nutritional value, high organoleptic and preventive properties. To carry out activities to develop the consumer in terms of nutrition, healthy lifestyle, as a result, and will encourage the consumer to buy this product. To pay attention to the packaging design and the informative nature of the marking; expansion of the product line by including a wide range of natural additives and raw materials;
– weak side, namely, a high price in comparison with similar products presented in the market, we suggest to solve by reducing the price of our own product by increasing production volumes. The increase in demand for a new product will occur due to the improvement of its consumer properties, primarily due to high organoleptic characteristics and the availability of preventive properties;
– one more weak side, namely, «the low information content of consumers about the new product and its advantages», we propose to solve at the expense of the complex of measures. They must begin at the initial stage of product development and continue throughout the whole stage of product development. Activities should be aimed at informing potential consumers about the properties of the new product and the principles of healthy nutrition;
– to reduce the impact of such factors as «the emergence of new competitors» and «growing competitive pressure» we offer: flexible pricing policy, development of new markets, the active role of marketing, product expansion. As for the factor of «reducing purchasing power», it is envisaged to carry out measures to position a new product among potential consumers, measures to develop the consumer himself in matters of nutrition, in matters of a healthy lifestyle;
– promotion of goods by merchandising means – if there is no possibility to use direct advertising for promotion of a new product, it is advisable to stimulate sales with the help of indirect communications, which are less expensive, but no less effective.

8. Conclusions

1. Optimum mass fractions of powder of milk thistle concentrate and table salt – 5.27 and 0.92 %, respectively, as components of crispbread.

2. Based on experimental studies, it has been established that crispbread produced using raw materials in an optimal ratio differ with:

– improved organoleptic properties, namely: they have a pleasant, pronounced smell and a slight taste of vegetable additives, which are harmoniously combined with the smell of grain raw materials;
– characterized by high fiber content – 11.41±0.21 %;
– normalized physical and chemical parameters – bulk mass of the products is 624.0±1.0 kg/dm^3, and swelling degree is 6.21±0.01 cm^3/g;
– are absolutely safe.

References

1. Yehorov, B. V. Naukovi osnovy formuvannia spozhyvnykh vlastyvostei novykh zernovykh produktiv [Text]: Monograph / B. V. Yehorov, M. R. Mardar. – Odesa: TES, 2013. – 388 p.
2. Shafranskyi, V. V. Shchorichna dopovid pro stan zdorovia naselennia Ukrainy, sanitarno-epidemichnu sytuatsiiu ta rezultaty diialnosti systemy okhorony zdorovia Ukrainy. 2015 rik [Text] / ed. by V. V. Shafranskyi. – Kyiv, 2016. – 452 p.

3. Bankovska, N. V. Hihiienichna otsinka stanu faktychnoho kharchuvannia dorosloho naselennia Ukrainy ta naukove obgruntuvannia shliakhiv yoho optymizatsii [Text]: Thesis of PhD: 14.02.01 / N. V. Bankovska. – Kyiv, 2008. – 26 p.
4. Simakhina, H. Innovatsiia u kharchovykh tekhnolohiiakh [Text] / H. Simakhina, N. Naumenko // Tovary i rynky. – 2015. – № 1. – P. 189–201.
5. Zverev, S. V. Funktsional'nye zernoprodukty [Text] / S. V. Zverev, N. S. Zvereva. – Moscow: DeLi print, 2006. – 119 p.
6. Ostrikov, A. N. Koekstruzionnye produkty: novye podhody i perspektivy [Text] / A. N. Ostrikov, V. N. Vasilenko, I. Yu. Sokolov. – Moscow: DeLi Print, 2009. – 232 p.
7. Mardar, M. QFD methodology to develop a new health-conducive grain product [Text] / M. Mardar, D. Zhygunov, R. Znachek // Eastern-European Journal of Enterprise Technologies. – 2016 – № 2/11 (80). – P. 42–47. Doi:10.15587/1729-4061.2016.65725
8. Suchowilska, E. A comparison of macro- and microelement concentrations in the whole grain of four Triticum species [Text] / E. Suchowilska, M. Wiwart, W. Kandler, R. Krska // Plant, Soil and Environment. – 2012 – Vol. 58, № 3. – P. 141–147.
9. ZVIT pro stan prodovolchoi bezpeky Ukrainy u 2013 rotsi [Electronic resource] // Ministry of Economic Development and Trade of Ukraine. – Available at: \www/URL: http://www.me.gov.ua/Documents/Download?id=c06d7392-f237-4e56-a2dd-9e511a3e53c4
10. State Statistics Service of Ukraine [Electronic resource]. – Available at: \www/URL: http://www.ukrstat.gov.ua
11. Mardar, M. Medical and biological estimation of grain small loaves on the basis of whole wheat grain with the inclusion of vegetable additives [Text] / M. Mardar, R. Znachek // Food and Environment Safety. – 2014. – Vol. XIII, № 4. – P. 365–371.
12. Mancino, L. Getting consumers to eat more whole-grains: The role of policy, information, and food manufacturers [Text] / L. Mancino, F. Kuchler, E. Leibtag // Food Policy. – 2008. – Vol. 33, № 6. – P. 489–496. Doi:10.1016/j.foodpol.2008.05.005
13. Wójtowicz, A. Selected Physical Properties, Texture and Sensory Characteristics of Extruded Breakfast Cereals based on Wholegrain Wheat Flour [Text] / A. Wójtowicz, M. Mitrus, T. Oniszczuk, L. Mościcki, M. Kręcisz, A. Oniszczuk // Agriculture and Agricultural Science Procedia. – 2015. – Vol. 7. – P. 301–308. doi:10.1016/j.aaspro.2015.12.051
14. Koletta, P. Physicochemical and technological properties of highly enriched wheat breads with wholegrain non wheat flours [Text] / P. Koletta, M. Irakli, M. Papageorgiou, A. Skendi // Journal of Cereal Science. – 2014. – Vol. 60, № 3. – P. 561–568. doi:10.1016/j.jcs.2014.08.003
15. Caldwell, E. F. Cereals: Breakfast Cereals [Text] / E. F. Caldwell, J. D. McKeehen, R. S. Kadan [Text] // Encyclopedia of Food Grains. – Elsevier, 2016. – P. 262–267. doi:10.1016/b978-0-12-394437-5.00143-1
16. Rakha, A. Fibre-enriched and wholegrain breads [Text] / A. Rakha, P. Aman, R. Andersson // Fibre-Rich and Wholegrain Foods. – 2013. – P. 211–235. doi:10.1533/9780857095787.3.211
17. Mardar, M. R. Analiz struktury asortymentu zernovykh khlibtsiv, shcho realizuiutsia u rozdribnii torhovelnii merezhi m. Odesy [Text] / M. R. Mardar, R. R. Znachek, A. V. Lazutkina, K. Tarnavska // Zernovi produkty i kombikormy. – 2013. – № 1. – P. 13–15.
18. Myers, R. Response Surface Methodology: Process and Product Optimization Using Designed Experiments [Text] / R. Myers, D. Montgomery, C. Anderson-Cook. – Ed. 4. – Hoboken, New Jersey: John Wiley&Sons, 2016. – 856 p.
19. Mardar, M. R. Rozrobka ta aprobatsiia balovoi shkaly dlia otsinky yakosti zernovykh khlibtsiv ozdorovchoho pryznachennia [Text] / M. R. Mardar, R. R. Znachek, M. B. Rebezov // Naukovi pratsi ONAKhT. – 2015. – Vol. 48. – P. 4–8.
20. GOST 15113.1-77. Kontsentraty pishchevye. Metody opredeleniia kachestva upakovki, massy netto, obiemnoi massy, massovoi doli otdel'nyh komponentov, razmera otdel'nyh vidov produkta i krupnosti pomola [Text]. – Introduced: 1977.01.01. – Moscow: Izdatel'stvo standartov, 1977. – 9 p.
21. Ostrikov, A. N. Ekstruziia v pishchevoi tehnologii [Text] / A. N. Ostrikov, O. V. Abramov, A. S. Rudometkin. – St. Petersburg: GIORD, 2004. – 288 p.
22. Tkachenko, N. Optimization of formulation composition of the low-calorie emulsion fat systems [Text] / N. Tkachenko, P. Nekrasov, T. Makovska, L. Lanzhenko // Eastern-European Journal of Enterprise Technologies. – 2016. – № 3/11 (81). – P. 20–27. Doi:10.15587/1729-4061.2016.70971
23. Tkachenko, N. Modelling formulae of strawberry whey drinks of prophylactic application [Text] / N. Tkachenko, P. Nekrasov, S. Vikul, Ya. Honcharuk // Food Science and Technology. – 2017. – № 1. – P. 3–8. Doi:10.15673/fst.v11i1.303

ОПТИМИЗАЦИЯ РЕЦЕПТУРНОГО СОСТАВА ЗЕРНОВЫХ ХЛЕБЦЕВ С УЛУЧШЕННЫМИ ПОТРЕБИТЕЛЬСКИМИ СВОЙСТВАМИ

Рассмотрены вопросы оптимизации рецептурного состава зерновых хлебцов с улучшенными потребительскими свойствами. Обоснованы оптимальные массовые доли порошка расторопши и поваренной соли – 5,27 и 0,92 % соответственно в качестве компонентов целевых продуктов. Доказано, что зерновые хлебцы с оптимальным составом характеризуются улучшенными органолептическими, нормированными физико-химическими показателями, высокой пищевой, биологической ценностью, являются безопасными.

Ключевые слова: зерновые хлебцы, спельта, цельнозерновые продукты, оптимизация рецептурного состава, комплексный показатель качества.

Mardar Marina, *Doctor of Technical Sciences, Professor, Vice-Rector for Scientific and Pedagogical Work and International Relation, Department of Marketing, Business and Trade, Odessa National Academy of Food Technologies, Ukraine, e-mail: mardar.marina@yandex.ua, ORCID: http://orcid.org/0000-0003-0831-500X*

Tkachenko Nataliia, *Doctor of Technical Sciences, Professor, Department of Dairy Technology and Technology of Fats and Perfume-Cosmetic Products, Odessa National Academy of Food Technologies, Ukraine, e-mail: nataliya.n-2013@yandex.ua, ORCID: http://orcid.org/0000-0002-2557-3927*

Znachek Rafaela, *Postgraduate, Department of Marketing, Business and Trade, Odessa National Academy of Food Technologies, Ukraine, e-mail: rafaehlab@yandex.ru, ORCID: http://orcid.org/0000-0001-9008-3863*

Cherubino Leonardi, *PhD, Professor, Department of Agriculture, Nutrition and Environment, Catania University, Italy, e-mail: cherubino.leonardi@unict.it, ORCID: http://orcid.org/0000-0002-9486-3231*