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OPTIMIZATION OF THE RECIPES OF FORCEMEAT PRODUCTS ON THE BASIS OF PROCESSED FRESHWATER MUSSELS

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Abstract. This article is devoted to the optimization of the formulations of mincemeat products (cutlets) based on the semi-finished product from the freshwater mussel of the genus Anodonta. Recipe of this semi-finished product that can be introduced into the composition of different groups of dishes and culinary products has been developed. The article presents the model developed of optimisation of the recipe composition of polycomponent systems according to the optimum daily consumption of protein, fats and carbohydrates, with the classical cutlet technology as an example. In the course of the research, a universal model of an orthogonal central composite design to optimize forcemeat products was developed based on the criterion of a balance of the basic nutrients. The orthogonal central composite design is described in detail with four (n) factors of the optimization of the formulations of forcemeat products, and the homogeneity of the dispersion is confirmed, using Cochran's C test at the significance level of x (0.05). The significance of the statistical model and the reliability of the regression equation were determined with an F-test. An organoleptic evaluation of the composition of each formulation of forcemeat products on the basis of processed freshwater mussels was made during the experiment by analytical methods – the qualitative method and the developed profile analysis method according to a point scale. The obtained results were presented in the form of a 3D model constructed using the least-squares smoothing method. After the graphic data obtained and the results of the direct measurements had been studied and the regression equation interpreted, we determined that the optimum composition of forcemeat products based on the processed freshwater mussel was the sample having the ratio of proteins, fats, and carbohydrates 1:1.03:4.18, which is the closest to the optimum ratio (1:1:4), and the organoleptic rating 14.25. Besides, basing on formulation 21 developed by us, we have determined the content of minerals, in particular Ca, P, Mg, Fe, I_2, in one portion.

Key words: semi-finished freshwater mussels, forcemeat systems, cutlet, optimization, orthogonal central composite design.

ОПТИМІЗАЦІЯ РЕЦЕПТУРНОГО СКЛАДУ ФАРШЕВИХ ВИРОБІВ НА ОСНОВІ НАПІВФАБРИКАТУ З МОЛЮСКА ПРІСНОВОДНОГО

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Анотація. Статтю присвячено оптимізації рецептурного складу фаршевих виробів (котлет) на основі напівфабрикату з молюска прісноводного роду Anodonta. Розроблено рецептуру напівфабрикату, який може бути введений до складу різних груп страв і кулінарних виробів. Спроектовано та представлено модель оптимізації рецептурного складу полікомпонентних систем за оптимальною добовою нормою споживання білків, жирів та вуглеводів. У ході досліджень розроблено універсальну модель ортогонального центрального композиційного плану для оптимізації фаршевих виробів по критерію збалансованості за основними поживними речовинами. Детально описано ортогональний центрально-композиційний план при чотирьох (n) факторах оптимізації рецептури фаршевих виробів та підтверджено однорідність дисперсії за допомогою G-критерія (Кохрена) при рівні значущості x (0,05). Значимість статистичної моделі та надійність рівняння регресії визначали за допомогою F-критерія Фішера. Проведено органолептичну оцінку кожної рецептурної композиції фаршевих виробів на основі напівфабрикату з молюска прісноводного. Оцінку здійснювали в ході експерименту аналітичними методами та методом розробленого профільного аналізу по баловій шкалі. Отримані результати представлено у вигляді 3D моделі, що побудована за допомогою метода згладжування найменших квадратів. Після дослідження отриманих графічних даних, результатів безпосередніх вимірювань та інтерпретації рівняння регресії, оптимальною рецептурною композицією фаршевих виробів на основі напівфабрикату з молюска прісноводного визначено зразок, який має найбільш близьке до оптимально (1:1:4) співвідношення білків, жирів та вуглеводів при органолептичній оцінці 14,25. Визначено вміст мінеральних речовинв одній порції розробленої рецептури.

Ключові слова: напівфабрикат з молюска прісноводного, фаршеві системи, котлети, оптимізація, ортогональний центрально-композиційний план.

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Introduction. Formulation of the problem

One of the main problems of providing wholesome food to people is the problem of dietary protein. The full value of the protein is determined by the presence in its composition of all essential aminoacids. One of the sources of dietary protein is hydrobionts. The vast majority of fish products and aquaculture products are imported to Ukraine. At the same time, the freshwater surface area in our state is one of Europe's largest. So, a topical issue is studying the nutritional potential of the bodies of freshwater. And this is especially urgent after the loss of a large part of the sea water area.

The technology of semi-finished freshwater mussels has been developed. Considering that the semi-finished product has high consumer properties and biological value, the important task is to introduce it into recipes of dishes and culinary products. Since forcemeat (stuffing) systems are multicomponent, their formulations allow using in their composition processed freshwater mussels as a source of complete protein, unsaturated fatty acids and minerals, including iodine. The introduction of this semi-finished product in the restaurants as an independent product and as part of the main groups of dishes will expand the assortment, add new qualities to the existing dishes and culinary products, and also allow balancing their composition.

In this paper we consider how using mathematical modelling methods, namely orthogonal central composite design, makes it possible to find the optimum ratio of the recipe components and obtain the optimum content of the main nutrient substances in a culinary product, for example, a cutlet, which uses processed freshwater mussels. The optimization takes into account the interdependence and the values of the four factors: the content of protein, fat, carbohydrates and organoleptic properties. The data on the protein, fat and carbohydrates are compared with the daily needs of an average person aged 19 to 38 years. The basis of the recipes is minced meat, the main component of which is processed freshwater mussels. The response function is interpreted and studied, then conclusions are made on the optimization of the chosen formulation. An important criterion for controlling the development of the optimum chemical composition of cutlets is the estimation of organoleptic parameters, namely taste, smell, colour and texture.

The importance of the research is in the creation of a model, methodological recommendations for the creation of an assortment of products for the use of new raw materials – processed freshwater mussel of the genus Anodonta, and its wider introduction in restaurants. Previous studies confirm that the soft body of Anodonta mussels is a high-nutrient raw material rich in essential aminoacids [1], unsaturated fatty acids [2] and micro and macro elements, among them iodine [3], and structural and mechanical parameters optimum for cooking forcemeat products.

Analysis of recent research and publications

A problem of the technology of forcemeat products with the use of semi-finished products is determining the optimum composition of the recipe. Besides, it is important to satisfy the organoleptic preferences of consumers, and provide them with nutritionally balanced food. The task is difficult to accomplish without the use of special statistical methods. Obviously, the volume of research is too large. Using freshwater hydrobionts instead of marine ones is associated with several factors. One of them is the remoteness of some regions from the sea and the ocean. Another is the loss of a large part of the sea area. This contributes to the increase in prices of marine hydrobionts and the drop in catches [4]. This has led to the need to revise the raw material base for the manufacture of semi-finished products and ready-made culinary products, as well as to changes in their production technology [5]. In order to reduce time expenditures in solving the optimization problem, it was decided to use mathematical methods and methods for profile analysis of organoleptic evaluation.

Among the main directions to solve the above-mentioned problem found in the world's scientific periodicals, the following can be distinguished:

– study of mussels (mussels Perna perna) as a food product in terms of physical, chemical, nutritional, and consumer properties [6];

– analysis of recipes of culinary products on the basis of the main chemical composition parameters that meet the requirements of a certain group of consumers (which corresponds to the physiological norms of feeding different population groups). The correlation of carbohydrates and proteins is analysed, which is determined to correlate the labour intensity group. On this basis, the criteria for the optimumy composition of the suggested culinary products were adopted [7];

– mathematical modelling of the recipe composition of cupcake with high nutritional value [8];

– optimization of production of biomass from kefir grain, using milk in the culture environment. Kefir grains were cultivated under varying conditions (temperature, time, shaker rotational speed, supplementation of cultural environments) to evaluate their effects [9];

– optimization and mathematical modelling of the attributes of quality of processed rice using the response surface method [10];

– in this study, the effects of hot air drying conditions on the colour, water content and total phenolic content of dried apples were investigated using an artificial neural network as an intelligent modelling system. After that, the genetic algorithm was used to optimize the drying conditions [11];

– the osmotic conditions for strawberry dehydration were optimized using a central combined rotary design [12];

– research of bivalve mussels of the Californian coast as an object of fishing and biotechnology, description of their way of life and features of cultivation [13];

– study of the dependence of the growth rate of bivalve mussels on the degree of water pollution [14];

– research on the chemical composition of mussels of the genus Stichaeidae [15].

The purpose of the study is to optimize the recipe of forcemeat products on the basis of freshwater mussels as for the content of proteins, fats and carbohydrates, at one of the maximum organoleptic values, and to create a universal model for other formulations in which the soft body of mussels of the genus Anodonta is used.

To achieve this goal, the following **tasks** were performed:

1. Develop an orthogonal central composite design with four (n) optimization factors for the product formulation with the fixation of each of the factors at five levels, taking into account the minimum and maximum number of the ingredients with constant basic characteristics of the dish.
2. Evaluate the organoleptic properties of each formulation determined during the experiment.
3. Determine a ratio (close to the optimum) of proteins, fats and carbohydrates in the diet to the norm in the diet of an average adult by interpreting the mathematical data obtained into the language of the experiment, taking into account the organoleptic characteristics.
4. To determine the content of mineral substances in the dish at the quantitative parameters of the optimum composition of the ingredients.

Research materials and methods

The objects of the study were: technology and the formulation of minced meat products (cutlets № 510), technology of the forcemeat products using freshwater mussels.

The object of the study were: the recipe components of cutlets № 510, processed freshwater mussels.

The general chemical composition was determined by standard methods: the total nitrogen content according to DSTU ISO 5983-2003, crude fat was determined according to DSTU ISO 6492: 2003. The conversion into pure protein was carried out by multiplying by the factor for translating nitrogen into crude protein for a given product group according to the methods indicated in GOST 766-85.

The results of the determining the level of the main micro and macro elements of the soft body of Anodonta mussels and all the components of the formulation of cutlets: phosphorus, iron were determined by atomic absorption spectrophotometry at the atomic absorption spectrophotometer AAAS-30 with appropriate light filters; potassium, iodine, calcium were determined on a photoelectric colorimeter KFK-2. The definitions were carried out according to DSTU ISO 6490 1: 2004, DSTU ISO 6491: 2004, DSTU ISO 7485-2003, GOST 27995-88, GOST 27997-88, GOST 27996-88, GOST 27998-88, GOST 26933-86, GOST 26932- 86.

The organoleptic assessment of the quality of the finished product was carried out by analytical methods – qualitative and the method of profile analysis. The essence of the profile method is that the complex concept of one of the organoleptic parameters (consistency, taste and smell, colour) was presented as a set of components (descriptors) that experts evaluated by quality, intensity and order of manifestation. The method is based on the determination of the organoleptic parameters of the cutlets using processed freshwater mussels in the formulation and the comparison with the control samples of the classical cutlets № 510 recipe (according to the register of recipes). The method is aimed at developing a product sensory evaluation scale. The scale is represented graphically in the form of separate descriptors on semicircular profiles. The axes in the charts correspond to separate descriptors, and the values of each component of the sensory evaluation are marked on the corresponding axes on a five-point scale, taking into account the weight factors of individual descriptors and indicators in general.

For optimization, the response function is formed in the form of a complete square polynomial of the second order for n=4, which is given in formula 1. To determine the coefficients of the polynomial, an orthogonal central composite design of the second order (OCCD) is used [12].

$$Y=b_0+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_{12}x_1x_2+b_{13}x_1x_3+b_{14}x_1x_4+b_{23}x_2x_3+b_{24}x_2x_4+b_{34}x_3x_4+b_{123}x_1x_2x_3+b_{124}x_1x_2x_4+b_{234}x_2x_3x_4+b_{1234}x_1x_2x_3x_4+b_{11}x_1^2+b_{22}x_2^2+b_{33}x_3^2+b_{44}x_4 \quad (1)$$

An orthogonal central composite design is a design whose matrix of planning X is constructed so that the matrix $C=X_tX$ is diagonal. We use this approach when constructing designs of the second order. The design is called central if all the points are symmetrically centred on the plan.

To determine the OCCD so that it can be used in the research, 3 criteria are used, the data about which are well-known:

1. Student's t-test is the general name for a class of methods for statistical testing of hypotheses (statistical criteria) based on comparison with Student's distribution. The most frequent cases of t-test application are related to checking the equality of mean values in two samples [1].
2. Cochran's C test, used to compare three or more choices of the same volume.
3. F-test, or Fisher's criterion (F-criterion, φ*-criterion) – any statistical criterion, the test statistics of which has a Fisher distribution (F-distribution) when performing the zero hypothesis.

Results of the research and their discussion

The optimization parameter is the optimum ratio in the formulation of proteins, fats and carbohydrates at the highest values of organoleptic parameters. According to established rational norms of daily consumption of basic nutrients, the optimum daily ratio of protein, fat and carbohydrates for an average adult is 1:1:4, respectively [1]. In the OCCD, each factor is fixed at five levels. Considering the maximum and minimum number of grams of ingredients, with agreed valuation of the organoleptic characteristics of forcemeat products, as shown in Table

1, the experimental plan, the results of direct measurements and their initial analysis are presented in Table 2 and Table 3, respectively.

As a result of the research, coefficients of the regression equation have been obtained. The statistical analysis of the model as a whole and its coefficients individually have been carried out. The results are summarized in Table 4.

After the construction of the OCCD, carrying out all necessary calculations and determining the regression equation as reliable, the coefficients in the formula 1 were replaced with the ones determined in the studies, which makes it possible to determine the interdependence of the formulation components and their influence on the optimization parameters. The resulting regression model in the coded units has the form:

$$Y=14.34+1.05x_1+0.28x_2+0.41x_3+0.22x_4+0.11x_1x_2+0.04x_1x_3-0.08x_1x_4+0.03x_2x_3-0.08x_1x_2x_3-0.01x_1x_2x_4-0.01x_2x_3x_4+0.03x_1x_2x_3x_4-0.07x_2^2+0.08x_3^2-0.09x_4^2 \quad (1)$$

Table 1 – Recipe components and fixing levels of factors affecting the formulation of forcemeat products

Factors influencing optimization (components of the formulation)		Levels of fixation of factors and their natural values, g					Content per 100 g of the product, g		
		-1.414	-1	0	1	1.414	Proteins	Fats	Carbohydrates
x_1	Wheat flour	27.93	30	35	40	42.07	7.5	2.6	56.1
x_2	Mussels	15.86	20	30	40	44.14	8.2	1.2	0.1
x_3	Chicken eggs	7.93	10	15	20	22.07	5.9	32.4	4.1
x_4	Onion	7.93	10	15	20	22.07	2	15.3	2
Component of the recipe that are not factors in the mathematical model		Content in 1 net portion, g					Proteins	Fats	Carbohydrates
Salt		2					0	0	0
Pepper		5					0.5	0.15	0.3

Table 2. Orthogonal central composite design for four (n) factors of optimization of the recipe formulation of minced meat products based on freshwater mussels (planning matrix)

No	x_0	x_1	x_2	x_3	x_4	x_1^2–0.8	x_2^2–0.8	x_3^2–0.8	x_4^2–0.8
1	1	1	1	1	1	0.20	0.20	0.20	0.20
2	1	-1	1	1	-1	0.20	0.20	0.20	0.20
3	1	1	-1	1	-1	0.20	0.20	0.20	0.20
4	1	-1	-1	1	1	0.20	0.20	0.20	0.20
5	1	1	1	-1	-1	0.20	0.20	0.20	0.20
6	1	-1	1	-1	1	0.20	0.20	0.20	0.20
7	1	1	-1	-1	1	0.20	0.20	0.20	0.20
8	1	-1	-1	-1	-1	0.20	0.20	0.20	0.20
9	1	1	-1	1	1	0.20	0.20	0.20	0.20
10	1	-1	-1	1	-1	0.20	0.20	0.20	0.20
11	1	1	1	1	-1	0.20	0.20	0.20	0.20
12	1	-1	1	1	1	0.20	0.20	0.20	0.20
13	1	1	-1	-1	-1	0.20	0.20	0.20	0.20
14	1	-1	-1	-1	1	0.20	0.20	0.20	0.20
15	1	1	1	-1	1	0.20	0.20	0.20	0.20
16	1	-1	1	-1	-1	0.20	0.20	0.20	0.20
17	1	-1.414	0	0	0	-0.80	-0.80	-0.80	1.20
18	1	1.414	0	0	0	-0.80	-0.80	-0.80	1.20
19	1	0	-1.414	0	0	-0.80	-0.80	1.20	-0.80
20	1	0	1.414	0	0	-0.80	-0.80	1.20	-0.80
21	1	0	0	-1.414	0	1.20	-0.80	-0.80	-0.80
22	1	0	0	1.414	0	1.20	-0.80	-0.80	-0.80
23	1	0	0	0	-1.414	-0.80	1.20	-0.80	-0.80
24	1	0	0	0	1.414	-0.80	1.20	-0.80	-0.80
25	1	0	0	0	0	-0.80	-0.80	-0.80	-0.80

Table 3 – Results of direct measurements

No	y_1	y_2	y_3	y_4	$\overline{y_j}$	s_j^2	$\hat{y}$	$\overline{y}$	s_{ad}^2
1	8.8	11.9	31.7	12.41	16.2	109.56	16.2	16.3	0.017
2	7.8	10.1	25.9	10.56	13.6	68.73	13.6	13.7	0.005
3	6.9	10.1	31.5	13.71	15.6	120.36	15.6	15.4	0.037
4	6.4	11.4	26.1	11.67	13.9	71.99	13.9	13.7	0.038
5	8.0	7.1	31.1	14.16	15.1	123.82	15.1	15.3	0.034
6	7.4	8.4	25.7	11.02	13.1	72.41	13.1	13.3	0.033
7	6.5	8.4	31.3	12.75	14.7	128.23	14.7	14.7	0.007
8	5.6	6.6	25.5	13.26	12.7	83.61	12.7	12.6	0.019
9	7.1	11.6	31.7	11.64	15.5	120.55	15.5	15.6	0.006
10	6.2	9.8	25.9	10.20	13.0	76.64	13.0	13.0	0.000
11	8.6	10.3	31.5	14.22	16.2	110.24	16.2	16.0	0.020
12	8.0	11.6	26.1	11.61	14.3	64.33	14.3	14.2	0.020
13	6.3	6.9	31.1	12.53	14.2	134.33	14.2	14.3	0.017
14	5.8	8.1	25.7	12.26	13.0	78.82	13.0	13.1	0.017
15	8.2	8.6	31.3	14.01	15.5	117.50	15.5	15.5	0.001
16	7.2	6.8	25.5	11.26	12.7	76.60	12.7	12.6	0.007
17	6.7	9.0	24.6	10.25	12.6	65.96	12.6	12.7	0.010
18	7.7	9.4	32.5	13.49	15.8	130.66	15.8	15.7	0.005
19	6.0	9.1	28.6	12.34	14.0	100.95	14.0	14.2	0.027
20	8.3	9.4	28.6	14.05	15.1	87.17	15.1	15.0	0.018
21	6.8	6.9	28.3	14.25	14.1	102.16	14.1	13.8	0.049
22	7.6	11.5	28.9	10.96	14.7	91.77	14.7	15.0	0.064
23	7.0	8.1	28.4	11.83	13.9	98.60	13.9	14.0	0.009
24	7.3	10.3	28.7	12.18	14.6	92.21	14.6	14.6	0.004
25	7.2	9.2	28.6	12.84	14.5	94.11	14.5	14.4	0.002

Table 4 – Results of the statistical analysis of the experiment

	x_0	x_1	x_2	x_3	x_4	x_1^2–0.8	x_2^2–0.8	x_3^2–0.8	x_4^2–0.8
$\sum x_i$*mid.	358.6	21.1	5.6	8.1	4.3	0.0	-0.6	0.6	-0.7
$\sum x_i^2$	25	20.0	20.0	20.0	20.0	8.0	8.0	8.0	8.0
b_i	14.34	1.05	0.28	0.41	0.22	0.00	-0.07	0.08	-0.09
$S_2\{b_i\}$	15.13	1.61	1.61	1.61	1.61	4.04	4.04	4.04	4.04
$S\{b_i\}$	3.89	1.27	1.27	1.27	1.27	2.01	2.01	2.01	2.01
t_i	3.69	0.83	0.22	0.32	0.17	0.00	0.04	0.04	0.04
t_i–$t_{cr.}$	1.63	-1.23	-1.84	-1.74	-1.89	-2.06	-2.02	-2.02	-2.02

	x_1x_2	x_1x_3	x_1x_4	x_2x_3	x_2x_4	x_3x_4	$x_1x_2x_3$	$x_1x_2x_4$	$x_2x_3x_4$	$x_1x_2x_3x_4$
$\sum x_i$*mid.	1.8	0.6	-1.3	0.5	0.1	0.0	-1.3	-0.1	-0.1	0.5
$\sum x_i^2$	16	16	16	16	16	16	16	16	16	16
b_i	0.11	0.04	-0.08	0.03	0.00	0.00	-0.08	-0.01	-0.01	0.03
$S_2\{b_i\}$	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
$S\{b_i\}$	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
t_i	0.08	0.03	0.06	0.02	0.00	0.00	0.06	0.00	0.01	0.02
t_i–t_{cr}	-1.98	-2.03	-2.00	-2.04	-2.06	-2.06	-2.00	-2.06	-2.05	-2.04

$\sum S_{j2}$	2421.28	$\sum S_{ad}$	0.466	S_{y2}	96.85
S_{j2max}	134.33	S^2	0.0233		
G	0.06	F	0.000240	α	0.05
m^{-1}	3.00	k_1	4		
N	25.00	k_2	20	f_1	24.00
G_{cr}	0.19	$F_{cr(tabl.)}$	2.87		
G– G_{cr}=	-0.13	F-F_{cr}	-2.86975952	t_T	2.06
(G<G_{cr}) dispersion is homogeneous		F<F_{cr} the statistical model is significant, the regression equation is reliable			

In order to determine the optimum formulation according to the given parameters, a 3D model (shown in Fig. 1) has been constructed using the least-squares smoothing method with the help of the software package for statistical analysis Statistica. After studying the graphic data, the results of the direct measurements and the regression equation, sample 21 (Tables 1, 2, 3) has been determined as having the optimum recipe composition.

The most important part of the review function is the interaction of two or more factors. Relying on the regression equation, the greatest influence on the optimization parameter is that of the interaction of the factors x_1 and x_2, which corresponds to the largest coefficient of 0.11. This conclusion is derived from the regression equation, and is also explained by the fact that the single optimization parameter y1 (protein) is mainly increased by increasing the factors x_1 and x_2, and the single optimization parameter y_3 (carbohydrate) by increasing the factor x_1. The increase of the single optimization parameter y_2 (fat) is due to the factors x_3 and x_4 containing a significant amount of fat in their composition, but having almost no effect on the optimization of the content of protein and carbohydrates, so their influence on the general optimization parameter is negligible, which is confirmed by the insignificant values of the coefficients in the regression equation.

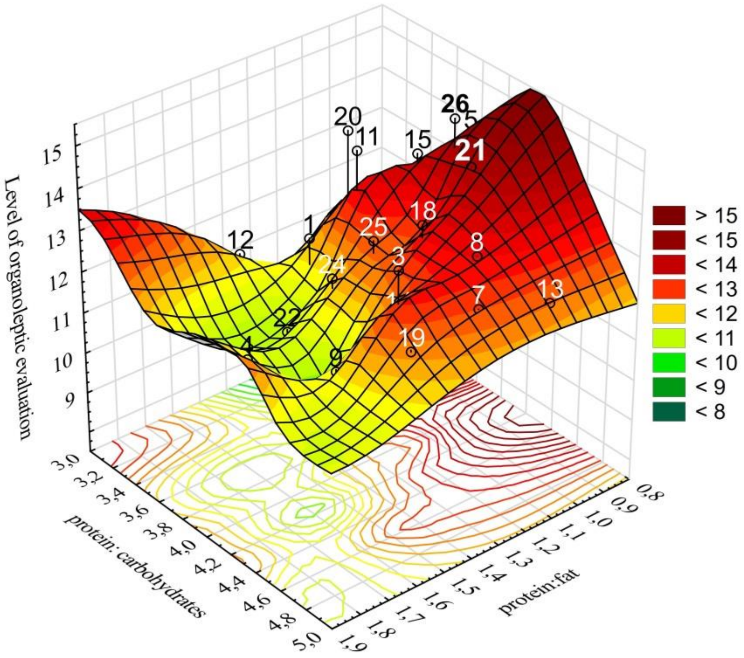

Fig. 1. 3D model of optimization of the formulation of forcemeat products on the basis of freshwater mussels

A parallel, three- and four-factor relationship is reduced to a lower level if there are factors that do not have a significant effect on the optimization parameter, so the content of wheat flour and freshwater mussels is the most important in the recipes, which have the greatest influence on the optimization of the formulation composition. The interpretation of a regression equation that is reliable (the dispersion is homogeneous, and the statistical model is significant) is the main way to make correct decisions when optimizing. Therefore, after studying the graphic data, the results of direct measurements and the interpretation of the regression equation with the optimum formulation, sample 21 with the ratio of proteins, fats and carbohydrates 1:1.03:4.18 (which is the closest to the optimum) has been organoleptically rated 14.25. An important condition for the study of the formulation composition is the fact that when obtaining high levels of organoleptic or nutrient ratios, other indicators can be unsatisfactory. That is why, it is necessary to choose a composition with the maximum balance of factors, although the parameters can have lower values, and this should be paid special attention to during the research and when interpreting the results.

According to the research and as the 3D model shows, the optimum formulation is the data of experiment number 21. Such a decision was made based on the main criteria of optimization. Since this recipe is close to the ideal ratio of proteins, fats and carbohydrates (1:1.03:4.18), it rates highest among all samples by the organoleptic characteristics – 14.25 points.

Table 5 shows the amount of minerals in the optimum formulation established in the course of the studies. These tables provide a clear idea that optimized recipes provide the human body with the main nutrients, but also have a balanced mineral composition. Cutlets contain a significant amount of calcium, phosphorus, magnesium, iron and iodine. The weights of the ingredients given for each ingredient individually allows you to understand immediately how much of this particular micro or macro element is in one portion of the product. Since the objects of our research were forcemeat systems (cutlets), we suggest considering the mass of a portion (one cutlet) equal to 95 g.

Table 5 – The amount of mineral substances for the optimum composition per one portion (m = 95 g)

Recipe Ingredients	Net weight, g	Mineral content, mg									
		Ca mg/100 g	Ca mg/w. ingr.	P mg/100 g	P mg/w. ingr.	Mg mg/100 g	Mg mg/w. ingr.	Fe mg/100 g	Fe mg/w. ingr.	I_2 mg/100 g	I_2 mg/w. ingr.
Wheat flour	35	40	14	328	114.8	116	40.6	2.1	0.735	0.0023	0.0008
Mussels	30	453	135.9	403	120.9	30	9	3.91	1.173	0.2530	0.0759
Chicken egg	8	98	7.84	106	8.48	9	0.72	0.38	0.0304	0	0
Onion	15	12	1.8	52	7.8	29	4.35	0.55	0.0825	0.0020	0.0003
Salt	2	368	7.36	75	1.5	22	0.44	2.9	0.058	0	0
Pepper	5	6	0.3	8	0.4	4	0.2	0.45	0.0225	0	0
Per one portion	–	–	169.44	–	254.88	–	55.31	–	2.1354	–	0.0772

Conclusions

In the course of the research, the goal has been achieved (the optimization of the composition of forcemeat products based on freshwater mussels) and the tasks solved:

1. An orthogonal central composite design has been developed with four (n) factors for optimizing the recipe content of forcemeat products based on freshwater mussels, and the homogeneity of the dispersion has been confirmed using Cochran's C test at the level of significance of x (0.05). The significance of the statistical model and the reliability of the regression equation has been confirmed by Fisher's F-test (Table 4).

2. Organoleptic evaluation of each composition has been carried out by analytical methods – qualitative and the method of profile analysis.

3. To determine the optimum formulation, the obtained results have been presented as a 3D model constructed by the least-squares smoothing method.

4. After studying the graphic data, the results of direct measurements and the interpretation of the regression equation, sample 21 (Table 1, 2, 3) has been determined as having the optimum composition, with the protein, fats and carbohydrate ratio 1:1.03:4.18 (i. e. the closest to the optimum – 1:1:4), with an organoleptic rating of 14.25.

5. Based on formulation No. 21, the content of mineral substances, namely: Ca, P, Mg, Fe, I_2, in one portion has been determined.

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