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FORMULATION OF MULTICOMPONENT MIXTURE IN THE PRODUCTION OF COMBINED SOFT CHEESE

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Abstract

Currently, scientists are constantly working to improve the principles of creating new food products, in accordance with changes in consumer requirements. When developing combined products, new sources of raw materials and rational ways of their processing, creation of new formulations, balanced by irreplaceable components of food, as well as the use of effective biotechnological methods are needed. The development of such products' production involves the use of dairy and vegetable raw materials and is an important issue to improve people's health. The aim of this research was to make a formulation of multicomponent mixture in the production of combined soft cheese.

Mathematical modeling methods were used, which were used to validate the recipes of products with specified properties and composition. To obtain reliable experimental research results, all the data obtained were subjected to mathematical processing. The purpose of mathematical processing of the experimental results was to evaluate the criterion for eliminating blunders, finding the critical values of controlled factors and the range of their variation, followed by their use in solving optimization problems.

The authors have developed a recipe for combined soft cheese with bio-additives of plant origin using regression-hydration technology. Soft combined cheese is produced from cow milk with vegetable bio-additive made from carrot and pumpkin cake using biotechnological methods. As a result of the use of regression-hydration technology in the preparation of a combined dairy-herbal mixture, a scheme for mixing the ingredients has been established: milk + bio-additive + starter + calcium chloride + rennet. And also improved structural and mechanical properties in all experimental samples. In the combined cheese with bio-additive, this indicator rises by 10% compared to the control one.

The formulation of combined soft cheese with bio-additives of plant origin using regression-hydration technology has been developed.

***Key words**: Milk, Protein, Hydration, Regression-hydration technology.*

1. Introduction

Modern nutritional science is based on the concept of balanced nutrition. Based on the concept for normal organism functioning it is necessary to provide the necessary amount of energy, protein and essential food components. These requirements are best met by combined dairy products.

In this regard, malnutrition is the cause of many diseases, since human health is largely dependent on the organism nutritional status. Any deviation from a balanced formula of nutrition causes a certain disorder of body functions. Nutrition is a major factor that ensures optimal development and growth of human body, its performance, and adaptation to the effects of various environmental agents [1].

Combined products have been created for over 30 years. The development of their production allowed to expand the range by regulating the composition and organoleptic characteristics of products. For this purpose, along with traditional ingredients, new ingredients of animal and vegetable origin are used. Creation of new products can be viewed as a regulated process by which it is possible to obtain a product with the desired properties. An important role in this process is played by the main raw materials and additives, which are used to give the product the desired properties [2].

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By FAO/WHO definition [3] a food additive is a material that is not normally used as food by itself. Some food additives increase the nutritional and energy value of the product, others give it the desired taste and aroma properties, others - color, still others - increase the biological value. Mainly natural food additives are used.

In the production of multicomponent products [4], various food additives can be used. For example, in the production of soft cheeses of the combined composition such additives of non-dairy origin can be used:

- Fruit and berry raw materials (berries, fruits, nuts);
- Vegetables;
- Bee products (honey, bee milk, propolis);
- Treatment-prophylactic additives (vegetable oil, vitamins, mineral additives, and other biologically active substances).

Theoretical and practical problems of creating combined multifunctional products are widely covered in the literature [5]. Using this methodology, a number of dairy products are created.

To optimize the composition of new combined products, combinatory technique is used [6]. Main attention is paid to the biomedical aspects of optimizing formulations. Multicomponent products of the new generation are safe products containing macro-and microelements, dietary fibers of plant origin [7]. Their number should be such that in addition to food adequacy, it does not cause negative taste sensations in consumers of different age groups.

We have analyzed the theoretical and practical aspects of food additives used in the cheese production [8 - 10]. In these works beside the information about new recipes of combined composition cheeses, features of their production and prospects for the use of vegetable raw materials can be found. From the presented literature review it is clear that the range of combined dairy products with vegetable proteins is very peculiar. In their production, in addition to the known additives, new types of plant materials are used. Use of modern technology and the creation of new formulations allows to obtain products with the desired functional properties that meet the needs of a wide range of consumers.

Soft cheese is a high-quality high-protein food product obtained by enzymatic, acidic, acid-rennet or thermos-acid fermentation of prepared (cheese-usable) milk, processing of the clot, molding of the cheese mass with subsequent maturation or without maturation [11]. In the production of soft cheeses, it can be used a wide range of various functional, flavor, aromatic and other additives. Technology of soft cheeses production allows application of huge set of technological operations and introduced components aimed at obtaining new, useful and enriched types of products. Many types of soft cheeses can also be made from goat and sheep milk. Therefore, it is not surprising that the production of soft cheeses is widespread in all advanced countries of cheese making and accounts for up to 40% of the total production of natural cheeses [12].

Equally important is positive economic factor in the production of soft cheeses due to the short production cycle (the absence of a long ripening period). In this respect, the design of soft cheeses without ripening has great prospects [13].

Soft cheese can be attributed to the products with protein composition. It is well known that proteins are vital components of organism, which form the basis for building cells of tissues and organs, as well as taking a part in the formation of enzymes, a variety of hormones, hemoglobin and other complex compounds that perform essential functions in the body. Lack of protein in the population diet reduces the protective properties of organism, and reduces the resistance to negative effects of various external factors. Obtaining a product with improved nutritional and biological value due to the inclusion in its composition of various components of non-dairy raw materials, allows increasing the positive effect of proteins and input components on organism, giving the product therapeutic and prophylactic properties [14]. Features of the soft cheeses technological production process make it possible to produce dairy products with therapeutic and prophylactic purposes using non-dairy raw materials of various types. Non-dairy raw materials can be introduced at various stages as in: milk preparation for coagulation, into cheese grain before molding, at the pressing stage, and also into the finished product, depending on the properties, composition, and fabricability [15].

An important condition ensuring creation of new types of soft cheeses is a good compatibility of sour-milk taste of the cheese mass with the taste of introduced components. Moreover, cheeses can be produced as salty, and without the addition of salt.

Currently, the dairy industry is experiencing a great need to increase the production of dairy products, in particular cheeses, with the lowest possible economic costs and waste-free use of raw milk. In this regard, we can distinguish the following real directions of development in the near future: an increase in the production of dairy composite products; development and expansion of the range of soft cheeses without ripening; increase production and development of recipes and technologies of cheeses with functional properties; improving the quality indicators of cheeses; use in the cheese industry of innovative technological methods [16].

Ability to coagulate milk is a result of enzymatic casein denaturation. Denaturation of casein, like other proteins, is associated with deep structural changes in its molecule. There is a splitting at the same time not only cross-links (hydrogen, disulfide, etc.), characteristic of proteins, but also peptides, which, presumably, are rearranged into salt bridges, causing dehydration of the protein. The decrease in milk viscosity observed in the initial phase of rennet action is also associated with dehydration [17]. Processes of formation and decay of clots occur at different rates, which depends on the activity (dose) of rennet, as well as the concentration of calcium salts in the medium. In both cases, pH and temperature play a role.

The aim of this research was to formulate multicomponent mixture in the production of combined soft cheese, and to formulate its optimal ratio of ingredients, biological and energy value.

2. Materials and Methods

One of the tasks of this work was to develop a formulation of soft cheese from cow milk with a bio-additive. Bio-additive was obtained from carrot and pumpkin cake using biotechnological methods [18]. The bio-additive is a puree-like mass of pumpkin or carrot, which was introduced into the milk in an amount of 5% to 20%. The starter was taken Choozit MA 11 (Danisco) and made in an amount of 1 - 2% by weight of the dairy-herbal mixture. Rennet and calcium chloride are also Danisco production according to the formulation.

Optimal ratio of ingredients was determined primarily by the criteria of food, biological and energy value with restrictions arising from structural and parametric models of adequate nutrition.

To solve this problem, we used mathematical modeling methods used to justify the formulations of products with specified properties and composition.

3. Results and Discussion

One of the main tasks in the design of specialized food products for different age groups is the correspondence of biochemical and qualitative characteristics of products to physiological characteristics of the human body.

When working out the parameters of the product production, introduced amounts of bio-additives, bacterial starter culture, rennet and calcium chloride were determined. In soft cheeses production of from cow milk, we used rennet enzyme and bacterial starter culture of direct application with a certain combination of strains [19].

To obtain reliable results of experimental studies, all the data were subjected to mathematical processing. The aim of the mathematical processing of the experimental results was to evaluate the criterion of elimination of gross errors, finding the critical values of the controlled factors and the range of their variation, followed by their use in solving optimization problems.

All experimental data obtained were processed in two stages. At the first stage, the experimental data were processed by methods of mathematical statistics. In order to avoid mistakes and obtain reliable results, the experiments were carried out with 5 multiple repetitions. To exclude the so-called "miss" in the experiment, a criterion for checking blunder by criterion *r* according to the following relationship was applied:

$$r = \frac{|x_{sus} - x|}{R\sqrt{\frac{n-1}{n}}} \quad (1)$$

Where: x_{sus} - "suspicious" result (the maximum or the minimum); *x* - average; and *R* - standard deviation.

R - standard deviation is calculated by the formula:

$$R = \sqrt{\frac{\sum_{i=1}^{n}(\Delta x_i)^2}{n(n-1)}} \quad (2)$$

Where: *n* - number of tests in the experiment.

Results processing showed the absence of gross errors, which indicates high correctness of the experiments and high accuracy of the methods used.

Final step in mathematical processing was the solution of optimization problems aimed at finding optimal parameters of variable factors. To solve optimization problems, method of mathematical planning of experiment was applied. Well-known advantage of method based on the construction of the scheme proposed by Fisher [20], orthogonal Latin rectangles, made it possible to obtain a formalized mathematical model that takes into account the influence of each input parameter (factors) and inter-factor effects on the technology.

Objective function (optimization criterion) was selected indicator - organoleptic evaluation (maximum score - 100) of the developed combined soft cheese from whole cow milk (X_1), bio-additives (X_2), starter (X_3) (Table 1).

Table 1. The variation levels of factors for the production of combined soft cheese

Levels	Variable factors			
	X_1	X_2	X_3	X_4
1	90	10	1	96
2	85	15	2	98
3	80	20	3	90
4	75	25	4	86

A generalized optimization graph is presented in Figure 1.

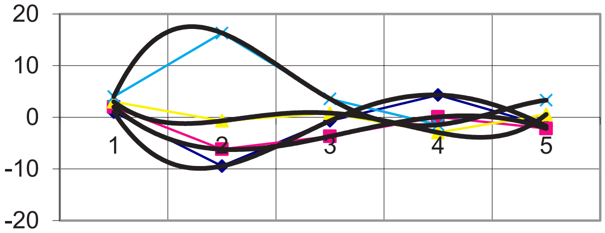

Figure 1. Generalized graph of optimization formulation of the combined soft cheese

As a result of calculation, 4 types of product were obtained. For each type of product, the program offered from 4 to 16 variants of formulations with different contents of one or another milk component.

To determine the values for 4 types of products, with different variants of variable factors, we wrote down the equations containing the factor of each level:

$$y1 = f1(C1j) + f2(C2j) + f3(C3j) + f4(C4j) \quad (3)$$

$$y2 = f1(C1j) + f2(C2j) + f3(C3j) + f4(C4j) \quad (4)$$

$$y3 = f1(C1j) + f2(C2j) + f3(C3j) + f4(C4j) \quad (5)$$

$$y4 = f1(C1j) + f2(C2j) + f3(C3j) + f4(C4j) \quad (6)$$

Then, we produce a term wise addition of these equations for each level.

To determine the average value of the target function, we used this formula:

$$Y = \frac{1}{N}\sum_{i=1}^{N} Y_u \quad (7)$$

Next, we determine the average value of the target function of the i-th factor at the j-th level by the formula:

$$Y_j = \frac{k}{N}\sum_{i=1}^{N/k} Y_{u(j)} \quad (8)$$

Where: N - number of experiences in the plan; k - number of factors.

Based on the calculations performed by formulas 7 and 8, we establish the effect of the i-th factor at the j-th level, for each factor by the number of levels $E_{ij} = Y - Y_u$.

At the same time, we have complied with the necessary condition, the equality of sum of the effects at each level is zero, which indicates the correctness of the experimental plan (Table 2).

The general equation of the objective function (organoleptic evaluation) in the production of combined soft cheese is as follows:

$$F = A \cdot x_1^4 + B \cdot x_2^3 + C \cdot x_3^2 + D \cdot x_4 + E \rightarrow max \quad (9)$$

Where the coefficients (A, B, C, D and E) are presented in Table 3.

Table 2. Inter-factor effects of the plan of full-factor experiment in optimizing the formulation of combined soft cheese

Controlled factors	№ of levels	Value of levels	Objective function Eij
Amount of contributed cow milk, % X_1	1	90	-9.4375
	2	85	-6.1875
	3	80	-0.6875
	4	75	16.3125
Amount of contributed bio-additives, % X_2	1	10	-0.6875
	2	15	-3.6875
	3	20	0.8125
	4	25	3.5625
Amount of contributed starter, % X_3	1	1	4.3125
	2	2	0.0625
	3	3	-2.9375
	4	4	-1.4375
Organoleptic characteristics, points X_4	1	98	-1.6875
	2	96	-2.1875
	3	94	0.5625
	4	90	3.3125

Table 3. Empirical coefficients of the regression equation

Controlled factors	COEFFICIENTS OF REGRESSION				
	A	B	C	D	E
Amount of contributed cow milk, (Y_1)	0.6536	-10.359	55.409	-113.95	69.25
Amount of contributed bio-additives, (Y_2)	0.0911	- 2.4844	17.971	- 46.078	32.5
Amount of contributed starter, (Y_3)	0.9557	-11.297	46.482	-78.391	45.25
Organoleptic evaluation (Y_4)	-1.2839	18.307	- 90.279	174.26	-97

With the following limitations on controlled factors:

1) Amount of contributed cow milk:

$$Y_1 = 0{,}6536x^4 - 10{,}359x^3 + 55{,}409x^2 - 113{,}95x + 69{,}25 \leq 80 \quad (10)$$

2) Amount of contributed bio-additives:

$$Y_2 = 0{,}0911x^4 - 2{,}4844x^3 + 17{,}971x^2 - 46{,}078x + 32{,}5 \leq 20 \quad (11)$$

3) Amount of contributed starter:

$$Y_3 = 0{,}9557x^4 - 11{,}297x^3 + 46{,}482x^2 - 78{,}391x + 45{,}25 \leq 2 \quad (12)$$

4) Organoleptic evaluation:

$$Y_4 = -1{,}2839x^4 + 18{,}307x^3 - 90{,}279x^2 + 174{,}26x - 97 \leq 98 \quad (13)$$

Based on the analysis of obtained results, it was established that with the maximum organoleptic evaluation of amount of milk and the ingredients contributed, the technological parameters of production of combined soft cheese will be as follows:

- Amount of contributed cow milk - (80 ± 2) %;
- Amount of contributed bio-additives - (15 ± 3) %;
- Amount of contributed starter - (2 ± 0.2) %;
- Organoleptic evaluation - (98 ± 2) points.

Protein hydration is the most important factor in the stability of their solutions. The hydration of ionized groups of protein is due to the orientation of dipole water molecules in the electric field of the ion, and the hydration of polar groups of the protein is due to the orientation of water molecules as a result of the interaction of dipoles and the formation of hydrogen bonds [21, 22]. Considering hydration, as an integral part of all food processing technologies, and studying the hydration properties of components of a multicomponent system and their influence on the main physicochemical and technological parameters, we are able to purposefully manage the hydration process [23, 24].

The process of hydration of a multicomponent biological system must be carried out taking into account knowledge of the forms and energy of binding of moisture, and evaluation of the contribution of each component to the total energy of moisture binding [25, 26]. In this regard, the physical and thermodynamic characteristics of components used in the production of combined soft cheeses (Table 4) are determined.

Binding energy was calculated using the Polyani-Rebinder formula, and the enthalpy of moisture binding, according to the dependence proposed by the author [27] and represented by the following expression:

$$Ibi = L \cdot mmo \quad (14)$$

Where: m_{mo} - mass of moisture in the product, kg.

Mass of moisture (m_{mo}) in the product was determined by the equation:

$$mmo = W \cdot mpr \quad (15)$$

All technological parameters in the production of combined soft cheeses remained the same.

Components main characteristics are shown in Table 4.

As a result of the use of regression-hydration technology and the use of its basic principles in the design of multicomponent food systems, we calculated the binding energy of each component's moisture, since when hydrating it is necessary to mix components with the same enthalpy of moisture binding.

When developing food products with a multicomponent system - the process of hydration should begin with the hydration of component with the maximum enthalpy of moisture binding, with the successive addition of hydrated components to it in order of decreasing their moisture enthalpy.

Next, to confirm the obtained mixing order of components in the production of combined soft cheese, experimental studies of structural and mechanical characteristics were conducted. According to the classical technology, we previously adopted the following mixing scheme: milk + bio-additive (1) + starter (2) + calcium chloride (3) + enzyme rennet (4) (Figure 2).

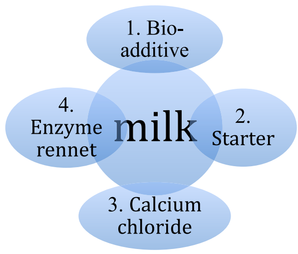

Figure 2. Hydration row of combined soft cheese

Table 4. The main characteristics of components (based on 100 kg of dairy-herbal mixture)

Component	Moisture W, kg	Mass of product $m \cdot 10^{-3}$, kg	Mass of moisture m_{mo}, kg	Activity of water a_w, sh.un.	Energy of moisture binding L, kJ/kg	Enthalpy of bound moisture I_{bi}, kJ
Cow milk	88.22	80	7.058	0.995	0.68	4.799
Bio-additive	68.3	15	1.025	0.988	1.5	1.538
Starter	4	0.2	0.0008	0.33	78.51	0.063
Enzyme rennet	5	0.1	0.0005	0.33	76.57	0.038
Calcium chloride	95.4	0.4	0.038	0.988	1.63	0.062

In this regard, we investigated the critical shear stress of combined soft cheese, depending on the mixing scheme. The results are presented in Table 5.

Table 5. Critical shear stress of combined soft cheeses

Combined soft cheeses	Critical shear stress, Pa	
	On classical technology	On regression-hydration technology
Control sample without additives	304	312
Soft cheese with bio-additive	315	346

Based on experimental studies (Table 5), it was found that the mixing scheme of components affects the value of critical shear stress. In the experimental products, the critical shear stress varies, firstly, depending on the raw materials used (dairy and vegetable), secondly, on the production technology.

In the prototype, with the introduction of fermented vegetable bio-additives, the increase in the critical shear stress is due to the fact that dietary fiber is added with the herbal additive, which have moisture-binding capacity, as a result, the density of soft cheese increases by 3.5%.

4. Conclusions

- Thus, as a result of mathematical data processing, the limiting values of components ratio (recipes) were obtained, allowing to obtain a combined soft cheese with a high organoleptic evaluation (98 points), which meets the requirements set in the problem.

- Based on the obtained physical and thermodynamic characteristics of components, a hydration row of combined soft cheese was built (Figure 2). According to the regression-hydration technology in preparation of the combined dairy-herbal mixture, it is necessary to adhere to the following order: milk + bio-additive + starter + calcium chloride + enzyme rennet.

- In the production of soft cheeses according to the regression-hydration technology, the critical shear stress increases in all experimental samples. In the combined cheese with bio-additive, this indicator rises by 10% compared to the control one.

- Thus, products developed according to the mixing scheme according to regression-hydration technology are distinguished by a dense structure, which confirms the theory of hydration of multi-component food products.

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