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DEVELOPMENT OF FOOD SYSTEMS OF INCREASED BIOLOGICAL VALUE BASED ON OIL-RAW MATERIALS AND FLOUR

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Goal. To develop using mathematical modeling methods several food systems with improved amino acid composition based on wheat flour and oil-containing raw materials, including soybean meal and flax. To determine the biological value of proteins of simulated food systems. **Methods.** The mass fraction of protein in oilseed meal and wheat flour was determined by the Kjeldahl titrimetric method. Amino acid composition of flax and soybean meal proteins was determined by the method of ion-exchange column chromatography. Indicators of the biological value of oilseed meal and wheat flour were determined by comparing the content of each essential amino acid of their proteins with the content of the same amino acid of the so-called “ideal” reference protein amino acid scale of the FAO/ WHO Committee. Modeling of the amino acid composition of meal composition and food systems was performed using mathematical methods. **Results.** Soybean meal protein, in contrast to wheat flour and flaxseed meal, contains sufficient quantities of all (except for the amount of sulfur-containing methionine and cystine) essential amino acids necessary for full human life. You can compensate for the lack of such essential acids in soybean meals by adding flaxseed meals. To obtain the amino acid composition of the protein, which will be as close as possible to the reference, the ratio of components in the composition of oilseed meal, namely — flaxseed meal: soybean meal = 68:32. It was found that the addition of 10 to 20% of this composition to the flour makes it possible to obtain a food system with an amino acid composition as close as possible to the formula of the protein taken as a standard. **Conclusions.** It is established that the food system containing 20% of meal composition and 80% of wheat flour has the greatest biological value in comparison with wheat flour. The developed food systems have the consistency of flour, so they can be recommended for use in the technology of flour products with high biological value.

Key words: *oilseeds, meal, amino acids, SCOR, essential substances, food modeling systems.*
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Among the main factors that ensure and maintain human health there is a balanced diet. In a complete diet, proteins must always be present – it’s important component of food. Protein - the main source of essential amino acids - plays the role of a building material in the process of cell development and metabolism in the organism. Lack of proteins in the diet can lead to a decrease in the protective properties of the organism, disrupt digestion progress, blood formation, the activity of the central nervous system, or weaken mental activity. About half of the world's population is experiencing lack of proteins. In such conditions, the main source of protein can be not only food products of animal origin, but also vegetable products, in particular, grain and oilseeds [1]. At the same time, in the diet of a certain part of the population, mainly in the developed countries of the world, there are violations of the nutritional status, namely, a mismatch between the low level of energy consumption and the high level of consumption of high-calorie food products with a reduced content of essential substances. Now such nutritional problems cannot be successfully solved only by improving the agricultural technologies of food crops, increasing the productivity of meat and dairy cattle breeding and poultry farming. It is necessary to solve problems related to the principles and methods of modeling the composition of balanced products.

Each country has unique traditions and food culture, but bread and bakery products are included in the daily diet of a significant part of the world's population. However, in terms of amino acid composition, flour protein, which is the main component of the bread or bakery product formulation, is not balanced. So, in wheat flour, out of 8 essential amino acids for an adult, 6 are limited, including, such important ones as sulfur-containing ones, they are methionine and cystine and, as in many crops, lysine. This does not have a negative effect if a person's diet contains enough lysine-rich foods - dairy or such as meat, fish. Otherwise, when the proportion of bread and/or other grain products increases in the daily diet, the issue of increasing the lysine content in flour products becomes important. Therefore, flour and products from it can be considered promising products for the enrichment of essential ingredients.

An effective method of increasing the biological value of flour is to optimize its nutritional composition by using promising types of additives that have not only a sufficient amount of necessary substances, but also an affordable cost. These additives include oilseed meal, namely, hemp [2] or pumpkin seeds [3], almonds [4], amaranth [5-8] or their mixtures, as well as seeds of flax, pumpkin, sunflower, sesame [9]. The addition of

oilseed meal to wheat flour not only increases the biological value of the last one, but also improves the quality of flour products obtained from such mixtures [2-9]. However, despite the high biological value of meals, now their using cannot be called rational, because traditionally a significant part of them goes to livestock feed and only 15% is processed for using in various food products [10].

Thus, taking into account the above, the solution to the problems of modeling balanced amino acid composition of food systems based on wheat flour and oilseed meal, for using in flour products technologies aimed at preserving the health of the nation, remains relevant at the present time.

The purpose of the research. To develop using mathematical modeling methods several food systems with improved amino acid composition based on wheat flour and oil-containing raw materials, including soybean meal and flax. To determine the biological value of proteins of simulated food systems.

Materials and research methods. For the research, it was used wheat flour of the highest grade in accordance with GSTU 46.004, soybean meal in accordance with GOST 4593, and flaxseed meal.

Determination of protein mass fraction in oilseed meal and wheat flour was carried out in accordance with GOST 4924. The amino acid composition of flax and soybean meal proteins was determined using the method of ion exchange column chromatography on an amino acid analyzer LKB 4151 "Alpha Plus" (Sweden). Indicators of the biological value of proteins (SCORE) of oilseed meals and wheat flour is determined by comparing the content of each essential amino acid of their proteins with the content of this amino acid in the so-called "ideal" reference protein of the amino acid scale of the FAO / WHO Committee. A reference protein is a theoretical protein ideally balanced in terms of amino acid composition. Accordingly, SCORE of all amino acids in the reference protein is 100%. Calculations of the amino acid SCORE of essential amino acids were carried out according to the formula (1):

$$\text{SCORE} = (\grave{a} / \grave{a}_e) \cdot 100\,\%, \tag{1}$$

where a_i – is the amino acid content in a protein weighing 100 g from the raw material under study; a_e – is the content of the same amino acid in a reference protein weighing 100 g.

The amino acid (AA), which has the lowest SCORE in the protein under study, is called limited.

Modeling of the amino acid composition of the meal composition and food systems directly with the aim of improving was carried out using mathematical methods according to [2].

The content of essential amino acids of the protein in the oilseed meal composition, C_{EAA} (c_{sf}, c_{sb}) is calculated by the formula:

$$C_{EAA}(c_{sf}, c_{sb}) = C_{EAA} \cdot c_{sf} + C_{EAA} \cdot c_{sb}, \tag{2}$$

where C_{EAA} – the content of the essential amino acid in the protein of the meal (flaxseed or soybean); c_{sf} – the mass fraction of the protein of the flaxseed meal in the meal composition; c_{sb} – **the** mass fraction of soybean meal protein in meal composition.

The calculation of the amino acid content in food systems based on wheat flour and a composition of flaxseed and soybean meal with an improved amino acid composition was carried out according to the formula (3):

$$\grave{A}_i = \frac{\sum_{i=1}^{n} a_{ik} p_k x_k}{\sum_{k=1}^{n} p_k x_k}, \tag{3}$$

where A_i – the mass fraction of the i-th amino acid in the protein of the model formulation,%; a_{ik} – the mass fraction of the i-th amino acid in the protein in the k-th ingredient,%; p_k – the mass fraction of protein in the k-th ingredient,% (p_{flour} = 10.34; p_{mixture} = 37.21); x_k – the mass fraction of the k-th ingredient,%.

The research results were processed using the *Microsoft Excel* software package.

Results. At the first stage of the work, the amino acid composition was established and the biological value of proteins included in flaxseed, soybean meal and wheat flour was determined using formula (1). These data were compared with the amino acid composition of the reference protein described in [11].

The content of 8 essential amino acids included in the amino acid composition of the reference protein, proteins of soybean and flaxseed meal, wheat flour and their biological value are given in table. 1.

1. Amino acid composition and biological value of proteins

AA	AA scale for FAO / WHO	Flaxseed meal		Soybean meal		Wheat flour	
		AA, g/100g	SCORE %	AA, g/100g	SCORE%	AA, g/100g	SCORE %
Valine	5,00	3,79	75,80	4,82	96,40	4,10	82,00
Isoleucine	4,00	3,25	81,25	4,63	115,75	3,70	92,50
Leucine	7,00	6,89	98,43	7,32	104,57	7,00	100,00
Lysine	5,50	**4,49**	**81,64**	**6,09**	**110,73**	**2,10**	**38,18**
Methionine + Cysteine	3,50	**3,5**	**100,00**	**2,79**	**79,71**	**1,50**	**42,86**
Threonine	4,00	4,09	102,25	3,64	91,00	2,72	68,00
Tryptophan	1,00	2,39	239,00	1,35	135,00	1,10	110,00
Phenylalanine + Tyrosine	6,00	7,7	128,33	7,61	126,83	7,30	121,67
∑	36,00	36,63	101,75	38,58	107,17	29,52	82,00

Analysis of the amino acid composition of wheat flour protein (Table 1) indicates a lack of certain amino acids in it, especially lysine (2.10 g / 100g) and sulfur-containing amino acids - methionine + cystine (1.5 g / 100g). Flax meal proteins have an amino acid composition of higher quality than flour proteins. Since the content of the sum of methionine + cystine, which has antioxidant properties, reaches 3.5 g / 100 g, and the lysine content is higher than in flour protein by 43.46% and amounts to 4.49 g / 100 g, the content of aromatic amino acids (phenylalanine + tryptophan), which can improve the activity of the nervous system, is higher compared to flour protein. In addition, the total content of essential amino acids in flaxseed meal protein is higher than in wheat flour protein: 36.63 versus 29.52 g / 100 g. At the same time, soybean meal protein is characterized by a higher lysine content compared to flaxseed meal (6, 09 versus 4.49 g / 100 g), and a lack of sulfur-containing amino acids (2.79 versus 3.5 g / 100 g). It is possible to compensate for the lack of amino acids and bring their content as close as possible to the indicators of the reference protein using the method of modeling compositions with meal.

The next stage of research was the development of a composition of oilseed meal with an improved amino acid composition. As you can see from the table. 1, lysine is the limited amino acid of flaxseed meal protein (SCORE is 81.64%), the sum of sulfur-containing amino acids (methionine and cystine) is limited for soybean meal protein (SCORE is 79.71%). Based on the analysis of the data given in table. 1, the influence of the ratio of flax and soybean meal on the content of limited amino acids in their composition was studied.

The problem of modeling the composition of soybean and flaxseed meal with an improved amino acid composition can be solved using the data on the content of these amino acids in the proteins of flaxseed meal, soybean and reference protein (Table 1), according to equation (2), using a system of two equations:

$$\begin{cases} C_{Lys} = 4{,}49 \cdot c_{sf} + 6{,}09 \cdot c_{sb} \\ C_{Met+Cys} = 3{,}5 \cdot c_{sf} + 2{,}79 \cdot c_{sb} \end{cases}, \quad (4)$$

where C_{Lys} – the lysine content in the protein of the meal composition, which is equated to the lysine content in the reference protein (5.50 g / 100 g); $C_{Met+Cys}$ – the content of the sum of methionine and cystine in the protein of the meal composition, which is equal to the content of the sum of methionine and cystine in the reference protein (3.50 g / 100 g).

Having solved the system of equations (4), we determine the mass fraction of flaxseed and soybean meal proteins in the meal composition with improved amino acid composition, close to the amino acid composition of the reference protein by increasing the content of lysine, methionine + cystine. Correspondingly, the mass fraction of flaxseed meal protein in the meal composition is 0.6, and soybean meal protein is 0.4.

Based on the analysis of the data presented in table. 1, the corresponding equations (5) - (10) are compiled, according to which the composition of essential amino acids in a substantiated composition of meals is calculated:

$$C_{val} = 3{,}79 \cdot c_{sf} + 4{,}82 \cdot c_{sb}, \quad (5)$$

$$C_{Ile} = 3{,}25 \cdot c_{sf} + 4{,}63 \cdot c_{sb}, \quad (6)$$

$$C_{Leu} = 6{,}89 \cdot c_{sf} + 7{,}32 \cdot c_{sb}, \quad (7)$$

$$C_{Tre} = 4{,}09 \cdot c_{sf} + 3{,}64 \cdot c_{sb}, \quad (8)$$

$$C_{Trp} = 2{,}39 \cdot c_{sf} + 1{,}35 \cdot c_{sb}, \quad (9)$$

$$C_{Tyr+Phe} = 7{,}7 \cdot c_{sf} + 7{,}61 \cdot c_{sb}, \quad (10)$$

where C_{Val} – the content of valine in the protein of the meal composition; C_{Ile} – isoleucine content in the protein of the meal composition; C_{Leu} – the content of leucine in the protein of the meal composition; C_{Tre} – the threonine content in the protein of the meal composition; C_{Trp} – the content of tryptophan in the protein of the meal composition; $C_{Tyr+Phe}$ – the content of the sum of phenylalanine and tyrosine in the protein of the meal composition.

According to formulas (5) - (10), the content and SCORE of essential amino acids of the protein of the composition of flaxseed and soybean meal were calculated, the results are shown in table. 2.

2. Amino acid composition and biological value of the protein of the composition of flaxseed and soybean meal

Essential amino acids	Content, g/100 g	SCORE, %
1	2	3
Valine	4,20	84,04
Isoleucine	3,80	95,05
Leucine	7,06	100,89
Lysine	**5,13**	**93,27**
Methionine + Cysteine	**3,22**	**91,89**
Threonine	3,91	97,75
Tryptophan	1,97	197,40
1	2	3
Phenylalanine + Tyrosine	7,66	127,73
The amount of essential amino acids	36,96	102,67

According to the table 2, the total content of essential amino acids in the composition increased in comparison with flax meal (36.96 versus 36.63 g / 100 g). However, to assess the physiological value, it is important not only the total content of essential amino acids, but also the biological value of the protein, determined by the value of SCORE. Comparing the amino acid SCORE of the meal composition and the reference protein, it was found that such amino acids as isoleucine, leucine, threonine, lysine and the amount of sulfur-containing ones (methionine + cystine), it is as close as possible to the reference one. For such amino acids as tryptophan and the sum of phenylalanine with tyrosine, the SCORE is 1.97 and 1.27 times higher than the reference one, respectively.

Based on the fact that 100 g of flaxseed meal contains 32.6 g of protein, and 100 g of soybean meal - 47.0 g, in order to obtain a composition of flaxseed and soybean meal with an improved amino acid composition, their rational ratio is 2.16: 1 or in percent - 68: 32%. If such proportions are observed, the amino acid composition of the protein of the meal mixture is as close as possible to the reference one. The obtained meal composition was used to develop food systems of increased biological value based on wheat flour.

The ratio of the components of food systems based on wheat flour and a composition of flaxseed and soybean meal with an improved amino acid composition is substantiated on the basis of technological features of wheat flour and its mixtures according to relevant studies [3-10]. The calculation of the amino acid composition of the protein of food systems containing 90 - 80% of wheat flour and 10 - 20% of the composition of soybean meal and flax with an improved amino acid composition was performed according to the formula (3). The calculation results are shown in table. 3.

To determine and analyze the biological value of food systems, the amino acid SCORE of their proteins was calculated. The calculation results are shown in table. 4.

Comparison of the SCORE of individual amino acids in the protein of food systems, provided that 10 - 20% of the meal composition is added to wheat flour (Table 4) with the SCORE of essential amino acids of wheat flour protein (Table 1), indicates the absence of a significant disproportion between essential amino acids. The amino acid SCORE of valine, isoleucine, lysine, methionine + cystine and threonine of food systems and wheat flour remains less than 100% and such amino acids will be lacking in products based on the developed food systems. But compared with wheat flour, the content of such amino acids has increased and is, respectively: 53.96 - 64.33% (lysine), 56.93 - 66.18% (methionine + cystine), 76.52 - 82.12% (threonine). The SCORE of valine, isoleucine and leucine remains quite high and is 82.57 - 82.95%, 93.22 - 93.69% and 100.25 - 100.41%, respectively.

3. Amino acid composition of proteins in food systems

Indicator	Component ratio (meal composition / wheat flour), %										
	10/90	11/89	12/88	13/87	14/86	15/85	16/84	17/83	18/82	19/81	20/80
Essential amino acids:	Amino acid content, g/100g										
Valine	4,13	4,13	4,13	4,14	4,14	4,14	4,14	4,14	4,14	4,14	4,15
Isoleucine	3,73	3,73	3,73	3,74	3,74	3,74	3,74	3,74	3,74	3,75	3,75
Leucine	7,02	7,02	7,02	7,02	7,02	7,02	7,02	7,03	7,03	7,03	7,03
Lysine	**2,97**	**3,04**	**3,10**	**3,16**	**3,22**	**3,28**	**3,34**	**3,39**	**3,44**	**3,49**	**3,54**
Methionine + Cysteine	**1,99**	**2,03**	**2,07**	**2,10**	**2,14**	**2,17**	**2,20**	**2,23**	**2,25**	**2,29**	**2,32**
Threonine	3,06	3,09	3,11	3,14	3,16	3,18	3,21	3,23	3,25	3,27	3,28
Tryptophan	1,35	1,37	1,39	1,40	1,42	1,44	1,45	1,47	1,48	1,50	1,51
Phenylalanine + Tyrosine	7,40	7,41	7,42	7,43	7,43	7,44	7,45	7,45	7,46	7,47	7,47
The amount of essential amino acids	31,65	31,81	31,97	32,12	32,27	32,41	32,55	32,68	32,81	32,93	33,05
	Protein content, %										
Protein	12,99	13,26	13,53	13,80	14,07	14,34	14,61	14,87	15,14	15,41	15,68

4. Amino acid rate of proteins in food systems

Component ratio (meal composition / wheat flour),%	SCORE of essential amino acids, %							
	valine	isoleucine	leucine	lysine	methionine + cysteine	threonine	tryptophan	phenylalanine + tyrosine
10/90	82,57	93,22	100,25	**53,96**	**56,93**	76,52	134,92	123,39
11/89	82,62	93,27	100,26	**55,19**	**58,03**	77,18	136,85	123,52
12/88	82,66	93,33	100,28	**56,36**	**59,08**	77,82	138,71	123,65
13/87	82,70	93,38	100,30	**57,50**	**60,09**	78,43	140,50	123,77
14/86	82,74	93,43	100,32	**58,58**	**61,06**	79,02	142,22	123,89
15/85	82,78	93,47	100,33	59,63	**61,99**	79,58	143,87	124,00
16/84	82,82	93,52	100,35	60,64	**62,89**	80,13	145,46	124,11
17/83	82,85	93,56	100,36	61,61	**63,76**	80,65	147,00	124,22
18/82	82,88	93,61	100,38	**62,55**	64,59	81,16	148,48	124,32
19/81	82,92	93,65	100,39	63,45	65,40	81,65	149,91	124,42
20/80	82,95	93,69	100,41	64,33	66,18	82,12	151,29	124,51

There is an excess of SCORE of phenylalanine (123.39 - 124.51%) and tryptophan (134.92 - 151.29%). Comparison of the amino acid SCORE of the food systems shown in table. 3, it shows that the recipe with the content of 20% of the meal composition and 80% of wheat flour has the greatest biological value. In such a food system, the SCORE of limited amino acids - lysine and sulfur-containing ones (methionine and cystine) - is as close as possible to the reference one and is 64.33% and 66.18%. Therefore, the developed food systems have a high biological value in comparison with wheat flour. It should be noted that the technological features of wheat flour, according to [3 - 10], make it impossible to increase the content of the oilseed meal composition in food systems to further increase their biological value.

Conclusions

Amino acid composition of proteins of wheat flour, flaxseed and soybean meal was experimentally researched. It was determined that in the protein of wheat flour the limited amino acids are lysine (SCORE 38.18%) and sulfur-containing ones - methionine and cystine (SCORE 42.86%). It was determined that flaxseed meal protein contains a high amount of lysine compared to wheat flour protein (SCOR 81.64% versus 38.18%) and methionine + cystine (SCORE 100.00% versus 42.86%), but compared to meal soybeans, the lysine content remains limited (SCOR 81.64% versus 110.73%), and the content of sulfur-containing amino acids (methionine + cystine) remains high (SCORE 100.00% versus 79.71%). It was found that only sulfur-containing amino acids - methionine and cystine (SCORE 79.71%) remain limited in the protein of soybean meal. It has been determined that the protein of a mixture of flaxseed and soybean meal can have an amino acid composition that is as close as possible to an ideal protein. A composition of flaxseed and soybean meal has been developed, the amino acid composition of the protein of which is as close as possible to the reference one. The ratio of the components in the composition is as follows: flaxseed meal: soybean meal = 68: 32. The combination of meal in this ratio with wheat flour reduces the deficiency of protein amino acids of the obtained

food systems. Food systems have been developed with an improved amino acid composition and, accordingly, an increased biological value in comparison with wheat flour. The flour content in them is 90 - 80%, the content of the meal composition is 10 - 20%. The amino acid composition and biological value of each of the obtained food systems were determined.

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