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DEVELOPMENT OF FLOUR COMBINED SYSTEMS WITH IMPROVED AMINO ACID COMPOSITION

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Abstract. Questions of mathematical calculation of combined flour systems with improved amino acid composition have been studied. To create such systems, it is proposed to use secondary products of oilseeds processing – meal, namely soybean, linseed and sunflower. The expediency of using the indicated meals is substantiated. It is emphasized that in order to create scientific foundations and practical directions for the use of new raw materials in the production of flour products, comprehensive studies are needed to study its composition, physical and chemical properties, as well as the impact on the quality of finished products. The amino acid composition of the proteins of these meals and wheat flour was experimentally determined. Calculated amino acid score. Particular attention is paid to the mathematical calculation of the composition of oilseed meal, which, in terms of amino acid composition, is as close as possible to the reference protein. The mass fractions of soybean, flaxseed and sunflower meal proteins in the composition were determined, namely: 0.51, 0.2 and 0.29, respectively. The amino acid composition and the biological value of the protein of the obtained meal composition were established. It was shown that for such amino acids as lysine, the amount of sulphurous (methionine + cystine) and threonine amino acid score of combined flour systems increased by 0.7–2 times compared to that of wheat flour. The ratio of soybean, linseed and sunflower meal in the composition of the improved amino acid composition in percentage terms was obtained: 44:25:31. Mathematically calculated the content and rate of essential amino acids in systems, which in their composition contain 90–80% wheat flour and 10–20% composition of oilseed meal. The results of studies of such systems showed that the moisture index is almost the same, and the acidity index is slightly higher than the index (4.68 versus 3.03 degrees) for premium wheat flour. Trial baking of bread was carried out, it's organoleptic, and physico-chemical parameters were determined in comparison with bread based on premium wheat flour. In a bread sample based on combined flour systems, the moisture content is 39.34%; porosity – 77.15%; acidity – 1.83 degrees. The characteristics of the developed systems make it easy to introduce it into the technological process of existing enterprises for the production of bakery products.

Keywords: flour, meal, combined system, amino acid, score, biological value.

Introduction. Formulation of the problem

During scientific and technological progress, taking into account the evolution of the rhythm of life and the nature of work, there is a tendency to underestimate the importance of diet. Demands for higher productivity and speed often translate into careless food choices, leading to the proliferation of fast food, sweets and drinks with excessive amounts of fat and/or sugar. This lifestyle is considered unhealthy. It contributes not only to the occurrence of disorders of the digestive system, the appearance of diseases of the nervous, cardiovascular, endocrine and immune systems, as well as overweight or underweight. All this together further worsens a person's health and ability to work. The main vital functions of the body depend on what we eat, how, when and how much. Food products contain all the necessary and equally important nutrients for humans: proteins, fats, carbohydrates, minerals, vitamins. However, in nature there is no universal product that contains all the nutrients. In other words, only a varied food palette contributes to maintaining optimal health and normal functional activity of the human body, while a monotonous and monotonous diet properly can cause functional impairments and disorders.

Bakery products for consumers are a significant carrier of food and biologically active substances, they improve the digestibility of food. Currently, the assortment of bread and bakery products produced by Ukrainian factories includes almost 1000 items, and several dozen more are added to them every year [1]. Manufacturers expand it due not so much to the use of new technologies, but to the use of additives (sesame, flax, raisins, spices, nuts, coconut shavings, etc.), fillers. Thanks to their recipe variety, these products can become the source of a wide range of protective components, which are so necessary for modern man. The analysis of dietary studies established that the recommended specific weight of the consumption of cereal crops in the composition of the total food diet should be at least 45–50%. Cereals are essential sources of complex carbohydrates, antioxidants, and phytonutrients. The quantity and quality of cereal crops and food products consumed, as well as their processing methods, have a significant impact on the processes of forming and ensuring a healthy dietary regime. For enterprises specializing in the production of bakery products, one of the remarkable methods of attracting consumers to their products, along with providing unsurpassed taste and aromatic qualities, turns out to be a strategically important direction of increasing the nutritional value of bakery products. This direction is focused on the systematic implementation of effective methods that contribute to the improvement of the general condition of the human body and the functioning of its immune mechanisms, providing protection against the negative effects of various harmful factors [2]. Considering the fact that more and more consumers are striving to maintain a healthy lifestyle and are fighting excess weight, the popularity of innovative products is growing – dietary and therapeutic bread containing grain mixtures, bran, fructose, honey, nuts, vegetable and fruit additives. This share of products accounts for about 5–7% of total sales in the country. However, according to marketers, the population's need is for a group of dietary bakery products, enriched with vitamins, with a high protein content, low sodium content, products made from fortified flour, with the addition of vegetable raw materials unconventional for baking, and gluten-free bread – will decline, as in many countries of the world, including the USA, France and other EU countries [2]. Such trends provide certain advantages to manufacturers producing baked goods with various additives [2]. So, in the context of the latest achievements in the field of nutrition science, creating a range of products of increased biological and nutritional value, aimed at strengthening the body and improving its general condition, is a priority task.

Analysis of recent research and publications

For many peoples of the world, bread remains one of the main sources of energy and many physiologically valuable compounds – plant proteins, starch, dietary fiber, vitamins B1, B2, B3, PP, E and macro- and microelements. At the same time, products made from premium, 1st grade wheat flour contain incomplete proteins [3], namely, of the eight essential amino acids for an adult, six are limited, in particular such important ones as methionine and lysine. If a person's diet contains foods rich in the amino acid lysine in sufficient quantities, such as dairy products, meat, fish, then the low lysine content in the protein of wheat bread should not cause alarm. However, when there is an increase in the relative proportion of bread made from wheat flour in the diet, an urgent need arises to solve the problem of adjusting the amino acid composition of the protein component of this type of bread product [4]. Thus, it is important to note that bread, and with it flour, is a clearly defined reserve for enriching and improving the quality of the daily diet and, accordingly, human health. Increasing the biological value of flour, and as a result – of bread, can be done either by adding protein concentrates, isolates or natural products with a high protein content, the amino acid composition of which is close to the reference one, to the flour. Natural products have the advantage of concentrates and isolates, because in addition to the increased protein content they also contain a significant amount of vitamins and minerals.

In [5], the influence of secondary products of pressing chia seeds, a source of polyphenols, on the baking of wheat and gluten-free bread was assessed. Chia seed cakes, which have a fat content of 15%, are added to the bread recipe at a level of 5%. The bread quality (pH, volume, color, consistency and organoleptic properties), polyphenol content and antioxidant activity were determined. It was found that adding a similar component to the recipe of wheat bread increases the volume without compromising the sensory properties of the bread. At the same time, this component of the recipe leads to darkening of the pulp of both wheat and gluten-free bread. It was noted that, compared to the control, the addition of secondary products of pressing chia seeds leads to a statistically significant decrease in the hardness of wheat and gluten-free bread. The authors [5] proposed to consider this secondary product of oil production as a valuable technological additive to bakery products. This additive allows you to expand the range and increase the attractiveness of wheat and gluten-free bread.

In [6], the effect of ground chia seeds on the texture and quality of wheat bread was studied in more detail. It was found that chia seeds in an amount not exceeding 5% did not deteriorate the quality of bread. The fatty acid composition of bread with chia seeds, especially when adding 5 and 7.5%, may be valuable from a nutritional point of view, because the fatty acid profile of products with the addition of 5 and 7.5% chia seeds compared to wheat bread (control) was characterized by more high ratio of polyunsaturated to saturated fatty acids. The ratio between polyunsaturated fatty acids ω6/ω3 in bread with added chia seeds ranged from 1.42 to 0.67, while in wheat bread it was 18.77.

In [7], the use of defatted kenaf seed flour to replace 10% wheat flour in bread recipes is considered. Kenaf seeds are a source of not only protein (27.07 g/100 g), but also dietary fiber (28.87 g/100 g), essential oil (23.78 g/100 g) and minerals (5.55 g/100 g). The resulting bread compared with samples of wheat bread enriched with 10% rice bran (negative control) and wheat bran (positive control). Adding 10% defatted kenaf seed flour to bread formulation significantly ($p < 0.05$) reduced bread height, volume, specific volume, water activity and hardness, and increased proofing time and bread surface color. The results of the sensory evaluation of bread samples also showed that bread with defatted kenaf seed flour was more acceptable compared to bread fortified with rice or wheat bran. The study confirms that kenaf seeds are a valuable source of both protein and dietary fiber, so it can be used in the development of health-promoting breads.

The study [8] aimed to obtain an optimized composition of a mixture of pumpkin seed flour (10–30%) and millet flour (10–50%) for gluten-free rice bread, which is used for patients with celiac disease. To establish the rational content of these components of the mixture, scientists used a central compositional plan. Textural and organoleptic properties and nutritional value were selected as response functions. Gluten-free baked goods often contain high amounts of starch and refined rice flour, hypoallergenic ingredients but low in nutritional value. Pumpkin seed cake is a gluten-free, nutrient-rich byproduct of the oil and fats industry that is primarily used as animal feed. While pumpkin seed flour increased the nutritional value of the baked goods, it also had a negative impact on its texture and color. These disadvantages were somewhat eliminated by the use of millet flour, which indicates the complementary effects between the two types of flour. The developed optimized gluten-free bread was characterized by high protein (14.1 g/100 g) and fiber (5.2 g/100 g) content.

A study [9] examined the effect on the texture and color profile of wheat flour bread by adding hemp cake, a by-product of oil production, to the recipe. Hemp and hemp seed cake are raw materials with a high protein content and the absence of gluten, so scientists have used them to increase the nutritional value of bread. The results showed that the addition of only 1% cake causes significant negative technological changes ($p > 0.05$), namely an increase in hardness, a decrease in elasticity and a noticeable darkening of the color of such bread compared to the control sample without the addition of cake. An increase in the proportion of hemp cake in the recipe led to further darkening and deterioration in the technological characteristics of baked goods. According to the authors, hemp seed cake does have high nutritional value, but it is imperative to establish its rational content to establish a balance of sensory properties, in particular texture and color.

The work [10] describes the use of safflower seeds as a fortifier for shortbread cookies. Safflower seeds are an unconventional herbal supplement, rich in complete plant protein (up to 16%), polyunsaturated fatty acids, dietary fiber, vitamins and minerals. The composition of amino acids and their content in protein is an important indicator of the physiological and nutritional value of safflower seeds. The effect of adding ground safflower seeds on the textural properties of the dough was studied. It was found that the water absorption capacity of the shortbread cookie sample with fortifier is 13% lower than the control sample without fortifier, which can be explained by the hydrophobicity of such an additive. A change in the rheological parameters of the prototype was revealed, due to the peculiarities of the chemical composition of the additive used. The authors [10] determined the optimal concentration of ground safflower seeds, as well as the rheological, functional and organoleptic properties of the dough and new shortbread cookies. The presented studies contribute to the expansion of the range of cookies enriched with bioactive compounds.

In the study [11], 5% of the mixture of gluten-free flour (75% rice flour + 15% chickpea flour + 10% carrot flour) was replaced with grape seed flour or pomegranate seeds, or flax seeds, or poppy seeds, or turmeric to improve the nutrition of the products. By-products of the food industry are valuable ingredients due to their rich content of various biologically active substances. It was found that the content of protein and fat in samples of products made from flax and poppy seed flour is higher than in control samples without gluten. A significant increase ($p<0.05$) in antioxidant activity and total phenol content was determined in samples of gluten-free products with all additives. Flax and poppy seed flour increases the content of Ca, Mg and P in product samples. The hardness values of the product samples increased when all types of additives were used. The simultaneous inclusion of flaxseed flour and turmeric caused a decrease in the volume index compared to the gluten-free control sample. It should be noted that gluten-free products, namely cakes containing flax and poppy seed flour, were highly rated by the tasting committee. Such developments will contribute to the expansion of the market for gluten-free products.

Today, not all countries have access to animal products containing valuable protein. In many countries of the world there is a shortage of dietary protein, estimated at 10–25 million tons per year [10]. In addition, protein quality is a huge problem in such countries [12]. The lack of dietary protein is not only an economic, but also a social problem in the modern world. Based on the above, it has been established that a traditional and alternative method of increasing dietary protein resources can be the use in the diet of products enriched with vegetable protein from legumes, cereals and oilseeds. It has been found that by-products of food industry production, which not only have a sufficient amount of necessary substances, but also have an insignificant cost, can also be considered as fortifiers [1-11]. For example, by-products of oil production – cakes or meal of oilseeds. At the same time, studies that would be devoted to increasing the biological value of flour by adding cakes or meal of oilseeds are not sufficiently covered in the literature. Therefore, research in this direction is relevant.

The purpose of this work is the developing a flour combined system (FCS) with an improved amino acid composition, which will consist of wheat flour and a composition of oilseed meal, such as soybean, flax and sunflower.

Research objectives:

– scientifically substantiate the choice of raw materials for creating FCS;

– to develop, using mathematical modeling methods, a composition of soybean, flax and sunflower meal that is close in amino acid composition to the reference protein and determine its biological value;

– mathematically calculate a number of FCS using the developed composition of soybean, flax and sunflower meal and determine their biological value. Justify the selected ratio of wheat flour and meal composition for the development of FCS;

– to establish the organoleptic and physicochemical characteristics of the resulting FCS with an improved amino acid composition;

– experimentally determine the organoleptic and physicochemical characteristics of a bread sample with increased biological value based on the developed FCS with an improved amino acid composition.

Research materials and methods

The following materials were used for research: wheat flour according to GSTU 46.004; soybean meal according to DSTU 4593; Sunflower meal according to DSTU 4638; flaxseed meal.

Determination of the mass fraction of protein in soybean, flaxseed, sunflower meal and wheat flour was carried out in accordance with DSTU 4924:2008 Protein products of plant origin. Cake and meal. Method for determining crude protein content. The amino acid composition of the proteins of the specified raw materials for FCS was determined using the method of ion exchange column chromatography on an amino acid analyzer brand LKB 4151 Alpha Plus (Sweden).

The indicator of the biological value of proteins – amino acid score – of soybean, flax, sunflower meal and wheat flour is determined by comparing the content of each essential amino acid in the proteins of the specified raw material for FCS to the content of the same amino acid in the so-called reference protein [1]. The reference protein is a ratio of essential amino acids that allows the body to easily renew certain internal structures [13]. Accordingly, the score of all amino acids in the reference protein is 100%. The indicator of biological value (score, %) of amino acids of raw materials proteins is calculated according to the formula:

$$\text{score} = \left(\frac{a_i}{a_e}\right) \cdot 100\%, \quad (1)$$

where a_i – amino acid content in protein weighing 100 g from the raw material under study;

a_e – content of the same amino acid in a reference protein weighing 100 g.

Modeling of the composition in a three-component meal composition to optimize its amino acid composition was carried out using mathematical methods according to [4]. The content of each of the eight essential amino acids of a protein of such a composition, C_{EAA} (c_{sb}, c_{sf}, c_{ss}) is calculated using the formula:

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

where C_{EAA} – content of essential amino acids in meal protein (soybean, flaxseed or sunflower);

c_{sb}– mass fraction of soybean meal protein in the meal composition;

c_{sf} – mass fraction of flaxseed meal protein in the meal composition;

c_{ss} – mass fraction of sunflower meal protein in the meal composition;

$c_{sb}+ c_{sf}+ c_{ss}=1$.

Determination of the amino acid content in FCS based on components such as wheat flour and a composition of soybean, flax and sunflower meal optimized for the amino acid composition was carried out according to formula (3):

$$A_i = \frac{\sum_{i=1}^{n} a_{ik} p_k x_k}{\sum_{k=1}^{n} p_k x_k}, \quad (3)$$

where A_i – mass fraction of the *i*-th amino acids in the FCS protein, %;

a_{ik} – mass fraction of the *i*-th amino acid in the protein of the *k*-th component of the FCS, %;

p_k – mass fraction of protein *k*-th component of FCS, % (p_{flour}=10.34; p_{mixture}=41.24);

x_k – mass fraction of the kth component of the FCS, %.

Organoleptic characteristics of flour and FCS were determined according to GOST 27558-87 methods. Physico-chemical indicators, namely: humidity, acidity, raw gluten content are determined according to the methods of GOST 9404-88, GOST 27493-87, DSTU ISO 21415-1:2009, respectively.

Organoleptic characteristics of bread were assessed by shape, color and condition of the crust, taste, smell, crust thickness, crumb by kneading, porosity, taste, crunch according to DSTU-P 8536:2015. Physico-chemical methods were used to determine the humidity, acidity and porosity of bread in accordance with DSTU 7517:2014.

To process the data, mathematical methods were used in the *Microsoft Excel* software package.

Results of the research and their discussion

An effective means of increasing the biological value of flour is to optimize its nutrient composition through the use of promising types of additives that have a sufficient amount of necessary substances and are of low cost. Such additives include oilseed meal – secondary products of seed processing. These by-products of the oil and fat industry are valuable sources of essential fatty acids for food [14]. It is known that the addition of meal, crushed oilseeds to wheat flour helps not only to improve the condition of flour products, but also to increase their nutritional value [3-11], reducing production costs [15-17].

In order to increase the biological value of wheat flour, meal of the following oilseed crops was selected – soybean, flax, sunflower. Soybean meal is the most popular type of meal in the world, the protein of which has a high lysine content, but lacks sulfur-containing amino acids – methionine and cystine. At the same time, sunflower meal protein, the most common in Ukraine, has a high content of sulfur-containing amino acids, but a low content of lysine. Flaxseed meal protein has great nutritional properties, making it a valuable addition to cereal-based products [12]. It is characterized by a high level of sulfur-containing amino acids – methionine and cystine, as well as aromatic amino acids – phenylalanine + tyrosine and tryptophan, branched amino acid – leucine and neutral amino acid – threonine.

The experimentally established amino acid composition of essential amino acids in soybean, flaxseed, sunflower meal and wheat flour proteins in comparison with the reference protein [13] is presented in Fig. 1. The results of calculations using formula (1) are presented in Fig. 2.

The results of the analyzes presented in Fig. 1 and 2 confirm that there is indeed a sharp disproportion between the content of essential amino acids in wheat and standard flour proteins. Thus, in flour protein, score leucine is 100.00%, the score of the sum of phenylalanine + tyrosine is 121.67%, the score of tryptophan is 110.00%, the score of valine and isoleucine are also quite high – 82.00 and 92.50%, respectively. At the same time, the score of lysine, methionine and threonine in wheat flour are very low and amount to only 38.18, 42.86 and 68.00%. Soybean meal protein, unlike wheat flour protein, contains all essential amino acids in sufficient quantities, with the exception of the amount of sulfur-containing (2.79 g/100 g, 79.21%). Flax meal proteins also have a more perfect amino acid composition than flour proteins, namely 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 (7.7 g/100 g, score 128.33%), which can improve the functioning of the nervous system, is higher compared to flour protein. Analysis of the amino acid composition of sunflower meal protein indicates a high content of sulfur-containing amounts (4.05 g/100 g, score 115.714%) and a lack of certain amino acids, for example, lysine (3.21 g/100 g, score 58.364%). Due to the fact that the proteins of soybean, flax and sunflower meal are limited in different amino acids, they will complement each other well, as a result of which the amino acid score of the protein composition will increase. It is possible to develop a composition of soybean, flax and sunflower meal, which in amino acid composition is as close as possible to the amino acid composition of the reference protein, using the calculation method [4] and formula (2).

To create the specified composition, data on the content of the indicated amino acids in the proteins of soybean, flax, sunflower meal and the reference protein were used (Fig. 1).

According to equation (2), a system of two equations has been compiled for important limited acids – lysine and a mixture of methionine + cystine:

$$\begin{cases} C_{Lys} = 6.09 \cdot c_{sb} + 4.09 \cdot 0.2 + 3.21 \cdot c_{ss} \\ C_{Met+Cys} = 2.79 \cdot c_{sb} + 3.5 \cdot 0.2 + 4.05 \cdot c_{ss} \end{cases}, \quad (4)$$

where C_{Lys} – the lysine content in the protein of the meal composition is equal to the lysine content in the reference protein.y (5.50 g/100 g);

$C_{Met+Cys}$ – the content of methionine and cystine in the protein of the meal composition is equal to the content of the sum of methionine and cystine in the reference protein (3.50 g/100 g).

Based on the technological properties of flax, it was decided to introduce its protein into the composition at the level of 20%. Having solved the system of equations (4), the mass fraction of soybean and sunflower meal proteins in the composition was established, the amino acid composition of which is close to the reference protein. Accordingly, the mass fraction of soybean meal protein in the meal composition is 0.51, and the sunflower meal protein is 0.29.

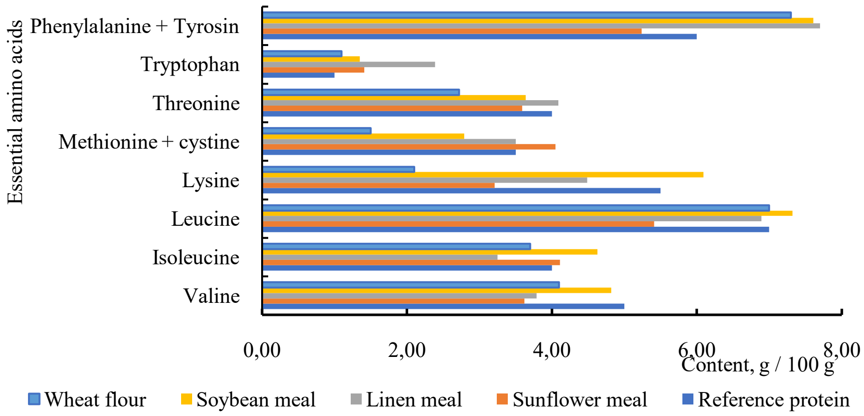

Fig. 1. Amino acid composition of essential amino acids of raw materials proteins for BCS in comparison with the reference protein

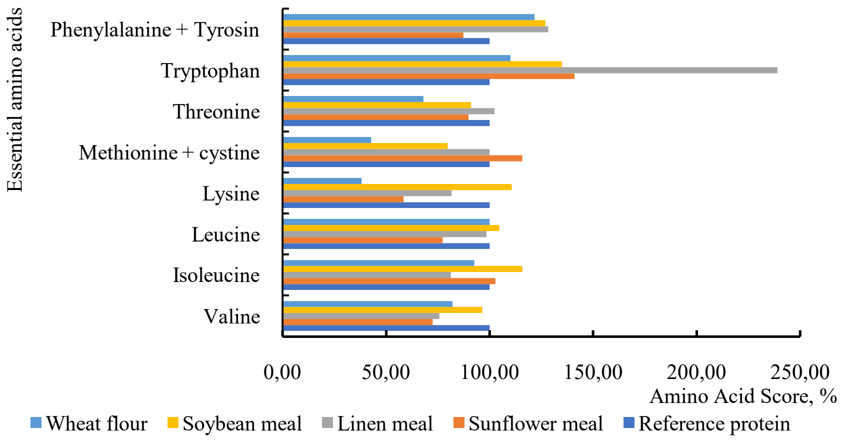

Fig. 2. Biological value of raw materials for FCS compared to the reference protein

The resulting mass particles of meal protein in the composition and the data on the content of the indicated amino acids in soybean, flax, and sunflower meal proteins were used to calculate the amino acid composition according to formula (2) and according to formula (1) – score the composition. The results are presented in Table. 1.

As evidenced by the data in Table 1, the composition of the meal compared to wheat flour has a higher protein content. Comparing the amino acid score of the protein composition of meal and wheat flour, it was found that for amino acids such as lysine, the amount of sulfur-containing (methionine + cystine) and threonine increased by 0.7–2 times. For amino acids such as isoleucine, tryptophan and the sum of phenylalanine with tyrosine, the established score is 1.05–1.57 times higher than the control.

Based on the fact that 100 g of soybean meal contains 47 g of protein, 100 g of flaxseed meal – 32.6 g and 100 g of sunflower meal – 37 g of protein, then to obtain a meal composition (a mixture of soybean, flaxseed and sunflower) with an improved amino acid composition the ratio of the components in it should be 1.78:1:1.27 or a percentage of 44:25:31. With this ratio of meal, the amino acid composition of the protein of their composition is closest to the reference one. The resulting composition can be used as a separate product, the biological value of which approaches the biological value of the reference protein, or can be used to develop FCS with an improved amino acid composition.

Table 1 – Amino acid composition and biological value of the protein composition of soybean, flax and sunflower meal

Essential amino acids	Content, g/100 g	Score, %
Valin	4.27	85.37
Isoleucine	4.20	105.11
Leucine	6.68	95.48
Lysine	4.94	89.83
Methionine+cystine	3.29	94.14
Threonine	3.72	92.89
Tryptophan	1.58	157.53
Phenylalanine+tyrosine	6.95	115.76
Total essential amino acids	35.63	98.97

The ratio of the components of FCS based on wheat flour and the composition of soybean, flax and sunflower meal, which in amino acid composition is as close as possible to the amino acid composition of the reference protein, is justified based on the technological features of various mixtures for flour [3-11]. Calculation of the amino acid composition of the FCS protein containing 90–80% wheat flour and 10–20% composition of soybean, flax and sunflower meals was carried out according to formula (3). The calculation results are given in Table 2.

To determine and analyze the biological value of FCS, the amino acid score for each of the eight essential amino acids was calculated using formula (1). The calculation results are given in Table 3.

When adding from 10 to 20% of the developed meal composition to wheat flour, a significant increase in the content of most essential protein amino acids can be observed (Table 2). The amino acid score of valine, isoleucine, lysine, methionine + cystine and threonine FCS remains less than 100%, but compared to wheat flour, the content of such amino acids increases and is respectively: 53.08–62.82% (lysine), 57,62–67,26% (methionine + cystine), 75,21–79,93% (threonine). The scores of valine, isoleucine and leucine remain high, namely: 82.98–83.62%, 96.11–98.46% and 98.68–97.82%, respectively. There is an excess score of phenylalanine (119.98–118.88%) and tryptophan (123.85–132.90%) by 100%. Comparison of FCS amino acid score given in Table 3 allows you to establish a formulation that has the greatest biological value. This is the recipe containing 20% meal composition and 80% wheat flour. In such a FCS, the content of limited amino acids – lysine and sulfur-containing ones (methionine and cystine) – is as close as possible to the reference one and score is 62.82% and 67.26%. The developed FCS have a higher biological value compared to wheat flour, but the technological features of wheat flour and meal according to [3-11] make it impossible to increase the content of the oilseed meal composition in the FCS to further increase the biological value of the latter. It should be noted that adding the meal composition to wheat flour leads to a change in the color and smell of the latter. An odor characteristic of oilseeds appears, but for the consumer such a change in color and odor does not pose a health threat. However, due to the content of dietary fiber in flax meal, which, compared to wheat flour, has a high water-absorbing capacity and forms mucus, as well as proteins, of which 60% are water- and salt-soluble, the addition of a composition with flax meal to the flour causes a decrease in the amount of gluten and gas-retaining properties. ability of the dough, which can lead to deterioration in the volume of baked goods [18-20].

Table 2 – Amino acid composition of FCS proteins

Index	**Component ratio (composition of meal/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										
Valin	4.15	4.15	4.16	4.16	4.16	4.17	4.17	4.17	4.18	4.18	4.18
Isoleucine	3.84	3.86	3.87	3.88	3.91	3.90	3.91	3.91	3.92	3.93	3.94
Leucine	6.91	6.90	6.89	6.89	6.88	6.87	6.87	6.86	6.86	6.85	6.85
Lysine	**2.92**	**2.98**	**3.04**	**3.10**	**3.16**	**3.21**	**3.26**	**3.31**	**3.36**	**3.41**	**3.46**
Methionine+cystine	**2.02**	**2.06**	**2.09**	**2.13**	**2.17**	**2.20**	**2.23**	**2.27**	**2.30**	**2.33**	**2.35**
Threonine	3.01	3.03	3.05	3.07	3.09	3.11	3.13	3.15	3.16	3.18	3.20
Tryptophan	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.31	1.32	1.33
Phenylalanine+tyrosine	7.20	7.19	7.18	7.18	7.17	7.16	7.16	7.15	7.14	7.14	7.13
Total essential amino acids	31.28	31.42	31.55	31.81	31.80	31.91	32.03	32.13	32.24	32.34	32.44
	Protein content, %										
Protein	13.03	13.30	13.58	13.85	14.12	14.40	14.67	14.94	15.21	15.49	15.76

Table 3 – Amino acid score FCS

Ratio of components (composition of meal/wheat flour), %	**Essential amino acids score, %**							
	Valin	**Isoleucine**	**Leucine**	**Lysine**	**Methionine +cystine**	**Threonine**	**Tryptophan**	**Phenylalanine +tyrosine**
10/90	82.98	96.11	98.68	53.08	57.62	75.21	123.85	119.98
11/89	83.06	96.39	98.58	54.24	58.76	75.77	124.92	119.85
12/88	83.13	96.65	98.48	55.34	59.85	76.31	125.95	119.73
13/87	83.20	96.91	98.39	56.41	60.91	76.82	126.94	119.61
14/86	83.27	97.81	98.30	57.43	61.92	77.32	127.89	119.49
15/85	83.33	97.40	98.21	58.41	62.90	77.80	128.81	119.38
16/84	83.39	97.63	98.13	59.36	63.83	78.25	129.69	119.27
17/83	83.45	97.85	98.04	60.27	64.74	78.70	130.54	119.17
18/82	83.51	98.06	97.97	61.15	65.61	79.12	131.35	119.07
19/81	83.57	98.27	97.89	62.00	66.45	79.53	132.14	118.98
20/80	83.62	98.46	97.82	62.82	67.26	79.93	132.90	118.88

Based on research [20], it was decided to prepare and study FCS containing 90% wheat flour and 10% composition of soybean, flax and sunflower meal. The FCS indicators were compared with the indicators of premium wheat flour. FCS had a white color with a grayish tint, with noticeable particles of grain, the smell was characteristic of flour, not musty. The wheat flour was white with a creamy tint. FCS moisture content was 13.31 versus 13.92% for wheat flour. Acidity 4.68 versus 3.03 degrees for flour. Consequently, the addition of a meal composition to wheat flour led to an increase in this indicator, which in the future may affect the shelf life of such FCS. The fiber content in the FCS could not be determined due to the characteristics of flax meal described above. The characteristics of the developed FCS make it easy to implement it into the technological process of enterprises producing bakery products.

Based on the developed FCS, a test baking of bread was carried out (Fig. 3) and its organoleptic and physicochemical characteristics were determined in comparison with the control –bread based on premium wheat flour.

a)

b)

Fig. 3. Bread from FKS: a) in a section; b) notches

The moisture content of bread based on FCS was 39.34 versus 41.37% for the highest wheat variety; porosity – 77.15 versus 78.95%; acidity – 1.83 versus 1.14 degrees. Consequently, a sample of baked bread based on FCS in terms of basic physical and chemical indicators, namely: humidity, acidity and porosity, meets the requirements of DSTU 7517:2014, because moisture does not exceed 44%, porosity is not less than 72%, and acidity is not more than 3 degrees.

Conclusions

1. To create FCS, the selection of oilseed meals, the proteins of which are limited in various amino acids, is justified, in particular soybean, flaxseed and sunflower. The amino acid composition of the essential amino acids of the proteins of the indicated meals and wheat flour was experimentally established. Their amino acid score was calculated. The results were compared with reference protein and wheat flour. The results obtained confirm that there is indeed a sharp disproportion between the content of essential amino acids in the proteins of wheat and reference flour, but with the help of selected oilseed meals it is possible to bring the amino acid composition as close as possible to the reference one and level out this deficiency.

2. Mathematically calculated composition of oilseed meal, which in terms of amino acid composition is as close as possible to the amino acid composition of the reference protein. To create the specified composition, data on the content of the specified amino acids in the proteins of soy, flax, sunflower meal and reference protein were used. The mass particles of soy, flax and sunflower meal proteins in the composition were established, namely: 0.51, 0.2 and 0.29, respectively. The amino acid composition and biological value of the protein of the obtained composition of soybean, flax and sunflower meal were established. It was found that for such amino acids as lysine, the sum of sulfur-containing ones (methionine + cystine) and threonine, the amino acid score of FCS increased by 0.7–2 times compared to the score of wheat flour. The ratio (%) of soy, flax and sunflower meal in the composition of the improved amino acid composition was obtained: 44:25:31. The resulting composition can be used as a separate product, the biological value of which is close to the biological value of the reference protein, and can be used for the development of FCS with an improved amino acid composition.

3. The amino acid composition of a number of FCS containing 90–80% wheat flour and 10–20% composition of soybean, flax and sunflower meal was mathematically calculated. The amino acid score for each of the eight essential amino acids of the FCS protein was calculated. It was determined that the amino acid score of valine, isoleucine, lysine, methionine + cystine and threonine FCS significantly increases compared to wheat flour. The developed FCS have a higher biological value compared to wheat flour, and the recipe containing 20% of the meal composition and 80% of wheat flour has the greatest biological value.

4. FCS was obtained and studied, containing 90% wheat flour and 10% composition of soybean meal, flax and sunflower. FCS indicators compared with the indicators of premium wheat flour. It was determined that the moisture indicators of FCS and premium wheat flour are almost the same. It was established that the acidity of FCS exceeds the acidity of flour (4.68 versus 3.03 degrees). It was not possible to determine the fiber content in the FCS due to the characteristics of its component – flax meal.

5. A test baking of bread was carried out and its organoleptic and physico-chemical parameters were determined in comparison with the control – bread based on premium wheat flour. A sample of bread based on FCS meets the requirements of the current regulatory document DSTU 7517:2014 according to the main physical and chemical indicators, namely: humidity, acidity and porosity, because moisture does not exceed 44%, porosity is not less than 72%, and acidity is not more than 3 degrees. The characteristics of the developed FCS make it easy to implement it into the technological process of bakery enterprises.

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РОЗРОБЛЕННЯ БОРОШНЯНИХ КОМБІНОВАНИХ СИСТЕМ З ПОЛІПШЕНИМ АМІНОКИСЛОТНИМ СКЛАДОМ

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Анотація. Досліджено питання математичного розрахунку борошняних комбінованих систем з поліпшеним амінокислотним складом. Для створення таких систем запропоновано використання вторинних продуктів перероблювання насіння олійних культур – шротів, а саме соєвого, лляного та соняшникового. Обґрунтована доцільність використання зазначених шротів. Підкреслено, що для створення наукових засад та практичних напрямів використання нової сировини у виробництві борошняних виробів необхідні комплексні дослідження щодо вивчення її складу, фізико-хімічних властивостей, а також впливу на якість готових виробів. Експериментально визначено амінокислотний склад білків вказаних шротів та борошна пшеничного. Розраховано амінокислотний скор. Особлива увага приділена математичному розрахунку композиції шротів олійних культур, яка за амінокислотним складом максимально наближена до еталонного білка. Визначені масові частки білка соєвого, лляного та соняшникового шротів в композиції, а саме: 0,51, 0,2 та 0,29 відповідно. Встановлено амінокислотний склад та біологічну цінність білка одержаної композиції шротів. Показано, що за такими амінокислотами, як лізин, сумою сірковмісних (метіонін+цистин) та треонін амінокислотний скор борошняних комбінованих систем в порівнянні зі скором борошна пшеничного піднявся в 0,7–2 рази. Одержано співвідношення соєвого, лляного та соняшникового шротів в композиції поліпшеного амінокислотного складу у відсотковому відношенні: 44:25:31. Математично розраховано вміст та скор незамінних амінокислот в системах, що містять у своєму складі 90–80% борошна пшеничного та 10–20% композиції шротів олійних культур. Результати досліджень таких систем показали, що показник вологості майже збігається, а показник кислотності дещо перевищує показник (4,68 проти 3,03 град.) для борошна пшеничного вищого ґатунку. Проведено пробну випічку хліба та визначено його органолептичні та фізико-хімічні показники в порівнянні з хлібом на основі борошна пшеничного вищого ґатунку. У зразку хліба на основі борошняних комбінованих систем вологість становила 39,34%; пористість – 77,15%; кислотність – 1,83 град. Характеристики розроблених систем дають змогу легко впроваджувати їх у технологічний процес підприємств з виготовлення хлібобулочних виробів.

Ключові слова: борошно, шрот, комбінована система, амінокислота, скор, біологічна цінність.