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Research of Effect of Protein-Containing Additives on Pasta Quality and Biological Value

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***Abstract*— The paper presents the results of complex studies on protein enrichment of pasta products as a mass consumption product. Meat products, legume flour and isolates of plant proteins were used as protein-containing additives. The analysis of results of experimental studies on the protein content and essential amino acids in the proposed additives allowed one to substantiate the expediency of their application with the purpose of increasing the biological value of pasta. In order to establish rational dosages of enriching additives, experimental studies have been carried out to determine their effect on the properties of raw gluten and wheat flour starch, which are the main formers of pasta, rheological properties of pasta and quality indicators of finished products, namely organoleptic and cooking properties. Let us take the following as rational dosages - 15% of the mass of flour for meat additives, 10% of the mixture weight - for pea and lentil flour and vegetable isolates and 7.5% by weight of the mixture - for soy flour. The positive influence of enriching additives added to pasta dough on increasing the protein content in the composition of products (by 1.59% - 8.19% in comparison with the control sample), an increase in the balance of its amino acid composition, biological value (by 6% -16%) was established. Also positive influence of enriching additives was found out in the values of the coefficients of the utilitarianism of the amino acid composition (by 0.2-0.26 fraction of units), the digestibility of proteins under the action of the proteolytic enzyme pepsin (11% -24%), the degree of satisfaction of the daily requirement for protein (13.4%, 5 %).**

Keywords*— *pasta, protein supplementation, biological value.

I. INTRODUCTION

The products of mass consumption that are vital for the ration of Russians include pasta. They are consumed by more than 94% of the inhabitants of Russia.

In accordance with the Russian Federation normative document for pasta, the main raw materials in the industry can be, among other things, wheat flour of the highest and first grades. The amount of protein in the composition of pasta produced from such flour is low [1] and allows satisfying on average from 10.2% to 16.9% of the daily protein requirement for adults [2]. But it is the mandatory presence of a physiologically required amount of protein in the human body that allows other food ingredients to manifest their biological functions. Moreover, the protein itself does not matter much, but the amino acids that enter it, released in the gastrointestinal tract during hydrolysis, predetermine its biological value.

Within the framework of this work, the authors studied the content of basic nutrients in pasta made from bakery flour obtained by grinding soft wheat grains grown in the Central region of the Russian Federation, the maximum amount of protein in which did not exceed 11.1% [3].

The solution of the problem of increasing the biological value of pasta products can be based on the introduction into the formulation of alternative types of additional raw materials or additives that contain in their composition a protein content and the most deficient amino acids in their composition: these may be the products of buckwheat processing [4]; egg products, including dry egg protein; rye protein concentrate; fungus powder; horse beans; corn gluten, and even beef emulsion [10]. In some cases, wheat flour is replaced with lupine flour [9], defatted soybean [7], bean [9], whole-hulled amaranth [9], banana [11], etc.

It is known that for the best absorption of protein coming from food and carbohydrates by the body, it is necessary that their ratio is 1:4 - 1:4.5. As follows from the chemical composition of pasta, the ratio is approximately 1:7. This fact should be taken into account when developing new types of pasta, characterized by increased biological value, as well as when choosing rational dosages of protein-containing supplements.

In this work, when choosing the protein-containing additives that are supposed to be used in pasta production, special attention was paid to the specific content of proteins in it, since this directly determines the efficiency of their use [12]. Additives usually lead to a decrease in the proportion of gluten proteins involved in the structure formation; therefore, the more enriched proteins the high-grade proteins contain, the lower their dosage is to achieve greater enrichment of products with this valuable food substance and maintain high quality characteristics of the finished product.

The purpose of this study is the development of recipes and technology of high-value pasta with improved quality characteristics based on the use of protein-containing enriching additives of vegetable and animal origin. The research of the properties of raw wheat gluten and starch, rheological characteristics of pasta, digestibility of “in vitro” proteins, physico-chemical and organoleptic characteristics of the product was conducted.

II. Objects and Methods of Research

The research samples of wheat flour of the highest grade, samples of pasta and pasta dough were selected in accordance with GOST R 52189-2003 "Wheat Flour. General specifications" (Table 1).

Enriching additives, which include a protein with a balanced amino acid composition, were meat products, namely chicken meat (breast carcass) and veal (I category, cooled); flour of legumes, namely soybean deodorized semi-fat, pea and lentil flour; isolates of soy, pea and corn proteins. The protein content and amino acid composition of the additives are presented in Table 2.

In the production of the protein-enriched pasta, a traditional technology was used, including the preparation of raw materials for production, dosing of the main raw materials and enriching additives, kneading and pressing pasta, shaping the semi-finished products of pasta, cutting them, blowing and placing on drying surfaces, drying, stabilizing and cooling of the dried products. The enriching additives were either pre-mixed with flour (legume flour and plant protein isolates), or added to a pasta dough (meat additives) with particles no larger than 325 μm, which was premixed with a prescripted amount of water. Rational dosages of enriching additives were determined experimentally by studying their effect on the properties of wheat gluten and starch, the rheological behavior of the pasta and the quality of the finished product.

TABLE I. Samples of Wheat Bakery Flour and Their Characteristics

Characteristics	**Samples of wheat bakery flour:**		
	№ 1	***№ 2***	***№ 3***
Humidity, %	10.60	10.80	13.00
Ash content, %	0.55	0.54	0.54
Acidity, degree	2.00	2.00	2.20
Mass fraction of crude gluten, %	28.80	29.50	29.50
Indications of the IDG device (identifier of deformation of gluten)	100.00	77.50	80.00
Cohesive strength, N	4.10	3.10	5.50
Hydration ability, %	200.70	183.00	198.00

Research of the properties of raw wheat gluten and starch, analysis of the properties of pasta dough, qualitative indicators of pasta production was carried out according to generally accepted techniques using the following technological devices: SESh-3M (Mogilev-Podolsky Instrument-Making Plant, Ukraine), Quartz-21M (Russia); "Structurometer ST-1" (modes 2 and 3) (LLC "NPF" Radius", Russia); "Amilotest" (mode 2) (LLC "NPF" Radius", Russia).

Rheological indicators of pasta were tested on a device made on the principle of a capillary viscometer with a capillary length equal to 30 mm and a diameter equal to 3 mm.

The mass fraction of proteins in the composition of enriching additives and finished products was determined by the methods of Nessler [13] and Lowry [14] (the calibration plot was plotted for serum albumin). Tests of the amino acid composition of proteins of additives and pasta products were made according to the modified method of liquid ion-exchange chromatography (by the method of Spackmana) with the help of the amino acid analyzer Chromaspek (USA). There are essential amino acid (AA) scores (AS), biological value (BV) as an indicator of the quality of food protein, reflecting the degree of correspondence of its amino acid composition to the needs of the organism in amino acids for protein synthesis; the coefficients of difference in amino acid scores (CDAS), i.e. an average excess of amino acid scores of essential amino acids in comparison with the lowest level of score of any essential amino acid; coefficients of utilitarian amino acid composition (U) proteins, numerically characterizing the balance of essential amino acids in relation to the physiologically necessary norm - the standard. The degree of satisfaction of the daily requirement in the protein was determined by calculation, for which the following formulas were used:

$$AS = \frac{\text{AA amount (mg) in 1 g of tested protein sample}}{\text{AA amount (mg) in 1 g of protein by amino acid scale}} \quad (1)$$

$$BV = 100 - \frac{\sum_{i=1}^{N}(AS_i - \text{Minimum AS})}{N}, \% \quad (2)$$

where N – the content of essential amino acids;

AS_i – the amino acid score of the i-th essential amino acid, %.

In this equation, a *CDAS* value is subtracted from 100.

$$U = C_{min} \cdot \frac{\sum M_{si}}{\sum M_i}\ ,\ \text{fraction of units} \qquad (3)$$

where C_{min} – minimum amino acid score, fraction of units;

M_{si} – the amount of the i-th essential amino acid, which corresponds to the physiologically necessary norm, the standard, g / 100 g of protein;

M_i - the amount of the i-th essential amino acid in the test product, g / 100 g protein.

The content of each essential amino acid was compared to its content in the "ideal" protein, using the amino acid scale of the "ideal" protein recommended by the FAO/WHO Committee (Table 3). The digestibility of pasta proteins was determined by the Anson method [15]. Mathematical processing of the results was carried out using MS Excel, Statistics 12.0.

TABLE II. QUANTITY OF PROTEIN IN THE COMPOSITION OF ENRICHING ADDITIVES, ITS AMINO ACID COMPOSITION AND BIOLOGICAL VALUES

The name of indicator	The protein-containing enriching additives:							
			flour of legumes:			*isolates of vegetable proteins:*		
	chicken meat	***veal***	***soybean***	***pea***	***lentils***	***pea***	***corn***	***soybean***
Mass fraction of proteins, %	23/0±0.1	22/3±0.1	44.2 ±0.1	24.25±0.1	31.4±0,1	90.9±0.1	91.3±0.1	92.5±0.1
The content of amino acids in enriching additives, mg/100 g of product / Score, %:								
isoleucine	916 / 100	1148 / 129	1807 / 102	1407 / 145	1291 / 103	4190 / 115	4510 / 123	4440 / 120
leucine	2017 / 125	1712 / 110	2678 / 87	1964 / 116	2393 / 109	7910 / 124	12760 / 199	7678 / 119
valine	994 / 86	1287 / 115	2517 / 114	1285 / 106	1608 / 102	4730 / 104	4510 / 99	4348 / 94
lysine	1879 / 149	1918 / 156	2195 / 90	1619 / 121	2178 / 126	7000 / 140	2770 / 55	5920 / 116
threonine	1052 / 114	975 / 109	1887 / 107	1062 / 109	1215 / 97	3545 / 97	3650 / 99	3608 / 98
methionine+cysteine	918 / 133	805 / 103	1062 / 69	648 / 76	652 / 59	2090 / 67	2050 / 64	2312 / 71
tryptophan	365 / 159	284 / 127	581 / 131	239 / 99	279 / 89	910 / 100	980 / 107	1018 / 110
phenylalanine+tyrosine	1274 / 92	1680 / 125	3891 / 147	2196 / 151	2603 / 138	8640 / 158	7260 / 133	8500 / 153

TABLE III. AMINO ACID SCALE OF THE FAO/WHO COMMITTEE FOR THE CALCULATION OF AMINO ACID SCORE

The name of an essential amino acid	Content (mg) in 1 g of the "ideal" protein
Isoleucine (Iso)	40
Leucine (Leu)	70
Valine (Val)	50
Lysine (Lys)	55
Threonine (Tre)	40
Methionine (Meth) + Cysteine (Cys)	35
Tryptophan (Try)	10
Phenylalanine (Phen) + Tyrosine (Tyr)	60

III. RESULTS AND DISCUSSION

The effect of enriching protein-containing additives on the quality of pasta products, primarily their organoleptic and cooking properties, on the properties of raw wheat gluten and starch as the main structure-forming agents and rheological indicators of pasta (Tables 4-5, figure 1) was investigated [3].

The obtained results allowed one to substantiate the choice of rational dosages of protein-containing additives, which influence the consumer properties of pasta products as much as possible, namely: 15% of the flour mass - meat additives; 7.5% of the weight of the flour mixture - soy flour; 10% of the mass of the flour mixture - pea flour and lentil flour, isolates of maize, pea and soy proteins. These dosages of additives provide:

- a significant increase in the elastic properties of wheat gluten (Ndef.IDK): by 35 (meat additives), by 2-10 (flour of legumes), by 12.5-22.5 (isolates of plant proteins) IDK units.
- increase in the temperature of the maximum viscosity of the starch gel: by 0.5-1.5 °C (legume flour and plant protein isolates) with the exception of the effect on this indicator of meat additives, which is probably due to a decrease in the mass fraction of starch in the water-flour suspensions;
- significant increase in the ultimate shear stress as the main rheological characteristic of the pasta: 2 (meat additives), 1.5-4 (legume flour) and 1.1-1.7 (plant protein isolates) times;
- reduction of the main indicator of cooking properties of pasta products - dry substances that switched from cooking to cooking water: by 1.93-2.29 (meat additives), by 1.6-2.22 (legume flour) per cent. The only exception is the isolates of plant proteins. The implementation of isolates into the structure of pasta slightly increases this index (by 0.4%).

It should be noted that one of the reasons for increasing the elastic properties of raw wheat gluten and rheological indicators of pasta is the interaction of protein substances with gluten proteins.

TABLE IV. INFLUENCE OF ENRICHING PROTEIN-CONTAINING ADDITIVES ON PROPERTIES OF RAW WHEAT GLUTEN AND STARCH

Name of the sample of pasta	**Values:**						
	of mass fraction of crude gluten,%	***of the DCO, units.***	***of gluing capacity of gluten, H***	***of a moisture-absorbing capacity of gluten,%***	***of temperature of a starch gelatinization start temperature, oC***	***of temperature of a maximum viscosity of a starch gel, oC***	***of viscosity of a starch gel at the gelatinization temperature (force, N)***
Control 1	28.83±0.1	100.0	4.1	200.7±0.75	65.0	93.5	10.5±0.1
Sample with veal (15% of the mass of flour)	28.5±0.1	65.0	4.0	212.5±0.75	61.0	90.5	8.95±0.1
Sample with chicken meat (15% of the mass of flour)	28.6±0.1	65.0	3.9	207.0±0.75	62..	91.0	9.23±0.1
Control 2	29.5±0.1	77.5	3.1	183±0.75	65.0	94.0	8.34±0.1
Samples with flour of legumes:							
Soybean (7.5% of the mixture)	28.9±0.1	75.5	3.44	178.9±0.75	66.0	94.5	5.75±0.1
Lentil (10 % by weight of the mixture)	28.3±0.1	67.5	3.9	161.66±0.75	65.5	95.5	6.27±0.1
peas (10% of weight of the mixture)	28.4±0.1	70.5	3.67	173.96±0.75	66.0	95.5	6.78±0.1
Control 3	29.5±0.1	80.0	5.5	198±0.75	75.0	95.0	5.55±0.1
Samples with isolates of plant proteins:							
corn (10% of weight of the mixture)	26.78±0.1	72.5	7.7	184±0.75	75.0	95.5	5.37±0.1
peas(10% of weight of the mixture)	29.21±0.1	57.5	5.9	165.3±0.75	75.0	95.5	4.94±0.1
soybean (10% of weight of the mixture)	28.42±0.1	67.5	6.9	166.7±0.75	74.5	95.5	4.83±0.1

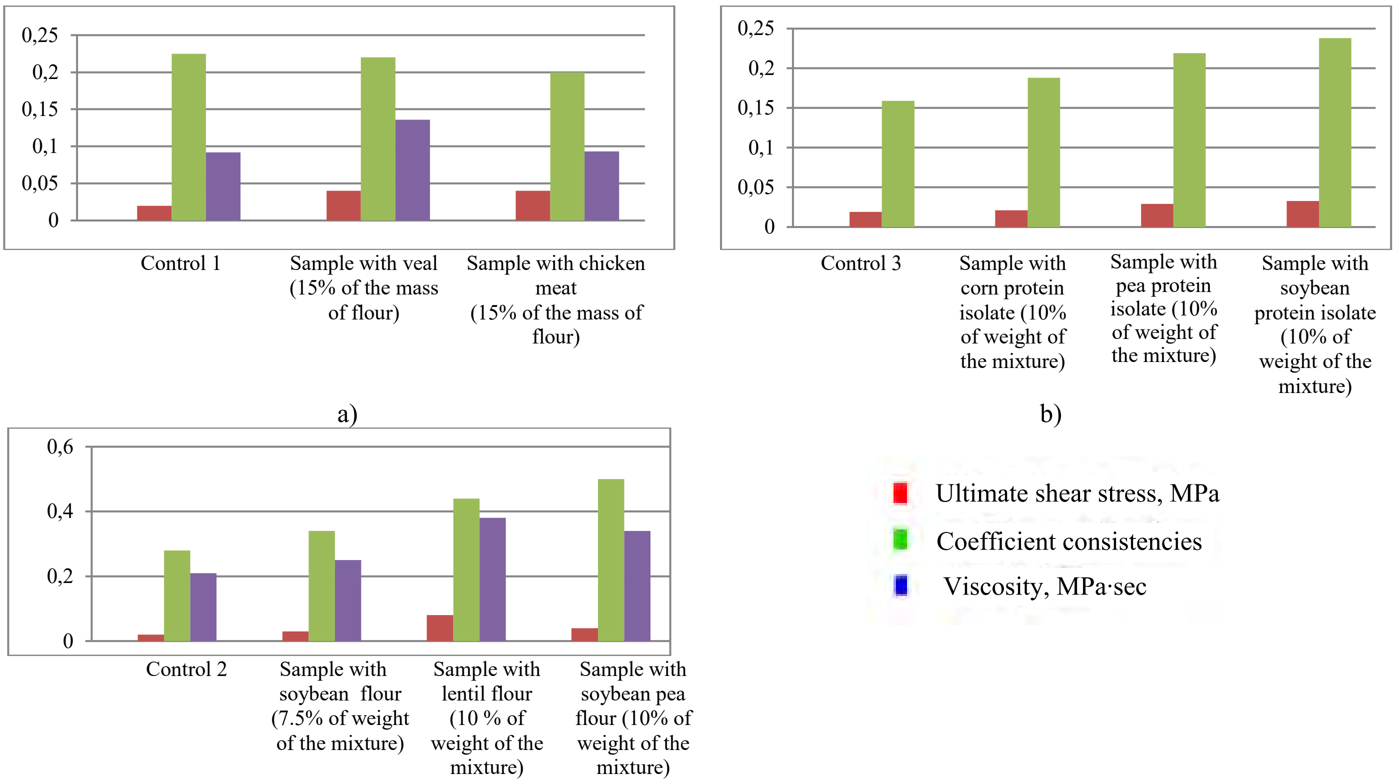

Fig. 1. Rheological properties of pasta without additives and with fortifying additives: a) samples with meat additives, b) samples with isolates of plant proteins, c) samples with legume flour

TABLE V. INFLUENCE OF ENRICHING PROTEIN-CONTAINING ADDITIVES ON QUALITY INDICATORS OF PASTA PRODUCTS

Name of the sample of pasta	**Values:**			
	of acidity, deg	*of shear strength, N*	*of mass gain factor*	*of dry matter converted to cooking water,%*
Control 1	2.0	4.3	2.1	9.66±0.1
Sample with veal (15% of the mass of flour)	2.5	5.2	1.88	7.37±0.1
Sample with chicken meat (15% of the mass of flour)	2.8	5.0	1.9	7.73±0.11
Control 2	-	2.96	1.83	6.2±0.1
Samples with flour of legumes:				
soybean (7.5% of the mixture)	-	3.09	2.3	4.76±0.1
lentil (10 % by weight of the mixture)	-	3.85	2.46	3.98±0.1
peas (10% of weight of the mixture)	-	3.61	2.46	4.21±0.1
Control 3	2.2	2.8	2.89	8.3±0.1
Samples with isolates of plant proteins:				
corn (10% of weight of the mixture)	2.2	3.4	2.93	8.5±0.1
peas (10% of weight of the mixture)	2.2	3.7	2.94	8.6±0.1
soybean (10% of weight of the mixture)	2.2	3.8	2.95	8.7±0.1

According to K.N. Chizhova, in creating an optimal spatial grid of gluten proteins, the uniform distribution of mass with different size of molecules is essential. For example, proteins with a low and medium molecular weight, soluble in water and salt solutions, can become an intermediate building material in the formation of a rigid gluten carcass. This fact is confirmed by P.V. Medvedev, who in his works proved that protein substances with a lower molecular weight than wheat proteins, added to the flour dough structure, interact with gluten proteins and take part in coagulation structure formation.

As is known, the strength of intermolecular bonds that determine the ordering of the structure of the gluten gel is directly related to the solubility of gluten proteins. Therefore, in order to establish the presence of interaction between protein substances of additives and gluten, the influence of supplement proteins on the change in the degree of solubility of gluten in a polar solvent was studied. The less the proteins interact with each other, the more their quantity passes into the solvent. That is why the proportion of gluten proteins transferred from gluten to a polar solvent was determined. As a polar solvent, a 6 M urea solution was used, because it is proved (P.V. Medvedev, 2004) that in this case the implemented protein-containing additive as well as its dosage (not the properties of the gluten itself) influence the solubility of gluten proteins. The amount of proteins converted into a polar solvent was determined using the Lowry method (the calibration plot was made for serum albumin).

It is found out that the introduction of protein additives into the structure of pasta dough in rational dosages reduces the amount of proteins passing from gluten into a 6 M urea solution, which proves the presence of stronger internal bonds between molecules of gluten proteins or their aggregates and a change in the structural arrangement of protein molecules.

In addition, it is established that during the movement of the dough in the screw chamber of the pasta squeezer, where the dough gradually compacts, plastic deformation of its particles occurs, the convergence of their internal surfaces, gluing them together, the forces of interaction of gluten proteins and additives substantially increase (Figure 2). It leads to a decrease in the degree of solubility of proteins.

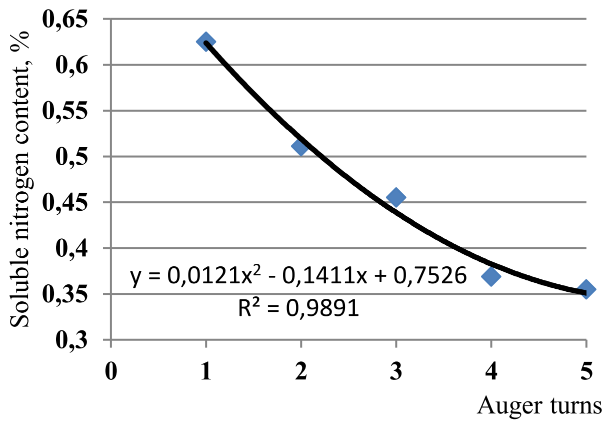

Fig. 2. The amount of ammonium nitrogen that passed into the solution when examining a dough taken from different dough-auger turns

The analysis of the data (Table 5) allows us to record a slight decrease in the cooking properties of pasta when adding vegetable isolates to the pasta dough: the amount of dry substances found in the cooking water after cooking increased slightly. The cause of this was revealed. And among other things, the qualitative characteristics of the feedstock, in particular, the mass fraction of raw wheat gluten, and their effect on the transition of solids to cooking water during cooking was also studied. For this, three samples of wheat flour were used, differing from each other in the content of raw gluten. It has been experimentally proven that with a smaller content of raw gluten in wheat flour, more solids enter the cooking water.

With the help of mathematical processing of experimental research data, a functional relationship was established between, on the one hand, the amount of raw wheat gluten and the dosages of plant isolates, and, on the other hand, the content of dry substances passing into the cooking water during the cooking of pasta:

$$P_{d.s.} = y = 8.3 \cdot (0.83 + 0.0133 \cdot x_1) \cdot (1.53 - 0.02 \cdot x_2), (4)$$

where y is the amount of dry substances passing into the cooking water, $P_{d.s.}$ (%);

x_1 - dosage of plant isolate, % to mass of mixture;

x_2 - gluten content, %.

Table 6 shows the main indicators of quality of food protein pasta with protein supplements.

TABLE VI. PERCENTAGE CONTENT AND PROTEIN QUALITY INDEXES OF MACARON PRODUCTS WITH PROTEIN-CONTAINING ADDITIVES

Index name	**Name of pasta:**								
	control	***with chicken meat (15%)***	***with veal (15%)***	***with soy flour (7.5%)***	***with pea flour (10%)***	***with lentil flour (10%)***	***with pea protein isolate (10%)***	***with corn protein isolate (10%)***	***with soy protein isolate (10%)***
Protein,%	11.10	13.91	14.18	13.58	12.69	13.03	18.59	18.68	19.29
Satisfaction of daily needs,%	18-11	22.6-13.6	23-14	22.1-13.3	20.6-12.5	21.2-12.8	30.2-18.2	30.4-18.3	31.4-18.9
Essential amino acids,%	2.69	3.53	3.82	3.58	3.30	3.52	5.52	6.21	5.79
Amino acid score,%									
isoleucine	65	66	71	74	75	75	78	91	91
leucine	71	72	77	75	83	80	85	135	90
valine	56	59	61	71	63	68	75	69	74
lysine	36	56	60	50	54	59	77	47	71
threonine	146	134	145	136	120	136	153	126	146
methionine + cystine	54	64	66	61	56	66	60	60	67
tryptophan									
phenylalanine + tyrosine	97	109	103	110	102	100	97	105	109
	92	91	98	103	95	93	108	142	104
Essential amino acids,% of total amino acids	24.9	25.6	27.3	27.0	26.7	28.6	30.5	33.8	30.8
Biological value,%	59	75	75	65	73	74	68	51	73
The coefficient of utility of the amino acid composition, units.	0.53	0.79	0.79	0.74	0.75	0.79	0.73	0.53	0.80
Coefficient of difference in amino acid score,%	41	25	25	35	27	26	32	49	27

It should be noted that the use of protein-containing additives slightly changed the course of one of the most important stages of production of pasta products - drying. The total duration of drying pasta with additives was reduced for almost all analyzed samples, except for the sample with soy flour. This, in our opinion, is due to the fact that the proportion of protein fractions characterized by a lower molecular weight than the gluten proteins has significantly increased, and the binding of moisture is mainly osmotically and less strongly, which sharply reduced the process of removal of adsorption-bound moisture. However, when using soy flour, the total drying time was increased by 10 minutes compared to the drying of the control sample, since additional lipids were added to the dough, as well as a sufficiently large amount of dietary fiber (2.9 g / 100 g), strongly and adsorptively binding the moisture, the removal of which took a little longer at the second drying stage [3].

IV. CONCLUSION

Thus, the conducted experimental studies made it possible to say that the introduction of protein-containing additives into the pasta structure contributes to the improvement of the quality of the finished product (due to the positive effect of the additives on the elastic properties of raw gluten, the temperature of the maximum viscosity of the starch gel, the viscosity and the structure of the pasta) and the quality of protein substances of pasta, produced from bakery flour. The biological value of protein samples of products with protein-containing additives increased in comparison with the control sample by 6% - 16%; the degree of balance of its amino acid composition increased. The inclusion in the diet of new protein-enriched pasta products that are mass consumption products will allow one to adjust its nutritional, including biological value in the desired direction. Technical documentation (technical conditions, technological instructions and recipes) was developed and approved according to Russian rules by authors for all new types of pasta with enriching protein-containing additives. The developed test compositions for the production of enriched pasta are protected by patents for inventions.

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