

Functional and Technological Properties of Composite Mixtures Based on Bean Protein- Carbohydrate Matrix (BPCM)

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Abstract— The work was completed in 2017-2018 on the base of Federal State Budget Educational Institution of Higher Education "Saratov State Agrarian University named after N.I. Vavilov" (a study of the chemical composition of bean samples) and the Federal State Budget Scientific Institution for Research and Development of Agricultural Sciences of the South-East, Saratov (study of the rheological dough properties). Samples of bean selection were provided by scientists at Omsk State Agrarian University named after P.A. Stolypin. "The aim of the work was to study the functional and technological properties of composite mixtures based on protein-carbohydrate bean matrix (BPCM) to justify the optimal ratio of their component composition. In the process of the work composite mixtures of wheat flour and BPCM were investigated in percentage ratio 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10: 90 and their stable effect on the rheological properties of the dough was revealed. For this purpose, the Mixolab device of the CHOPIN company (France), the Chopin + protocol, was used. It is found that with an increase in the number of BPCM both red and white food beans from 10 to 90%, the time of dough formation (kneading) and stabilization is reduced, as well as the costs of total energy consumed for kneading are reduced. Analysis of mixolabograms allows to choose the optimal ratio of components (flour from wheat and beans) in the mixture (80:20 and 70:30) providing rheological properties of the dough that are the most suitable for flour products. Thus, the obtained results make it possible to understand better the essence of the processes occurring in composite systems based on flour from composite mixtures of wheat and beans, as well as to predict the effect of the concentration of components on the production technology of flour products.

Keywords—wheat flour, bean flour, composite mixtures, dough, rheological properties, mixolabogram.

I. INTRODUCTION

In recent years, in order to eliminate the deficiency of dietary protein, essential vitamins, minerals and dietary fiber, bakery, flour confectionery and puff products with a high content of vegetable protein based on flour multicomponent mixtures (MCM) have become widespread. As a rule, the composition of flour mixtures includes rye flour, rye fermented flour, wheat flour, wheat germ, wheat bran, various kinds of flakes from cereal crops, whole-ground flour, flax seeds, sunflower seeds, sesame seeds, etc. However, in the scientific periodicals information on the use of haricot beans is very limited.

In order to obtain food products of various functional orientations, a team of authors led by Professor N.G. Kazydub [1, 2] at Omsk State Agrarian University carries out selection work on new resistant varieties of haricot beans with a high content of essential amino acids - methionine, tryptophan, phenylalanine, valine, leucine and isoleucine.

These bean varieties contain not only an increased amount of biologically active substances, but also microelements and macroelements: potassium and phosphorus, copper and zinc, selenium, and other equally important nutrients.

Since 2014, the Department of Food and Food Biotechnology of Omsk State Agrarian University has been studying the possibility of using haricot beans, both as an independent product and as functional ingredients used in bakery products [3, 4]. The use of beans as one of the main raw materials in the production of food products with a high content of vegetable protein makes it possible to enrich food with the necessary micro and macro elements and thereby, compensate the lack of animal proteins [5].

The aim of the study was to justify the optimal formulation, functional and technological properties of composite mixtures based on protein-carbohydrate matrix of food beans (BPCM).

II. RESEARCH METHODOLOGY

The objects of research were: whole-wheat flour (TU 10.61.20-001-38744625 "Flour in assortment"); whole-ground flour from white and red food beans (GOST 7758-75) obtained by sequential grinding of bean seeds in the MI grinding mechanism of the universal UKM kitchen machine and the laboratory mill Quadrumat Junior (Brabender company), composite mixtures based on a protein-carbohydrate matrix of beans (BPCM) from wheat flour (WF) and white bean flour (WBF), from red bean flour (RBF) in a percentage ratio of 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90.

The rheological properties of the dough were evaluated on a Mixolab device (Mixolab, Chopin, France) according to the method of GOST ISO 17718-2015. Grain and flour from soft wheat [6]. The Mixolab device in real time measures the torque in N · m that occurs between two dough mixing blades when mixing dough from flour and water for several consecutive kneading phases due to different temperatures.

This ensures that complete information is obtained that allows to comprehensively evaluate flour properties and objectively determine its intended use [7, 8,9]. The following indicators of the rheological dough state were analyzed: the time of formation of the dough (min), the stability of the dough (min), water absorption capacity (%), the extremum points of the rheogram — C2 and C5 (N * m). Statistical analysis of the data was carried out using a licensed package of computer software Statistika 10 with the calculation of the average and standard error of the mean. For all indicators, intergroup comparisons were performed using Student's t-test for independent samples at P <0.05. The smallest significant difference in HCP 05 - did not exceed the limit of variation under the influence of random factors.

III. RESULTS

Studies of the chemical composition of food beans (red, white) and varietal (Lukerya- black, Omichka - white), and the results are summarized in Table 1.

TABLE I. THE CHEMICAL COMPOSITION OF THE SEEDS OF FOOD BEANS AND VARIETAL (G / 100 G DRY WEIGHT)

Name	White food beans [10]	Red food beans [10]	Variety of beans Lukerya	Variety of beans Omichka
Calorie, kcal	333	337	327	275
Proteins, g	23.4	22.5	23.9	23.6
Fats, g	0.8	1.1	1.7	1.4
Carbohydrates, g	60.3	61.3	54.5	42.5
Dietary fiber, g	15.2	15.2	12.4	12.4

^a. The data presented in Table 1 correspond to a 95% probability level

As we can see at table 1, the differences in protein between white and red food beans and the bean varieties of breeds Omichka and Lukerya are insignificant. The difference in carbohydrates was more significant, the content of which in food beans is 11-29% higher than in beans of Omsk varieties. A comparative analysis of the amino acid bean composition of various origins in comparison with the amino acid composition in an ideal protein arouses no less interest (Table 2).

TABLE III. PARAMETERS OF MIXOLABOGRAMS OF DOUGH FROM WHEAT FLOUR (WF), COMPOSITE MIXTURES AND WHITE BEAN FLOUR (WBF) AND RED BEAN FLOUR (RBF)

Flour sample	UPU, %	Time of dough forming, min	Dough stability, min	Torque, N*m		Dough kneading energy, W * h/kg
				C ₂	C ₅	
Wheat flour (WF)	58.5	8.77	10.42	0.49	6.04	190.2
WF 90% +10% WBF	61.1	8.80	10.73	0.48	4.90	180.0
WF 80% + 20% WBF	61.4	6.28	9.43	0.38	3.96	146.2
WF 70% + 30% WBF	61.5	5.33	5.98	0.38	3.50	137.7
WF 60% + 40% WBF	62.0	5.18	8.52	0.36	3.53	128.9
WF 50% + 50% BF	61.0	4.72	8.70	0.37	3.81	132.1
WF 40% + 60%WBF	60.6	0.87	7.08	0.36	3.77	130.9
WF 30% + 70% WBF	61.9	1.02	6.48	0.37	3.58	114.9
WF 20% + 80% WBF	62.3	1.02	3.42	0.38	2.96	98.0
WF 10% + 90 WBF	63.4	1.18	3.15	0.42	2.60	86.8
White bean flour (WBF)	60.8	1.27	2.77	0.46	2.47	80.4
WF 90% + 10% RBF	59.4	7.42	11.95	0.52	5.59	184.6
WF 80% + 20% RBF	59.9	6.30	9.07	0.45	5.29	180.8
WF 70% + 30% RBF	60.2	7.00	7.03	0.40	4.65	164.1
WF 60% + 40% RBF	61.3	6.63	5.68	0.34	3.96	143.2
WF 50% + 50% RBF	59.5	6.,05	5.73	0.33	3.98	139.6
WF 40% + 60% RBF	59.2	6.20	6.78	0.30	3.86	147.7
WF 30% + 70% RBF	59.4	4.97	7.92	0.31	3.37	109.1
WF 20% + 80% RBF	59.5	0.93	6.22	0.34	0.23	66.3
WF 10% + 90% RBF	60.4	0.97	2.05	0.40	0.02	61.5
Red bean flour (RBF)	57.3	1.08	1.80	0.43	-	61.6

HCP₀₅= 0,08

TABLE II. INDICATORS OF THE CONTENT OF ESSENTIAL AMINO ACIDS IN SAMPLES OF THE MASS CONCENTRATION

№	Name of Amino Acids	Amino acid content, (g / 100 g dry matter / percentage of ideal protein content)				
		in ideal protein	in beans varieties Omichka	in beans varieties Lukerya	in white food beans	in red food beans
1	Threonine	4.0	1.03/25.7	0.91/22.7	1.10/27.5	1.02/25.5
2	Valin	5.0	1.16/23.2	0.97/19.4	1.11/22.2	1.06/21.2
3	Methionine + cystine	3.5	0.96/27.4	0.97/27.7	0.3/8.6	0.27/7.7
4	Lysine	5.5	1.75/31.8	1.60/29.1	1.88/34.2	1.90/34.5
5	Tryptophan	1.0	0.29/29.0	0.26/26.0	0.27/27.0	0.26/26.0
6	Isoleucine	4.0	0.89/22.2	0.75/18.7	0.89/22.2	0.75/18.7
7	Leucine	7.0	1.80/25.7	1.54/22.0	1.80/25.7	1.54/22.0
8	Phenylalanine + tyrosine	6.0	2.22/37.0	1.83/30.5	2.11/35.2	1.81/30.2
9	The amount of irreplaceable amino acids	36.0	10.1/28.1	8.83/24.5	9.46/26.3	8.61/23.9

HCP₀₅= 0,07

Analyzing table 2 it is clear that by the sum of the mass concentration of essential amino acids white food beans is closer to the beans Omichka and red food beans is similar to Lukerya beans. The limitative amino acids for beans of the selection variety Lukerya are valine and isoleucine, whereas for the food beans of red and white limitative amino acids are methionine and cystine. At the same time, the distinction in the amount of essential amino acids in absolute values does not exceed 0.64 g / 100 g dry matter for white and Omichka beans, and 0.22 g / 100 g dry matter for red and Lukerya beans.

The results of studies of the rheological properties of composite mixtures based on whole-wheat flour (WF), white bean flour (WBF) and red bean flour (RBF) are presented in Table 3.

It was found that with an increase in the mass fraction of bean flour in the composite mixture from 10 to 90%, an increase in water absorption capacity (WAC) from 61.1% to 63.4% is observed when using white bean flour and from 59.4% to 60.4% when using red bean flour, which is due to the hydrophilicity of high molecular weight compounds of bean proteins. Since an increase in WAC leads to better gelation and less thickening of starch, which, in turn, contributes to a higher rise in dough when making bakery products, it can be considered that the use of bean flour in a composite mixture has a beneficial effect on the baking properties of composite mixtures.

It is established that with an increase in the mass fraction of flour from varietal beans in the composite mixture from 10 to 90%, the following is observed:

A. steady decrease in the time of the dough forming:

- from 8.80 minutes to 1.18 minutes with white bean flour;
- from 7.42 minutes to 0.97 minutes with red bean flour;

B. steady decrease in the time of the dough stability:

- from 10.73 minutes to 3.15 minutes with white bean flour;
- from 11.95 minutes to 2.05 minutes with red bean flour.

At the same time, the dough formation time for wheat flour is higher than for the composite mixture at any percentage ratio of components and as the content of bean flour in the composite mixture increases this parameter decreases.

The revealed fact in time dependence of dough formation on the dosage of bean flour is associated with a change in the amino acid composition of the composite flour in comparison with wheat flour. It is known that in the process of mixing hydration and swelling of the protein complex occurs, at first, hydrogen and then disulfide bonds are strengthened [9]. With an increase in the amount of bean flour from 10% to 90% in the composite mixture, the total protein content increases and the number of disulfide hydrogen bonds supporting the protein framework grows. In this case there is a decrease in the number of gliadin and glutenin proteins of wheat with an increase in the mass fraction of bean globulin proteins [9].

The stability time for the composite mixture with the addition of 10% bean flour turned out to be longer than for pure wheat flour, however, with an increase in the concentration of bean flour, this indicator sharply decreases. For flour from bean seeds, the same indicators approach the values for composite flour with a minimum content of wheat flour (10%). It has been established that low stability negatively affects the baking process - the dough does not rise during proofing, but swells. This is explained by the fact that the process of gas formation is associated with stability. An increase in time stability has a beneficial effect on the dough, providing a good rise of bread during proofing.

For a composite mixture with the addition of white bean flour an increase in stability time is observed at 60:40 and 50:50 ratios, and for a composite mixture an increase in stability time is observed at a ratio of 30:70. The stability time decreases sharply with the addition of bean flour over 60%.

Analysis of the change in the moment of force C2 at which the minimum consistency of the dough is achieved during the

phase of "dough liquefaction" shows that as the content of bean flour in the mixture increases, the moment of force C2 gradually decreases from 0.48 N * m to 0.42 N * m for a composite mixture with white bean flour and from 0.52 N * m to 0.40 N * m - with red bean flour.

The moment of force during the liquefaction phase (C2) characterizes the activation process of proteolytic enzymes, which leads to a decrease in the dough consistency due to the breaking of hydrogen bonds in protein molecules that bind protein molecular chains. There happens gluten protein degradation and liquefaction of dough. Moreover, the lower the moment C2, the higher the volumetric yield of bread. The decrease in C2 moment is also explained by a decrease in the amount of gluten-free gliadin and glutenin wheat proteins with an increase in globulin proteins of beans.

With an increase in the content of bean flour in the composite mixture, a decrease in the value of C5 force moment is also observed that characterizes the maximum consistency of the dough during the end of the "starch retrograde" phase:

- from 4.90 N * m to 2.60 N * m with white bean flour;
- from 5.59 N * m to 0.02 N * m with red bean flour.

The moment of force C5 is characterized by the carbohydrate-amylase complex of the studied system and the processes occurring in it. High autolytic activity which is characterized by low C5 values ensures the formation of a finely divided crumb structure during baking. High values of C5 characterize weak enzymatic activity. The decrease in the moment of force C5 gives reason to believe that bakery and confectionery products obtained from composite mixtures will be more resistant to hardening and, therefore, longer storage life.

Another indicator to pay attention to is the total energy absorbed by the dough during the mixing of RA (W * h / kg). Undoubtedly, this property is important technologically as it is associated with energy costs.

There is a clear tendency to reduce energy costs per batch as the concentration of bean flour in the composite mixture increases.

IV. CONCLUSIONS

Conducted research has shown that an increase in the content of food bean flour in a composite mixture from 30% to 60% does not negatively affect the rheological properties of the dough with a bean component. Therefore, a composite mixture of wheat flour and bean flour in a ratio of 80:20; 70:30, 60:40; 50:50; 40:60 is quite acceptable for the production of bakery products.

Comparison of the obtained rheological dough properties from composite mixtures based on a protein-carbohydrate matrix using food beans showed identity with similar indicators for composite mixtures based on a protein-carbohydrate matrix from selection of beans [11, 12]. This proves the possibility of using food beans as a protein fortifier for flour composite mixtures.

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