

# Study of the structural and mechanical properties of flour from a composite mixture based on beans and premium wheat

Maxim Maradudin Saratov State Agrarian University named after N.I. Vavilov Saratov, Russia maradudinms@sgau.ru

Viktoriya Strizhevskaya Saratov State Agrarian University named after N.I. Vavilov Saratov, Russia strizhevskaiyvn@sgau.ru

Abstract—The work was performed in 2019 at the Department of Food Technology of Saratov State Agrarian University named after N.I. Vavilov and at the Research Agricultural Institute. Using the Mixolab instrument, the basic parameters of the rheological state of the dough from patent wheat flour, flour from seeds of food beans (white and red), and also flour from composite mixtures based on them were studied. These data were compared with the SDS-sedimentation indices and gluten content in the flour of the starting components and composite mixtures. It has been established that SDSsedimentation indicators correlate with the gluten content in the composite mixture, with water absorption capacity (WAC), the moment of force during the dilution phase C<sub>2</sub>, with the moment of force characterizing the maximum consistency of the dough at the end of the phase of "starch retrogradation" C5 and with the cost of total energy consumed per batch. To a lesser extent, SDS-sedimentation indices correlate with the dough formation time T<sub>1</sub>, the dough stability time T<sub>2</sub>, the force moment C<sub>3</sub> characterizing the dough stability during the gelatinization phase, and the force moment C<sub>4</sub> characterizing the minimum consistency of the dough during the "starch retrogradation" phase.

Data of the study will allow more efficiently regulate the technological dough process of the production of food products based on composite mixtures.

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

# I. INTRODUCTION

Currently, there is a fairly large number of works by domestic and foreign scientists on the production of functional foods of plant origin, aimed at improving the nutritional status of the population associated with a deficiency of dietary protein, polyunsaturated fatty acids, vitamins, minerals, dietary fiber and others.

One of the ways to solve this problem is the use of flour multicomponent mixtures for the production of bakery and flour confectionery and puff products with a high content of vegetable protein. Grain beans, being a crop with high Inna Simakova Saratov State Agrarian University named after N.I. Vavilov Saratov, Russia simakovaiv@yandex.ru

Ekaterina Volf Saratov State Agrarian University named after N.I. Vavilov Saratov, Russia wolfsgau@gmail.com

nutritional value and a high content of gluten-free vegetable protein, is one of the main types of protein-containing raw materials in the production of such food products [1-3].

The purpose of the research was to justify the optimal ratio of component composition and to establish a correlation between the SDS-sedimentation indices, the gluten content in flour and the rheological parameters of the composite mixture.

#### II. EXPERIMENTAL

The objects of research were patent wheat flour (GOST R 52189-2003), flour from seeds of food beans (white and red), produced by sequential grinding of beans' seeds in the grinding mechanism MI of the universal kitchen machine UKM and laboratory mill Quadrumat Junior of Brabender company, as well as composite mixtures based on them in a percentage ratio: 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90.

Assessment of SDS-sedimentation indices was carried out according to the SDS-sedimentation technique developed by Dick J.W. [4], improved at the Research Agricultural Institute for South-East Region [5]. The rheological properties of the dough were determined on a Mixolab instrument (Mixolab, Chopin, France) according to the GOST ISO 17718-2015. Grain and flour from soft wheat [6]. This instrument based on the "Chopin + protocol", measures the torque in N·m in real time. The torque occurs between two dough mixing blades when mixing dough from flour and water for several consecutive kneading phases due to different temperatures. It ensures obtaining the complete information that leads to a comprehensive assessment of the flour properties and objective determining its intended use [7, 8].

The main parameters of the rheological state of the dough were analyzed during the research: water absorption capacity (WAC,%), dough formation time (T<sub>1</sub>, min), stability time (T<sub>2</sub>, min), moment of force during the dilution phase (C<sub>2</sub>, N·m), moment of force during the gelatinization phase, (C<sub>3</sub>, N·m), the moment of force characterizing the minimum (C<sub>4</sub>, N·m)



and maximum (C<sub>5</sub>, N·m) consistency of the dough during the "starch retrogradation" phase, the energy absorbed by the dough in the process of dough formations (P, Wh/kg), which are compared with the SDS-sedimentation indices and gluten content in the flour of the starting components and composite mixtures.

The correlation between the studied parameters was determined using Microsoft Excel programs.

### III. RESULTS AND DISCUSSION

The results of studies of the rheological properties of composite mixtures based on premium flour, white bean flour and red bean flour, as well as SDS-sedimentation indies with correlation coefficients (R) between them are presented in Table I.

The analysis of the obtained data confirmed a high correlation between the SDS-sedimentation indices and gluten content in the studied samples (R = 0.97-0.98). It was found out that with an increase in the amount of bean flour in the composite mixture from 10 to 90%, the gluten content decreases and the value of the SDS-sedimentation index decreases. At the same time, there is an increase in water

absorption capacity from 55.8 to 66.7% when using white bean flour and from 55.3 to 64.0% when using red bean flour, which is due to the hydrophilicity of high molecular weight compounds of bean proteins. The correlation between the SDS-sedimentation indices and water absorption capacity is also quite high (R = 0.83-0.89). Since an increase in water absorption capacity leads to better gelation and less thickening of starch, which, in turn, contributes to a higher rise in dough when baking 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.

A change in the content of bean flour in the composite mixture from 10 to 90% affects the dough formation time (T<sub>1</sub>) and stabilization time (T<sub>2</sub>), however, the correlation dependence in this range between the SDS-sedimentation indices and these parameters was practically insignificant (R = 0, 03-0.01 for T<sub>1</sub>) and (R = 0.33-0.26 for T<sub>2</sub>). At the same time, in the range from 10 to 60% this correlation dependence is more significant (R = 0.59-0.93)

 TABLE I.
 PARAMETERS OF MIXOLABOGRAMS OF THE DOUGH FROM WHEAT FLOUR, COMPOSITE MIXES AND WHITE BEAN FLOUR, RED

 BEAN FOOD FLOUR

№	Content of bean flour in the mixture	SDS index, ml	Gluten content, %	WAC, %	T <sub>1</sub> , min	T <sub>2</sub> , min	C₂, N∙m	C₃, N∙m	C₄, N∙m	C₅, N∙m	P, (Wh/kg)
1	premium flour 100%	93	32.0	54.5	1.88	9.48	0.49	1.53	2.16	5.79	168.72
2	10% white bean flour	85	27.2	55.8	5.63	9.48	0.45	1.38	2.51	5.93	182.70
3	20% white bean flour	67	14.2	57.3	5.90	8.28	0.36	0.89	2.33	5.22	164.30
4	30% white bean flour	51	13.6	57.8	5.20	6.43	0.34	3.82	3.76	4.32	148.88
5	40% white bean flour	42	6.8	59.1	5.57	8.48	0.35	0.53	2.22	4.52	147.69
6	50% white bean flour	35	2.0	60.1	6.42	9.98	0.31	0.43	2.11	4.40	143.12
7	60% white bean flour	29	0.4	61.1	7.85	10.42	0.30	0.36	1.80	4.29	133.26
8	70% white bean flour	26	0.2	62.2	0.93	3.03	0.30	0.34	1.38	3.50	108.89
9	80% white bean flour	23	-	62.4	1.20	3.32	0.35	0.37	1.01	2.71	92.85
10	90%. white bean flour	20	-	66.7	0.98	2.02	0.37	0.40	0.79	2.17	76.35
11	white bean flour	19	-	63.8	1.07	3.20	0.43	0.44	0.61	1.98	73.11
12	100%		0.97	0.83	0.03	0.33	0.69	0.20	0.31	0.80	0.75
13	10% red bean flour	86	30.0	55.3	1.82	10.00	0.49	1.45	2 56	5.85	183 37
14	20% red bean flour	66	22.4	58.1	5.77	10.52	0.40	1.08	2.50	5.07	169.25
15	30% red bean flour	49	8.8	60.9	6.82	7.28	0.30	4.68	2.29	4.66	155.34
16	40% red bean flour	40	8.6	61.7	7.15	5.80	0.28	0.58	2.07	4.25	138.75
17	50% red bean flour	34	8.4	61.1	7.95	9.90	0.29	3.92	1.99	3.91	133.34
18	60% red bean flour	27	5.2	61.1	7.72	10.72	0.29	0.39	1.75	3.69	124.35
19	70% red bean flour	24	2.4	60.6	1.08	9.17	0.31	2.70	2.65	2.74	101.24
20	80% red bean flour	21	0.3	61.9	0.78	1.93	0.36	1.80	1.26	-	65.43
21	90% red bean flour	20	-	64.0	0.88	1.70	0.39	1.36	0.80	-	57.75
22	red bean flour	19	-	63.1	1.12	2.88	0.45	1.47	-	-	57.31
23	R		0.98	0.89	0.01	0.26	0.58	0.01	0.32	0.66	0.73

for the dough formation time ( $T_1$ ). It has been established that low stability negatively affects the baking process - the dough does not rise during proofing, but spreads. This is explained by the fact that the process of gas formation is associated with stability. Therefore, an increase in stability time also has a beneficial effect on the dough, providing a good rise of bread during proofing. This also confirms the beneficial effects of bean flour on baking properties, but to a certain ratio. The stability time decreases sharply with the addition of bean flour over 60%.

The moment of force during the liquefaction phase (C2) characterizes the process of activation of proteolytic enzymes, which leads to a decrease in the consistency of the dough due to the breaking of hydrogen bonds in protein molecules that bind protein molecular chains. Gluten protein degrades and dough liquefies. Moreover, the lower the moment C<sub>2</sub>, the higher the volumetric yield of bread. The correlation between the SDS-sedimentation indices and the C<sub>2</sub> moment is also significant (R = 0.69-0.58). The decrease in C<sub>2</sub> moment is also explained by a decrease in the amount of gluten-free gliadin and glutenin proteins of wheat with an increase in bean globulin proteins.

Moments of forces  $C_3$ ,  $C_4$ ,  $C_5$  characterize the carbohydrate-amylase complex of the studied system and the processes occurring in it. High autolytic activity, characterized by low values of  $C_3$ ,  $C_4$ ,  $C_5$ , ensures the formation of a finely divided crumb structure during baking. High values of  $C_4$  characterize weak enzymatic activity [9].

An increase in the amount of bean flour in the composite mixture also influenced the change in the  $C_3$  force moment, which characterizes the starch properties and amylolytic activity in the analyzed sample [7, 8]. But since the change in this parameter is spasmodic, and the dependence between the SDS-sedimentation indices and the  $C_3$  moment is insignificant (R = 0.20-0.01), then taking into account the available data, we can assume that varietal features of beans have a more significant effect on the gelatinization process.

It was also noted that an increase in the content of bean flour in the composite mixture, it provides a stable decrease in the moment of force characterizing the minimum  $C_4$  and maximum  $C_5$  consistency of the dough during the "starch retrogradation" phase, as well as decrease in the total energy consumed per batch. These parameters are highly correlated with indicators of SDS-sedimentation indices. This gives reason to believe that bakery and confectionery products produced from composite mixtures will be more resistant to staling, and, consequently, have longer shelf life.

# IV. CONCLUSION

SDS-sedimentation indices are highly correlated with the gluten content in the composite mixture, with water absorption capacity, the moment of force during the liquefaction phase ( $C_2$ ,  $N \cdot m$ ), with the moment of force characterizing the maximum consistency of the dough during the end of the "starch retrogradation" phase ( $C_5$ ,  $N \cdot m$ ) and with the energy absorbed in the process of dough formation (P, Wh/kg).

To a lesser extent, the SDS-sedimentation index correlates with the formation time ( $T_1$ , min) and the stability time ( $T_2$ , min) of the dough, the moment of force during the gelatinization phase ( $C_3$ ,  $N \cdot m$ ) and the moment of force characterizing the minimum ( $C_4$ ,  $N \cdot m$ ) consistency of the dough during the phase of "starch retrogradation".

Thus, using the less expensive SDS-sedimentation method, it is possible to evaluate with a high degree of certainty the effect of bean flour on the rheological properties of composite mixtures.

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