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The effect of bean flour addition on the rheological properties and baking quality of a triticale flour blends

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Abstract. The aim of this research work was to study and compare the main parameters of the rheological state of the dough made from triticale flour (a variety of George selection by the FSBIS Agricultural Research Institute of the South-East), dough made from flour of white and red bean seeds, as well as parameters of dough from flour of composite mixtures based on them. The rheological properties of the dough were determined using a Mixolab device according to the GOST ISO 17718-2015 method. The mixing ability of the blends was additionally tested by the SDS sedimentation method. It was found that the moment of force, which characterizes the gelatinization process, correlates well with the SDS sedimentation index. To a lesser extent, this indicator correlates with the values of the moments of force characterizing the process of 'starch retrogradation' and the energy intensity of the dough formation process. The water absorption capacity of flour highly correlates with the moment of force during the liquefaction phase and with the moments of force characterizing the minimum and maximum consistency of the dough during the 'starch retrogradation' phase. The correlation between the SDS sedimentation rate and water absorption capacity was found to be rather low. The rheological parameters were also significantly influenced by the type of beans. Taking into account the results of studies of the rheological state of the dough, test baking of bread with various mass fractions of components was carried out. The results obtained confirmed the improving effect of bean flour.

Key words: beans, triticale, composite mixtures, rheological properties, bakery qualities.

INTRODUCTION

One of the directions for creating functional products with an improved chemical composition is the development of multicomponent flour blends enriched with high-grade proteins, vitamins, minerals, and dietary fiber. The basis of such mixtures, as a rule, is cereal flour (mainly wheat and rye), which is supplemented with whole-ground or fermented flour, wheat germ, wheat bran, various types of cereal flakes, flax seeds, sunflower seeds, sesame seeds, and legume flour (mainly soybeans), etc. (Baturina & Muzalevskaya, 2010; Matveeva & Koryachkina, 2012). There is quite a large number of theoretical and experimental studies of the effect of the ingredients of composite mixtures on the carbohydrate-amylase and protein-proteinase complexes of such mixtures, on the basis of which new technologies for the production of bread with increased nutritional value have been developed. However, it is noted that, while possessing certain advantages, both wheat and rye have their own disadvantages, which include both the deficient amino acid composition of wheat and the low gluten capacity of rye. In this regard, triticale is a more promising crop as the basis of the composite mixture, which combines the best properties of its progenitors, wheat and rye, namely, a high protein content with its best amino acid composition. In this regard, Triticale flour is a more promising culture as the basis of a composite mixture combining the best properties of its predecessors, wheat and rye, namely the high protein content with its best amino acid composition. It is noted that due to the increased content of the most complete vegetable proteins, sugars, vitamins, macro - and microelements, grain triticale has a high biological value.It is noted that due to the increased content of the most complete protein substances, sugars, vitamins, fiber, macro- and microelements, triticale grain has a high biological value (Koryachkina et al., 2012; Matveeva & Koryachkina, 2016).

As an additional raw material in the production of functional bakery and flour confectionery products, it is proposed to use legumes, which, due to their unique biochemical composition, occupy a special place among food raw materials of plant origin. Due to the high content of protein, micro- and macro elements, as well as other equally important nutrients, they can be widely used as one of the main raw materials in the production of multicomponent flour mixtures (MFM) with a high content of plant protein, thereby compensating for the lack of animal proteins (Baturina & Muzalevskaya, 2010; Matveeva & Koryachkina, 2012).

Among all the variety of legumes, one of the most attractive crops, as an additional component for composite mixtures, is beans. The flour obtained from bean seeds has a high protein content and a balanced amino acid composition. The protein content ranges from 23.2 to 33.4%, essential amino acids vary from 8,384 to 12,147 mg, the predominant amino acids were leucine and lysine. In addition, it has a significant content of vitamins (thiamine, riboflavin, niacin, vitamin E). The total amount of ash is 2.6–3.7%, while the flour contains potassium, calcium, magnesium, sulfur, phosphorus, iron, copper, manganese Gorbatovskaya et al., 2015; Korshenko & Chizhikova, 2015). Thus, a composite mixture of triticale and bean flours is undoubtedly promising for creating functional bakery products.

Thus, a composite mixture of triticale flour and beans is undoubtedly promising for creating functional bakery products.

The aim of the research work was to study the effect of bean flour addition, on the rheological properties of dough from a composite mixture, to confirm the possibility of its use in bakery production. The impact was determined by establishing a correlation between the qualitative characteristics of composite flour from triticale with bean and the rheological properties of dough based on it. The objects of research were triticale flour of the promising selection line of the FSBIS Agricultural Research Institute of the South-East and whole-ground flour from white and red beans (GOST 7758-75), obtained by successive grinding of beans in the grinding mechanism of a multifunction kitchen machine (MKM) and a laboratory mill Quadrumat Junior (Brabender), as well as flour blends based on them in percentage ratio (triticale:bean): 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90.

MATERIALS AND METHODS

The rheological properties of the dough were determined using a Mixolab device (Mixolab, Chopin, France) according to the GOST ISO 17718-2015 method (GOST ISO 17718-2015et al., 2015). This device, based on the Chopin + protocol, in real time, measures the rotation moment in $N \cdot m$ (Nwm) that occurs between two kneading blades when mixing dough out of flour and water for several successive kneading phases due to different temperatures. This provides complete information that provides a comprehensive assessment of the technological properties of flour and objectively determines its intended use (Dubat & Risev, 2008; Kulevatova et al., 2017; Kazantseva et al., 2018).

The main parameters of the rheological state of the dough were analyzed, including water absorption capacity (WAC,%), stabilization time (T_2, min), moment of force during the liquefaction phase (C_2, $N \cdot m$), moment of force during the gelatinization phase, (C_3, $N \cdot m$), moments of force characterizing the minimum (C_4, $N \cdot m$) and maximum (C_5, $N \cdot m$) consistency of the dough during the phase of starch retrogradation, as well as the energy absorbed during the dough formation (P, $\frac{W \cdot h}{kg}$), which were compared with the indicators of the water absorption capacity for the flour of the initial components and composite mixtures.

In order to test the mixing ability of the composite mixture, we used the SDS sedimentation method (dodecyl sulfate sedimentation) modified by V.M. Bebyakina, M.V. Buntina (Bebyakin & Buntina, 1991).

The bread baking of flour blends was carried out in the laboratory of the FSBIS Agricultural Research Institute of the South-East according to the method of state crop variety testing of agricultural crops. During the research, we used composite mixtures based on triticale flour (TrF) and white bean flour (WBF) and red bean flour (RBF) in a ratio of 90:10; 80:20; 70:30; 60:40, 50:50, 40:60, 30:70. 20:80, 10:90. Experimental dough samples were prepared in accordance with the recipe for the unpaired method of laboratory baking with intensive dough kneading in fivefold repetition (Methodology… et al., 1991).

The correlation between the studied parameters was determined using Microsoft Excel programs. Critical values of the correlation coefficient (r) at 5% significance were identified by the method of V.M. Dospekhov (Dospekhov, 1985).

RESULTS AND DISCUSSION

The research results of the rheological properties of the dough and the correlation coefficients between them and the water absorption capacity are presented in Table 1.

The data obtained (Table 1) confirmed the effect of the content of bean flour in the flour blend on the rheological properties of the dough from composite mixtures based on triticale with white and red bean flour. At the same time, for all indicators, the correlation between water absorption capacity and rheological properties had a significant character (at a 5% significance level r = 0.553 (Dospekhov, 1985).

Table 1. Parameters of mixolabograms of dough made from blends of triticale (TrF) white bean flour (WBF) or red (RBF) bean flour

	Composite mixture, %	SDS Sedimentation Index, mm	BWAC, %	T_2, min	C_2	C_3	C_4	C_5	PA, $\frac{W \cdot h}{kg}$
					$N \cdot m$				
		On the basis of White bean flour (WBF)							
1	triticale flour 100%	40	55.8	2.5	0.38	1.15	2.38	4.83	123.88
2	TrF 90%+10% WBF	36	55.7	3.83	0.33	0.93	2.14	4.68	120.65
3	TrF 80%+20% WBF	35	54.7	3.80	0.36	0.96	2.42	5.26	132.80
4	TrF 70%+30% WBF	32	55.7	4.80	0.36	0.61	2.38	4.96	127.99
5	TrF 60%+40% WBF	30	55.3	5.00	0.34	0.50	2.44	5.16	129.29
6	TrF 50%+50% WBF	29	55.4	5.50	0.36	0.46	2.24	4.75	108.53
7	TrF 40%+60% WBF	29	58.4	3.60	0.37	0.45	2.00	4.26	108.02
8	TrF 30%+70% WBF	28	56.2	3.0	0.43	0.46	1.73	4.40	102.30
9	TrF 20%+80% WBF	29	57.2	7.63	0.47	0.53	1.58	4.25	99.09
10	TrF 10%+90% WBF	29	59.5	7.75	0.51	0.53	1.21	3.87	82.18
11	WBF 100%	28	61.6	5.95	0.48	0.50	0.76	2.59	56.50
12	SDS correlation coefficient	1.0	**0.25**	**0.01**	**0.24**	**0.95**	**0.32**	**0.25**	**0.35**
13	WAC correlation coefficient (*r*)	-	**1.0**	**0.23**	**0.58**	**0.18**	**0.84**	**0.92**	**0.85**
		On the basis of Red bean flour (RBF)							
1	triticale flour 100%	40	55.8	2.5	0.38	1.15	2.38	4.83	123.88
2	TrF 90%+10% RBF	37	56.4	3.33	0.35	0.99	2.23	4.24	114.80
3	TrF 80%+20% RBF	32	56.1	4.15	0.34	1.40	2.43	5.14	132.32
4	TrF 70%+30% RBF	30	56.9	4.18	0.31	0.67	2.29	4.25	112.39
5	TrF 60%+40% RBF	27	54.7	4.73	0.29	0.44	2.24	4.48	113.20
6	TrF 50%+50% RBF	26	55.3	4.48	0.30	0.45	2.15	4.14	108.53
7	TrF 40%+60% RBF	25	56.1	4.87	0.31	0.46	1.90	4.06	100.49
8	TrF 30%+70% RBF	24	56.1	2.87	0.32	0.45	1.75	3.27	79.74
9	TrF 20%+80% RBF	25	57.7	3.55	0.37	0.42	1.22	2.10	52.72
10	TrF 10%+90% RBF	25	59.4	3.55	0.43	0.47	1.03	2.0	45.84
11	RBF 100%	24	56.9	3.0	0.46	0.53	0.65	0.02	29.84
12	SDS correlation coefficient	1.0	**0.07**	**0.07**	**0**	**0.58**	**0.36**	**0.39**	**0.43**
13	WAC correlation coefficient (*r*)	-	**1.0**	**0.09**	**0.45**	**0.03**	**0.45**	**0.47**	**0.46**

It was found that with the increase in the amount of bean flour in the flour blend from 10 to 90%, the SDS-sedimentation indicator steadily decreases from the maximum to the minimum value (1.24 for WBF and 1.48 for RBF). Moreover, this indicator is highly correlated with the moment of force C3, which characterizes the gelatinization process. Since the SDS Sedimentation Index is a measure of the quality and quantity of gluten, therefore, increasing the bean flour content in the composite mixture is guaranteed to reduce the amount of gluten.

In addition, with the increase in the amount of bean flour in the composite mixture from 10 to 90%, the water absorption capacity increases by 6.4% (from 55.7% to 59.5%) when using white bean flour and by 5.1% (from 56, 4% to 59.4%) when using red bean flour. This confirmed the previously obtained data on the effect of morphological features of bean products addition on the water absorption capacity (Maradudin & Simakova, 2019; Simakova et al., 2019).

The change in the content of bean flour in the composite mixture affected the stabilization time (C_2), however, since this parameter changed abruptly, the correlation dependence between the WAC parameters and the stabilization time was not significant. Moreover, up to a certain ratio (60:40) of the components, the stabilization time increased (for both white and red beans), and then this indicator decreased. It is known that increasing the stabilization time has a positive effect on the dough, providing a good rise in the bread during proofing. Therefore, it can be expected that increasing the content of bean flour in the composite mixture in the range of 40–50% will not significantly reduce the rise of the baked goods.

The correlation between water absorption capacity and moment of force during the liquefaction phase (C_2) (r = 0.58 and r = 0.45) was more significant. This parameter characterizes the process of activating proteolytic enzymes, leading to a decrease in the consistency of the dough due to the rupture of hydrogen bonds in the protein molecules that hold the protein molecular chains together. Degradation of gluten proteins and liquefaction of the dough occurs. Moreover, the lower the moment C_2 is, the higher the volumetric bread yield becomes. Since in our case the opposite process was observed, we can expect a decrease in the volumetric yield of baked products as the content of bean flour in the flour blend increases.

The increase in the amount of bean flour in the composite mixture affected the change in the moment of force (C_3), which characterizes the properties of starch and amylolytic activity in the analyzed sample (Gorbatovskaya et al., 2015; Korshenko & Chizhikova, 2015). High values of C_3 characterize a weak enzymatic activity, and low values, on the contrary, characterize high enzymatic activity (GOST ISO 17718-2015 et al., 2015).

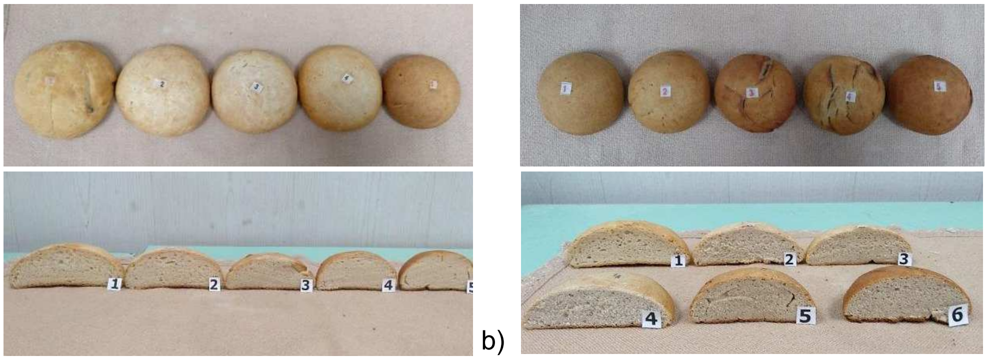
However, since the change in this parameter had an abrupt character, and the relationship between the water absorption capacity and the moment C_3 is insignificant (r = 0.18 and r = 0.03), then, taking into account the available data, it can be assumed that the varietal characteristics of beans have a more significant influence on the gelatinization process. This is indicated by a high correlation between the sedimentation index and the moment C_3 (r = 0.95 and r = 0.58).

It was also noted that the bean flour content increase in the composite mixture affects the change in the moments of force characterizing the minimum (C_4) and maximum (C_5) dough consistency during the 'starch retrogradation' phase. However, this impact is ambiguous due to the varietal characteristics of the beans.

The moments of force at the extremum points C_3, C_4, C_5 characterize the carbohydrate-amylase complex of the studied system and the processes occurring in it. Low values of these parameters, characterizing high autolytic activity, ensure the formation of a finely dispersed crumb structure during baking. Bakery and confectionery products obtained from composite mixtures with low values of the C_5 moment are distinguished by greater resistance to staleness, and, therefore, increased shelf life. However, for composite mixtures based on triticale, with the bean flour content increase in the mixture from 10% to 40%, the increase in the moments of force is observed from the minimum to the maximum value. With a subsequent increase in the content of bean flour in the mixture, the C_5 moment decreases. In a smoother mode, bean flour content is 80%. When there is a sharper decrease, a further increase of bean flour content to 90%

is observed. This indicates a more complex interaction of the protein-carbohydrate complex of triticale and beans, and the need for a deeper study of these systems.

The results of triticale-bean bread baking test (Fig. 1, a; b) are shown in Table 2.



a) b)

Figure 1. Samples of test bread baking from composite mixtures with different mass fractions of components: a) with the use of white bean flour (WBF); b) with the use of red bean flour (RBF).

Table 2. Selected quality indicator of flour-blend and bread made from flour blends based on triticale flour and white bean flour (WBF) and red bean flour (RBF)

No.	Bean flour content in mixture	SDS Indicator, mm	Weight of loaf, g	Diameter, mm	Height of a loaf, mm	Ratio, H d^{-1} cm^3	Loaf volume	Porosity, points	Acidity, degree
1	TrF 100%	40	134.5	125.0	47.0	0.38	410	4.8	3.0
2	10% WBF	36	137.6	111.3	45.0	0.40	350	4.6	2.2
3	20% WBF	35	137.8	107.7	40.0	0.37	300	4.4	2.9
4	30% WBF	32	138.0	103.3	44.3	0.43	275	4.1	3.1
5	40% WBF	30	138.2	140.0	43.7	0.31	270	4.0	3.7
6	50% WBF	29	150.2	95.2	41.7	0.44	260	4.0	2.5
7	60% WBF	29	149.1	92.3	44.0	0.48	270	4.0	2.9
8	70% WBF	28	152.2	90.4	46.3	0.51	270	4.0	3.6
9	80% WBF	29	152.4	91.2	49.0	0.54	270	3.8	3.2
10	90% WBF	29	151.8	89.3	51.7	0.59	280	3.8	3.5
11	100% WBF	*28*	155.7	91.0	52.0	0.57	295	3.5	3.3
	R. correlation coefficient	1.0	**0.71**	**0.34**	**0.08**	**0.37**	**0.80**	**0.21**	**0.21**
1	TrF 100%	40	134.5	125.0	47.0	0.38	410	4.8	3.0
2	10% RBF	27	137.0	116.0	42.0	0.36	380	4.8	3.4
3	20% RBF	32	137.4	113.3	39.7	0.35	355	4.8	3.3
4	30% RBF	30	138.8	110.0	33.7	0.31	300	4.6	3.7
5	40% RBF	27	140.3	94.7	39.0	0.41	255	4.3	3.9
6	50% RBF	26	141.9	94.7	38.3	0.40	220	4.3	4.2
7	60% RBF	25	145.4	86.0	43.0	0.50	220	4.0	3.4
8	70% RBF	24	146.0	85.3	42.0	0.49	225	4.0	3.0
9	80% RBF	25	146.6	82.2	45.0	0.54	220	4.0	3.6
10	90% RBF	25	148.0	82.1	47.0	0.57	220	3.8	4.0
11	100% RBF	24	148.1	83.0	48.0	0.58	250	3.8	4.8
	R. correlation coefficient	1.0	**0.67**	**0.73**	**0.0**	**0.37**	**0.67**	**0.58**	**0.23**

Table 2 data show that the ratio of flour triticale and flour beans significantly affects the bakery properties of the composite mixture. Moreover, the qualitative characteristics of baked bread samples are well correlated with an indicator of SDS-sedimation (for weight R = 0.67, for the diameter R = 0.73, for the volume R = 0.67 and for porosity R = 0.58). With the increase of bean flour amount in the composite mixture from 10 to 90%, an increase in weight, height and the ratio of height to diameter of the baked loaves is observed. At the same time, the decrease in the SDS-sedimentation index is proportional to the diameter, volume and porosity of the baked loaves decrease. This indicates a significant effect of bean flour on the protein-proteinase complex of the composite mixture.

CONCLUSIONS

The improving effect of bean flour lies in the fact that even with a high mass fraction of bean flour in the composite mixture (60–100%), it was possible to obtain a full rheological profile of this system, which indicates the preservation of the optimal dough structure. In addition, dosed use of bean flour as a component in a flour composite mixture or a complete replacement of triticale flour with bean flour, increasing the protein content in bakery, pasta and confectionery products, allows one to influence the shape stabilization of the final product:

– when the content of bean flour in the mixture is up to 10%, the stabilization time changes insignificantly, therefore, the shape and volume of bakery products (tin bread) will not change significantly either;

– when the content of bean flour is up to 50%, the stabilization time increases 2.2–1.8 times, which indicates a more significant effect on the shape stabilization of the final product, and, therefore, such mixtures can be recommended for functional food products, for which he content of the final product is more important than its shape;

– when the content of bean flour is more than 70%, the stabilization time is reduced 3–4 times, and, therefore, such mixtures can be used for low-gluten food products of functional purpose with an unfixed shape.

At the same time, a significant difference in the tendencies of changes in the rheological properties of the dough made from composite mixtures with triticale, in comparison with the rheological properties of the dough based on wheat, indicates a more complex interaction of the components that requires a more careful research study.

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