Rheological properties of wheat dough with the addition of green buckwheat flour

Sergey Gur'ev[1*], *Vera* Ivanova[1], Vyacheslav Korovyansky[1], Alexander Novichenko[1], and *Ilia* Kostin[2]

[1]ITMO University, 191002 Saint-Petersburg, Russia
[2]Baltic State Technical University «VOENMEH» named after D.F. Ustinov, 190005 Saint-Petersburg, Russia

Abstract. Bread is the most affordable products in the world. In addition, bread and bakery products have high indicators of nutritional and biological value. The most important direction in this sphere, according to experts, is the enrichment of bakery products with proteins, essential amino acids, and various macro- and micronutrients. At the same time, it is important that the final product has high quality, attractive consumer properties and can be effectively sold in retail chains. Rheological studies make it possible to judge the characteristics, quality and prospects of obtaining bakery products. To the date, there is not enough information about the effect of green buckwheat flour additives on the rheological parameters of dough semi-finished products. The solution of this problem formed the basis of the study. According to the conducted research, it is optimal to introduce up to 10% of green buckwheat flour into the dough semi-finished product. In these dosages, green buckwheat flour does not have a negative effect on the rheological properties of the dough. Therefore, the resulting mixture can be used for standard bread production technologies. In addition, the addition of green buckwheat flour in the quantities described has a positive effect on the farinograph quality number, the stability of the dough and the degree of softening of the dough compared to the check sample.

1 Introduction

Bread is the most affordable products in the world. In addition, bread and bakery products have high indicators of nutritional and biological value.
They are able to provide the body with complex carbohydrates (starch and dietary fiber), protein, vitamins of group B. Bread is one of the most popular components of the consumer basket. Therefore, the improvement of the quality and composition of bread has a positive effect on the nutritional quality of broad population groups and allows them to satisfy their need for nutrients. The most important direction in this area, according to experts, is the enrichment of bakery products with proteins, essential amino acids, and various macro- and micronutrients [1-3]. In addition to the direct impact on the nutritional quality of the

* Corresponding author: sergeygurev@gmail.com

population, products enriched with these substances cause increased demand from consumers [4].

It is important that the final product has high quality, attractive consumer properties and can be effectively sold in retail chains.

Green buckwheat flour is a product obtained from peeled buckwheat groats that have not undergone hydrothermal treatment. The absence of hydrothermal treatment allows you to preserve a significant part of the vitamins and biologically active substances of buckwheat, which are lost during heat treatment. Green buckwheat has a high content of antioxidants (including flavonoids and catechins, which protect the product from oxidation). In addition, green buckwheat is rich in B vitamins and vitamins E and P,and inositol. Inositol is a vitamin. This substance that contributes to the normalization of metabolic processes of the body [5].

Thus, taking into account the unique composition of the studied flour from green buckwheat, we can talk about the expediency of using it for the preparation of preventive and functional products. It can be assumed that in the composition of bakery products, green buckwheat flour will contribute to an increase in nutritional value and antioxidant activity.

Rheological properties of dough semi-finished products make it possible to evaluate their behavior in technological processes and predict the quality of the finished product. A number of important rheological characteristics of the test include extensibility, dough tenacity and water absorption capacity. All of these indicators directly affect the quality of the product and its consumer properties. The study of the rheological properties of wheat dough with the addition of various types of flour attracts the attention of many scientists around the globe.

Researchers from Turkey studied mixtures of wheat and wheat bran hydrolysates. The results of this study showed the addition of the hydrolysate obtained at 150 °C hydrothermal treatment to dough had a positive effect on its rheological properties [6].

Slovak researchers have determined the rheological properties of wheat flour dough with the addition of quinoa flour. According to the available data, it was found that the addition of quinoa flour up to 5.0% by weight to wheat flour does not significantly worsen the rheological properties of the dough, but provides increased nutritional value of finished bakery products [7].

Rheological studies have shown the effect of barley and barley components on the rheological properties of wheat dough with the addition of starch. The researchers concluded that the combination of a large number of non-starchy polysaccharides and the properties of barley starch increased the durability of the dough. Non-starch polysaccharides improve dough elasticity by forming elastic networks and weak secondary bonds with other carbohydrates and proteins However, it was noted that further studies were needed to assess the effect of barley on the general baking characteristics of wheat-barley mixtures [8, 9].

Rheological studies make it possible to judge the characteristics, quality and prospects of obtaining bakery products. To date, there is not enough information about the effect of green buckwheat flour additives on the rheological parameters of test semi-finished products. The task to expand this area of knowledge formed the basis of this study.

2 Objects and methods of research

In this paper, researched objects are test samples of semi-finished products from a mixture of wheat flour and green buckwheat flour.

To determine rheological properties of the dough, a number of indicators were determinated, studied using farinograph, alveograph, amylograph and rheofermentometer. This indicators are the water absorbtion of flour, %; dough development time (DDT),min; dough stability (S), min; degree of softening (DS), FU; farinograph quality number (FQN), mm; begin of gelatinization, °C ; gelatinization point, °C; gelatinization maximum, AU; baking strength (W), ·10-4; dough tenacity (P), mm H2O; dough extensibility (L), mm, and

the falling number characterizing the activity of amylolytic enzymes of flour was also determined according to GOST ISO 7973-2013 Cereals and cereal products.

Farinographic studies were carried out with farinograph AT Brabender (Germany). The research process looks like this. The example of studied flour gets into dough mixer, in which an example is mechanically affected by agitator blades. Depending on the degree of viscosity, the product resist, which is measured by means of sensors and recorded as a farinogram. As a result of the test, the values of water absorption, dough development time, dough stability, degree of softening and farinograph quality number are recorded.

Chopin Alveograph (France) was used to determine the elastic properties of dough. The operation of the device is as follows. The dough, formed after kneading in the form of a round plate, is placed on the device table and, under the pressure of the incoming air, is stretched into a bubble until it breaks. The increase in the volume of the expanded bubble before rupture is recorded by a manometer. The peak height determines the dough resistance to expansion. Length of curve determines an indicator of dough extensibility and gas-retaining ability of the dough.

Amylolytic activity was determined on a Brabender amylograph (Germany) according to GOST ISO 7973-2013 Cereals and cereal products. The test is carried out with an increase the suspension temperature by 1.5°C/min, corresponding to an temperature increase of the bread during the baking process, simulating the technological process in production.

The gas release of test semi-finished products was determined using a Chopin rheofermentometer (France) using the method described in the manual for using the device

As a basis for studying the effect of adding green buckwheat flour, we used premium wheat backing flour produced by Saint-Petersburg Milling Plant JSC and green buckwheat flour produced by Garnec Development LLC. The mixture was prepared by replacing wheat flour with 5, 10, 15 and 25% of green buckwheat flour by dry substances. The control was a sample of wheat flour without additional.

Organoleptic analysis of flour was carried out according to GOST 26574-2017 “Baking wheat flour. Specifications".

Titratable acid was determined in accordance with GOST 27493-872 “Flour and bran. Method for determining acidity by mash.”

Flour moisture was determined by express analysis on a Shimadzu moisture analyser at 160°C.

3 Results and discussion

The quality indicators of premium backing wheat flour and green buckwheat flour were studied in accordance with the current regulatory documents (table 1)

Table 1. Flour quality indicators

Name of indicator	**Kind of flour**	
	Premium wheat backing floar produced by Saint-Petersburg Milling Plant JSC	**Buckwheat flour produced by Garnec Development LLC**
Color	White	Grey
Aroma	characteristic of this type of flour, odorless, fresh, not musty, without dampness, not moldy	

Taste	characteristic of this type of flour, without foreign flavors, not sour, not bitter	
Mass part of moisture, %	14.4	10.4
Presence of mineral impurity	the crunch when chewing flour is not felt	
Acidity, degrees of acidity	0.8	3.2
Falling number, s	327	Not defined

Table 1 shows that wheat flour according to the Russian state standard. There are no state standards in Russia for green buckwheat flour, however, the test sample has indicators characteristic of this type of flour. The falling number of green buckwheat flour is not determined due to the increase in the volume of the suspension during heating, which prevents dough.

3.1 Determination of rheological properties of test semi-finished products using a farinograph

Studies of flour mixture using a farinograph makes it possible to evaluate water absorption and rheological characteristics of dough semi-finished products.
The formation of the structure of dough semi-finished products is based on hydration (water absorption) and structure formation. Structure formation is the result of the formation of intermolecular disulfide bonds between gluten proteins, followed by the development of a gluten network that is responsible for binding starch and other flour components. [10].
The time of dough formation characterizes the end of the process of forming the dough structure. Subsequent mechanical processing leads to a gradual softening of the dough.

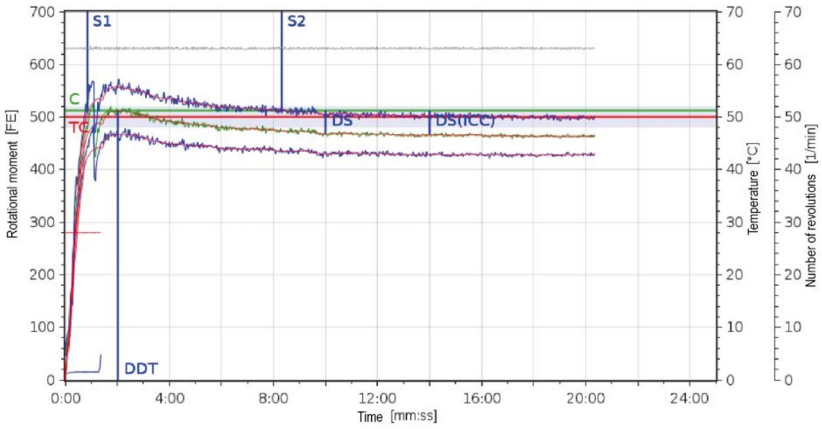

Fig. 1. Farinogram of dough product from wheat premium backing flour (check sample).

The changes described above occurring in the test can be visualized using farinograms. It is also worth noting that a typical farinogram of wheat flour (figure 1), without adding additional ingredients, has one peak [10, 11].

The results of studies of dough semi-finished products on a farinograph are shown in Table 2.

Table 2. Quality indicators of test semi-finished products from wheat flour and green buckwheat flour according to the Farinograph-TS

Content of green buckwheat flour mixed with wheat premium backing flour, %	0	5	10	15	25
Water absorption of flour, %	57.7	57.4	56.9	56.8	57.1
Dough development time DDT, MIN	2:01	2:48	3:12	2:01	1:35
Dough stability S, min	10:30	13:31	12:00	8:54	7:16
Degree of softening 10 minutes after the start DS, FU	33	21	21	33	40
Degree of softening 12 minutes after maximum DS (ICC), FU	41	33	37	52	51
Farinograph quality number FQN, mm	83	135	122	94	78

The data obtained from Table 2 indicate that the addition of green buckwheat flour entails a change in all rheological parameters of dough semi-finished products. A change in the time of dough formation was noted, i.e., the time from the beginning of the introduction of water into the mixer chamber of the device to the first signs of a decrease in the dough consistency.

Dough development time is the duration of time at which swelling of flour particles occurs to obtain maximal dough consistence. The maximal value 3:12 min of this indicator was noted in sample with 10% of green buckwheat flour relative to the value 2:01 min of the check sample. These results may be the consequence of a higher percentage of fat and protein in the green buckwheat flour [4].

Consequently, it was found that the partial replacement of wheat flour with green buckwheat flour leads to an increase in the dough stability during kneading. Stability has improved when we added from 5% to 10% green buckwheat flour. Obviously, the structure of the gluten framework with a large amount of the green buckwheat flour. Thus, dough stability decreased.

The degree of softening in 10 and 12 minutes (according standard ICC) after the start of kneading in the samples with 5-10% of green buckwheat flour was lower, then in the check sample. This indicated an improvement in rheological dough properties.

Consequently, it was found that adding up to 10% of green buckwheat flour in check sample improve the quality of the dough. Adding green buckwheat flour in large quantities led to decrease in the quality number, which is explain by the lack of gluten in the green buckwheat flour.

It was found that adding green buckwheat flour in dosages of 5% and 10% increased S (dough stability at 3:01 and 1:30 min) and FQT (farinograph quality number by 52 and 39 respectively). However, these indicators were set to the value of check sample and lower, when the concentration of green buckwheat flour increased.

The water absorption of flour depends on the grinding, the integrity of the starch grain, the strength of gluten, proteins, dietary fibers, and other factors [10, 12, 13]. Analysing the data, it can be noted that the added green buckwheat flour has a nigligible effect on the water absorbtion of the mixture.

The sample with 5 % of green buckwheat flour has the best farinograph quality number.

3.2 Determination of rheological properties of test semi-finished products using amilograph

Table 3 shows the results of amylogram processing.

Table 3. Quality indicators of test semi-finished products from wheat flour and green buckwheat flour according to the Amilograph-E

Content of green buckwheat flour mixed with wheat premium backing flour, %	**0**	**5**	**10**	**15**	**25**
Begin of gelantinization, °C	61.1	60.9	61.1	62.1	60.0
Gelantinization point, °C	76.8	77.1	78.6	79.6	79.3
Gelatinization maximum, AU	445	485	526	627	902

Amylograph-E provides reliable and reproducible data on the activity of enzymes (α-amylase) in flour and coarse products. Consequently, the values that we obtain on the Amylograph-E help us to obtain reliable information about the gelatinization process and the state of the amylolytic complex of enzymes in the flour mixture. Based on these data, it is possible to judge the baking properties of flour and control the addition of, baking malt or enzyme preparations.

The table 3 shows, that the adding of green buckwheat flour entailed an increase in the maximum gelatinization index on the amylograph. This confirms the data that buckwheat carbohydrates are mainly complex (cellulose, non-starch polysaccharides and lignans) and resistant to amylase. In addition, depending on the hydrothermal (steam) treatment, buckwheat contains from 7 to 37% resistant starch [14-16].

3.3 Determination of rheological properties of test semi-finished products using alveograph

Table 4 shows the results of alveogram processing.

Table 4. Results of alveographic studies

Content of green buckwheat flour mixed with wheat premium backing flour, %	0	5	10	15	25
W, *10-4 (Baking strength)	320	249	214	192	139
P (Dough tenacity), mm H2O	104	93	86	85	82
L (Dough extensibility), mm	95	84	83	75	52
P/L	1.09	1.11	1.04	1.13	1.58

According to the results of alveographic studies in a sample with 25% of green buckwheat flour, a decrease in the L index (extensibility) by 45.3% was noted, with a decrease in the P index (tenacity) by 21.2%. As a result, the P/L index (the ratio of tenacity to extensibility) increased by 45%, and W (baking strength) decreased by 56.6%. A linear decrease in the W index (baking strength) in combination with a decrease in L (extensibility) indicates a significant weakening of the gluten framework of the dough.

3.4 Determination of gas emission indicators of test semi-finished products

Table 5 show the results of the study of test semi-finished products on a rheofermentometer.

Table 5. Results of gas emission studies of test semi-finished products

Content of green buckwheat flour mixed with wheat premium backing flour, %	0	5	10	15	25
Maximum lifting height of wheat dough under load, mm	43.2	46.1	43.1	39.9	42
Time of maximum gas release, hh:mm:ss	02:30:00	02:55:30	02:57:00	03:00:00	02:24:00
Time of pore formation, hh:mm:ss	01:09:00	00:54:00	00:43:30	00:51:00	00:49:30
Gas release volume, ml	1438	1623	1735	1614	1871
Gas retention volume, ml	1167	1257	1296	1228	1324
Retention coefficient, %	81.1	77.4	74.7	76.0	70.8

Table 5 shows that the addition of green buckwheat flour to the dough increase gas release and the volume of retention CO2, despite the reduced retention coefficient at the same dough volume. Increased gas release may be a consequence of large number of sugars in green buckwheat flour (more than 2,6 times than in wheat flour) [1].

In addition, the time reduction of pore formation in the dough was noted during the experiment. This change may be due to the increased yeast activity in the mixture, and a decrease in the amount of gluten in the mixture.

4 Conclusion

The results of the study showed that the replacement of wheat flour in the semi-finished dough with green buckwheat flour leads to significant changes in the properties of the dough. The addition of green buckwheat flour as a substitute for wheat flour led to an increase in the maximum of gelatinization from 445 to 902 units of amylograph. However, addition 10% of green buckwheat flour increased this number to 526 units of amylograph. The alveograph shows a decrease in the baking strength of flour.

When adding green buckwheat flour in an amount of up to 10% instead of wheat flour, the following indicators changed: degree of softening decreased by 4 EF and the dough stability increased by 1:30 minute. Therefore, we could note that rheological properties were improved.

The dough degree of softening was increased and the dough stability was decreased with an increase the amount of green buckwheat flour in the mixture.

Also, the volume of retention CO2 and released CO2 in the dough semi-finished products increased and the pore formation time was reduced by more than 20 minutes when adding green buckwheat flour in an amount of up to 10%.

According to the research results, it is possible to recommend to addition up to 10% of green buckwheat flour into wheat dough without adversely affecting the technological parameters of the dough.

It is reasonable to continue further research in the direction of studying the effect of green buckwheat flour on the properties of dough semi-finished products during their fermentation and proofing, and on finished products.

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