Study of the relationship between the quality indicators of flour and its technological properties

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Abstract. This work aimed to study the quality indicators and technological properties of rye and wheat flour. 24 samples of wheat flour and 18 samples of rye flour obtained from different milling companies located in Russia were assessed. No correlation between protein content and wheat gluten quality was found. 5 samples of wheat flour containing 10-10.3% of protein had good quality gluten, while wheat flour containing 11% and 12.7% of protein had satisfactory weak gluten. At the same time, in 5 samples of flour containing 10.3% protein, both gluten of good quality and unsatisfactory weak gluten were found. Only 3 from 18 samples of rye flour met the requirements of the standards for the studied quality indicators. Fifteen samples of rye flour had increased ash content (higher than 1.45%). Two samples of rye flour had increased enzymatic activity and one sample had reduced enzymatic activity. Additives with an alkaline reaction were found, which were used to adjust the baking properties of the flour of these samples.

1 INTRODUCTION

Flour of different grade differs in chemical composition due to its yield during grain grinding. Flour yield is the amount of flour obtained from 100 kg of grain, expressed as a percentage of the grain mass. The higher flour yield means the higher content of proteins, fats, total sugar, fiber, pentosanes, and the lower starch content. The chemical composition of flour affects its baking properties.

For wheat flour, the quality of its proteins is of great importance. Flour of the highest grade from soft wheat contains an average of 10.3% of protein and flour of the first grade contains an average of 11.1% of protein [1]. The content of protein substances in flour, its composition, state and properties are of high importance, as it determines not only the bread nutritional value but also the baking properties of wheat flour [2, 3].

For the process of bread making, the most important part of wheat flour protein is gluten, because it affects dough water-absorbing capacity, cohesiveness, viscosity and elasticity. Gluten is a complex of insoluble in water flour protein substances capable of forming a cohesive elastic mass when swollen in water. The composition of gluten varies and depends on the varietal and natural properties of wheat. Gluten proteins can be divided into two main fractions according to their solubility in aqueous alcohols: the soluble gliadins and the insoluble glutenins [4-7].

The raw gluten content in flour is the ratio of the weight of washed raw gluten to the weight of the sample of flour, expressed as a percentage. In Russia, the amount of raw

gluten for the flour of the highest grade should exceed 28% and for the first grade flour it should exceed 30% [7].

The quality of gluten is a characteristic determined by a combination of rheological properties (extensibility, elasticity) [2- 5].

The direct relationship between the content of protein substances and gluten in wheat flour was reported earlier [3, 8]. The higher is the protein content in the flour, the higher the amount of gluten is. The higher gluten content in the flour results in better rheological properties and stronger flour. The higher protein content in the flour results in the denser and stronger structure, lower proteinase activity in the flour, stronger flour and better and more stable rheological properties of the dough [2, 3, 8].

The protein and gluten content is an important indicator. For different types of baking, flour with different gluten content and quality is used. Flour with a low protein content and weak gluten should be used for the confectionery products (cookies, waffles). It is also recommended to use flour with a content of 28-32% with satisfactory weak gluten for the biscuit [3, 8].

Studies conducted in the St. Petersburg branch of the State Research Institute of the Baking Industry in recent years have shown that information on the protein content indicated by the manufacturer on the label does not always guarantee the good baking properties of flour.

The quality of rye flour also directly depends on its chemical composition. The indicators of the baking properties of rye flour include those that characterize the state of its carbohydrate-amylase complex.

In accordance with the Russian State Standard (GOST 7045-2017 “Baking rye flour, technical specifications”), peeled rye flour must have the following quality indicators: moisture content - no more than 15%, ash content - no more than 1.45%, the falling number (FN) not less than 150 s.

The use of peeled rye flour with increased (FN less than 150 s) or reduced (FN more than 250 s) enzymatic activity worsens the quality of sourdoughs and bread. It was established that the flour having good quality indicators does not always ensure the good quality of sourdough, brews and bread during the technological process. And only the investigation of additional indicators allows identifying the cause of these problems [3].

The use of flour with unsatisfactory baking properties worsens the organoleptic and physico-chemical indicators of bread. Therefore, it is extremely important that flour quality indicators comply with certain requirements, either of the State regulatory documents or established by the enterprise. Of particular importance is the stability of flour quality indicators during bread production on automated technological lines.

The aim of this research was to study the quality indicators and technological properties of rye and wheat flour from Russian milling companies.

2 MATERIALS AND METHODS

2.1 Wheat flour assessment

24 samples of wheat flour and 18 samples of rye flour obtained from different milling companies located in Russia were used in this study.

The protein content in rye and wheat flour was determined by the Kjeldahl method [9]

The wet gluten content in wheat flour and gluten quality were determined according to the Russian Standard [10]. The amount of gluten was determined in the following way. Dough was mixed with 25 g of flour and 14 g of water, and then it was held for 20 min for hydration and the formation of intra- and intermolecular bonds in substances forming gluten (gliadin and glutenin). Crude gluten was washed by a working body of the

mechanized device MOK-1M (Mototeh, Russia) using water to remove water-soluble substances, starch and brans from the dough. The obtained gluten was weighed and the percentage of crude gluten was calculated relative to the mass of the analyzed flour sample.

The gluten quality was determined as the deformation index of raw gluten under the influence of a load (120 g) for 30 s using the IDK-3M device (Plaun, Russian). The results were expressed in units of the IDK device.

According to the Russian State Standard [10], the gluten quality is divided into the following groups: unsatisfactory strong (less than 32 units of the device), satisfactory strong (33- 52 units of the device), good (53-77 units of the device), satisfactory weak (78 -102 units of the device), unsatisfactory weak (more 103 units).

2.2 Rye flour assessment

In the studies, samples of only peeled rye flour were used, since it occupies 85-90% of rye flour in Russia.

Moisture content in rye flour was determined by drying it at a temperature of 130°C for 40 minutes in drier (SHS-1M, Russia) [11]. Acidity was determined by titration, using the 0.1 N. solution of NaOH (the Russian State Standard, 1996) [12]. The FN was determined according to ICC approved method 107/1 (1995) [13]. The ash content was determined according to ICC approved method 104/1 (Determination of Ash in Cereals and Cereal Products) [14].

The content of water-soluble substances in flour was determined according to the Russian State Standard GOST 27495-87 [15]. 1.0 g of flour was mixed with 10.0 ml of distilled water, heated in a boiling water bath for 15 minutes with constant stirring. At the end of gelatinization, 20.0 ml of distilled water was added, then vigorously stirred and cooled to room temperature. Further water was added to the flask (until weight of 30.0 g), stirred with a stick (until foam appears) and filtered. When filtering, the first two drops were discarded, and the next 2-3 drops were applied to the refractometer prism.

The samples were examined on a refractometer. The amount of water-soluble substances in the flour was recalculated per dry matter (in %), taking into account the moisture content of the flour.

The enzymatic activity of rye flour was assessed by amylogram height, gelatinization start temperature and maximum viscosity using the Amylograph (Brabender GmbH & Co).

2.3 Flour brew assessment

The content of reducing sugars in self-saccharified brews was determined at the beginning and after 2 hours of saccharification at a temperature of 45 °C by the Bertrand permanganate method and expressed in % per dry matter in terms of maltose [16]. Flour and water ratio was 1:2.5. 10% of the total amount of flour in the brew was added for saccharification after gelatinization.

Moisture content in brew was determined by 40 minutes drying at a temperature of 130 °C in the drier (SHS-1M, Russia). Acidity was determined by titration with sodium hydroxide solution in the presence of the phenolphthalein indicator and expressed in degrees [17].

2.4 Statistical analysis

All experiments were carried out three times. Statistical processing was performed using the Excel software. The effects of the different factors were compared using a method with significance testing at the 95% confidence level. The differences between means were determined using the least significant difference and Duncan's two-factor analysis of variance test with one repetition (ANOVA). Results were given as mean value ± standard deviation.

3 RESULTS

3.1 Wheat flour assessment

It was found that flour samples containing lower amount of protein (10%) had both good quality gluten (samples 1, 2) and satisfactory weak gluten (sample 6). Samples of flour containing 10.3% of protein had both good quality gluten (samples 4, 7) and unsatisfactory weak gluten (samples 11, 12). The flour containing 11% of protein (sample 10) and 12.7% protein (sample 22) had satisfactory weak gluten.

3.2 Rye flour assessment

Analysis of data presented in Fig. 1 showed that about 83% of samples (fifteen out of eighteen) of rye flour did not comply with the Standard GOST 7045-2017 in terms of ash content. The excess of the ash content ranged from 0.7% in the sample 8 to 40.7% in sample 12.

The falling number was assessed (Fig. 2). Samples 1, 15 and 17 had low baking properties. Samples 1 and 15 had increased enzymatic activity and sample 17 had low enzymatic activity. In other samples, FN ranged from 177 s (sample 10) to 241 s (sample 18). FN was determined only once out of three times in sample 13. In other times, the stirrer rod did not fall, because the gelatinized water-flour suspension foamed and poured out of the test tube, pushing out the cap and the stirrer rod. This indicates that additives have been added to the flour to adjust its baking properties.

It was found (Fig. 3), that sample 15 had a very high acidity (7.6 degrees), and samples 1, 11, 13 had very low acidity (lower than 2.0 degrees). Water-flour suspensions of these samples (1, 11, 13) had a yellow tint and, when phenolphthalein was added, turned pink before titration. Acidity in other samples was from 2.8 degrees (sample 2) to 3.9 degrees (sample 6).

Table 1. Wheat flour characteristics

⊢ e	Protein content, %	Wet gluten content,%	IDK, u.d.	Gluten quality
Wheat flour of the highest grade				
1.	10.0 ± 0.3^{a}	28.0 ± 0.4^{a}	65 ± 1^{a}	good
2.	10.0 ± 0.3^{a}	27.8 ± 0.3^{a}	65 ± 1^{a}	good
3.	10.5 ± 0.2^{b}	28.2 ± 0.4^{a}	50 ± 1^{b}	satisfactory strong
4.	10.3 ± 0.4^{a}	30.6 ± 0.3^{b}	65 ± 1^{a}	good
5.	10.3 ± 0.4^{a}	29.8 ± 0.4^{c}	65 ± 1^{a}	good
6.	10.0 ± 0.3^{a}	21.6 ± 0.5^{d}	80 ± 1^{c}	satisfactory weak
7.	10.3 ± 0.3^{a}	30.4 ± 0.3^{b}	65 ± 1^{a}	good
8.	12.3 ± 0.3^{c}	32.6 ± 0.4^{e}	75 ± 1^{d}	good

9.	12.0±0.4^{c}	28.0±0.3^{a}	65±1^{a}	good
10.	11.0±0.3^{d}	32.6±0.3^{e}	80±1^{c}	satisfactory weak
11.	10.3±0.3^{a}	27.0±0.4^{f}	105±2^{e}	unsatisfactory weak
12.	10.3±0.3^{a}	26.0±0.2^{g}	105±2^{e}	unsatisfactory weak
Wheat flour of the first grade				
13.	11.0±0.2^{c}	30.0±0.3^{c}	70±1^{g}	good
14.	10.6±0.3^{b}	27.8±0.3^{a}	65±1^{a}	good
15.	10.6±0.3^{b}	29.9±0.4^{c}	65±1^{a}	good
16.	10.6±0.4^{b}	27.0±0.3^{f}	70±1^{f}	good
17.	10.6±0.3^{b}	25.0±0.2^{h}	70±1^{f}	good
18.	11.5±0.3^{e}	27.4±0.3^{f}	70±1^{f}	good
19.	11.5±0.3^{e}	30.3±0.3^{a}	65±1^{a}	good
20.	11.5±0.3^{e}	29.5±0.3^{c}	60±1^{g}	good
21.	11.5±0.3^{e}	30.5±0.3^{a}	60±1^{g}	good
22.	12.7±0.2^{f}	32.0±0.5^{e}	85±1^{h}	satisfactory weak
23.	12.2±0.3^{c}	27.6±0.3^{a}	65±1^{a}	good
24.	12.6±0.2^{f}	31.0±0.2^{i}	65±1^{a}	good

a-i = Mean value±standard deviation within the same row with different lowercase superscript letters are significantly different ($P \leq 0.05$)

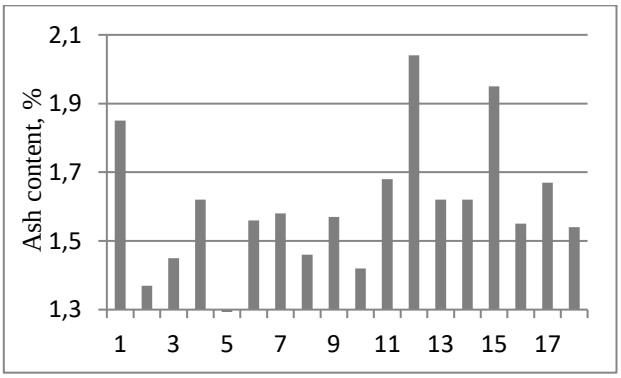

Fig. 1. Ash content in rye flour

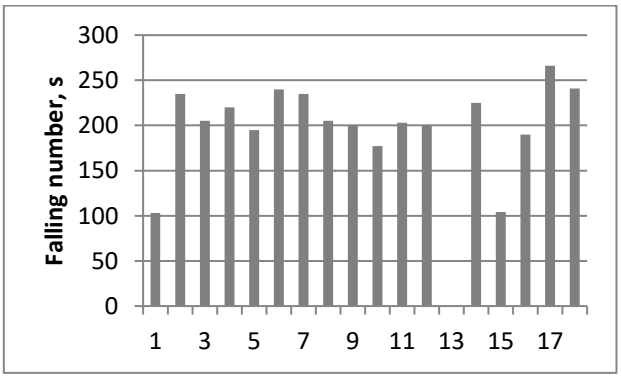

Fig. 2. Falling number in rye flour

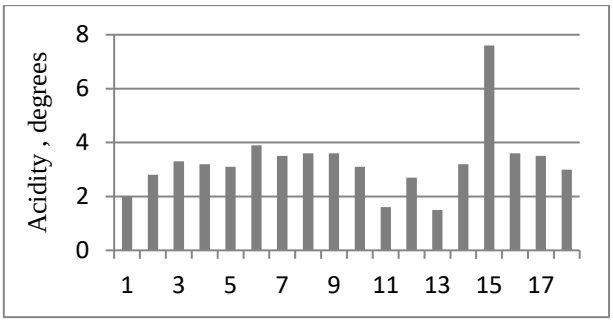

Fig. 3. Acidity in rye flour

Table 2. Rye flour characteristics

Sample	Content of water-soluble substances, % of dry weight	Amylogram height, u.a.	Gelatinization start temperature, °C	Maximum viscosity temperature, °C
1	67.8±0.7^{a}	180±10^{a}	55.0±1.0^{a}	65.5±0.5^{a}
10	47.4±0.7^{b}	350±10^{b}	56.5±1.0^{b}	65.5±0.5^{a}
11	28.3±0.5^{c}	350±10^{b}	55.0±1.0^{a}	67.0±0.5^{b}
12	33.4±0.4^{d}	345±10^{b}	55.0±1.0^{a}	67.8±0.4^{c}
13	35.2±0.5^{e}	365±10^{c}	56.5±1.0^{b}	67.8±0.3^{c}
14	31.6±0.6^{f}	430±10^{d}	56.5±1.0^{b}	70.8±0.5^{d}
15	35.5±0.7^{g}	170±10^{a}	55.0±1.0^{a}	67.0±0.5^{b}

a-g = Mean value±standard deviation within the same row with different lowercase superscript letters are significantly different ($P \leq 0.05$)

The technological properties of rye flour in flour brew were investigated (Table 3). Flour brew is an ingredient made from scalded flour, which is widely used in rye bread technology. Brew made from sample 1 had a dark brown color with a yellowish tinge. The brews made from samples 11 and 13 had a light brown color with a greenish tint. Brew made from sample 1 had not typical for brews smell. The smell was like the smell of baking soda.

The acidity of brews was different (Table 3). The acidity of brews made from flour samples 1, 11, 13 was almost the same at the beginning and after 2 hours of saccharification. In brews made from samples 10 and 14, the acidity increased by 12-13% by the end of saccharification. In brews made from samples 10 and 15, the acidity was significantly higher, both at the beginning and after 2 hours of saccharification. Thus, in the brews made from sample 15, the increase in acidity was 44% in 2 hours of saccharification.

Brew made from sample 13 had the lowest content of sugars at the beginning and at the end of saccharification (Table 3). Sugar content in samples 11, 12, 13, 14 was 2-3 times lower than in other samples at the end of saccharification.

Table 3. Characteristics of flour brew

Sample	Acidity, degrees		The content of reducing sugars in terms of maltose, % of dry weight	
	0h	2h	0 h	2h
1	1.1±0.1[a]	1.2±0.1[a]	3.3±0.2[a]	30.5±0.7[a]
10	1.7±0.1[b]	1.9±0.1[b]	10.8±0.5[b]	35.1±0.7[b]
11	1.2±0.3[c]	1.2±0.1[a]	3.9±0.3[c]	11.5±0.7[c]
12	1.2±0.3[c]	1.6±0.1[c]	3.2±0.2[a]	11.1±0.7[c]
13	1.2±0.3[c]	1.2±0.1[a]	2.8±0.2[d]	6.7±0.3[d]
14	1.5±0.3[d]	1.7±0.1[d]	3.8±0.2[c]	15.3±0.7[e]
15	1.8±0.3[f]	2.6±0.1[f]	11.7±0.2[e]	38.3±0.6[f]

a-f = Mean value±standard deviation within the same row with different lowercase superscript letters are significantly different ($P \leq 0.05$)

4 DISCUSSION

4.1 Wheat flour assessment

No direct correlation between the amount of protein and the quality of wheat gluten was found. The flour with high protein content can have weak or strong gluten. Therefore, a bread manufacturer cannot rely solely on the protein content of flour. It is necessary to investigate the quality of gluten in order to understand the baking properties of flour.

4.2 Rye flour assessment

The acidity of flour is an important indicator that is not standardized, but it characterizes the type of flour and its freshness, affects the taste and smell of bread. Recommended acidity values are established for each type of flour. Acidity of peeled rye flour should not exceed 5.0 degrees [5].

The pink color of the aqueous suspension when phenolphthalein was added to samples 1, 11, 13 (Fig. 3) indicated the admixture of additives with an alkaline reaction and confirms the assumption that alkaline additives were used to adjust the baking properties of this flour.

Samples 1 and 15 had similar FN (Fig.2) and Amylogram height (Table 2). However, the content of water-soluble substances in sample 1 was 1.9 times higher than in sample 15 (Table 2). This can be explained by the fact that the values of FN, amylograms and the content of water-soluble substances according to the spreadability of the gelatinized water-flour suspension depend not only on the activity of flour enzymes, but also on the viscosity of the suspension. The content of water-soluble substances is mainly influenced by the flour enzymatic activity, which depends on the acidity of the medium. Since the acidity of sample 1 was 2.0 degrees and the acidity of samples 15 was 7.6 degrees, it can be assumed that the high acidity of the sample may affect the decrease in the content of water-soluble substances.

The amount of reducing sugars in brewing (scalded flour) made from samples 10 and 15 was comparable to their content in brewing made from flour with normal baking properties [8]. The low content of sugars at the beginning of saccharification and their slow

accumulation in brewing made from samples 11, 12, 13, 14 was due to the decrease of β-amylase activity in an alkaline medium under 60-70 °C.

5 CONCLUSIONS

Studies have shown that standard indicators are not enough to determine the baking properties of rye and wheat flour.

The data obtained showed that the baking properties of wheat flour cannot be predicted based only on the protein content. For Russian bakers, gluten quality must be the major indicator of the baking properties of wheat flour. The examination of gluten makes it possible to decide for what type of products (biscuits, pizza, dumplings, waffles, cookies, dryers) this flour suits best. In addition, the study of the gluten quality enables to decide on managing of the bread making process by regulating the dough preparation modes (changing the duration of operations, strengthening or weakening the mechanical processing of the dough, changing its temperature, optimizing the amount of water in the dough), and regulating the dosage of additional raw materials.

It is also recommended to control the acidity of rye flour. The determination of acidity, which is not standardized, revealed that three samples had additives with an alkaline reaction of the medium. This can lead to problems in the technological process at bakeries.

Bakeries should conduct extensive monitoring of the quality of rye and wheat flour which makes it possible to predict and manage the process of bread production..

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