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TYPE 600 WHEAT-SPELT FLOUR WITH IMPROVED BAKERY PROPERTIES

D. Zhygunov, Doctor of Technical Sciences, Associate Professor[1]
Y. Barkovska, Master[1], Laboratory Assistant [2]
Y. Yehorshyn, Master [1]
H. Zhyhunova, Master [1], Master Student [3]
K. Barikian, Master [1], Intern [4]
[1] Odessa National Academy of Food Technologies
Kanatna str., 112, Odessa, Ukraine, 65039
[2] SC Agmintest Control Union
Ovidiopol road, 3, Odessa, Ukraine, 65036
[3] The Higher Institute of Agriculture
Boulevard Vauban, 48, Lille, France, 59014
[4] Hemelter Mühle Dr. Cordesmeyer GmbH & Co
Surenburgstraße, 69, Rheine, Germany, 48429

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Correspondence:

Zhygunov D.
E-mail: dmytro.zhygunov@gmail.com

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Abstract. The article presents the results of comparative studies of the quality characteristics of top-grade wheat flour, spelt flour, and 9 blends of them. The blends were obtained by mixing the two flours in different ratios (from 10 to 90%). It has been established that wheat flour has a lower protein content (11.5%) and lower gluten content (26.0%) compared to 14.2% and 36.5%, respectively, in spelt flour. Rheological analysis of common wheat dough has shown its high strength $W=280 \cdot 10^{-4}$J and high resilience P=109 mm. However, its insufficient extensibility L=66 mm makes the configuration of the curve P/L=1.65 sub-optimal for baking purposes (P/L=0.8–1.2). On the contrary, spelt flour has the strength $W=110 \cdot 10^{-4}$J, low resistance to extension (P=50 mm), high extensibility (L=95 mm), low ratio P/L=0.56. Dough from spelt flour is highly fluid and sticky. That is why, to impart specific technological properties to wheat dough, it has been suggested to blend common wheat flour and spelt flour. It has been established that the addition of spelt flour in an amount up to 30–40% increases the volume of bread by 1.13–1.16 times – from 440 cm^3 to 480–490 cm^3, and its porosity from 78% for wheat flour to 81% for wheat and spelt mixture. The best combination of sensory characteristics (shape, condition and colour of the surface, elasticity and colour of the crumb, nature of porosity, taste and aroma of the loaf) was obtained by adding 20–30% of spelt flour – this is the ratio recommended in the production of spelt-containing wheat flour. This will increase the cost of the end-use flour by 1.15–1.25 times, but still, it will be more economical than having to improve commercial wheat flour with enzyme preparations. This flour will not only have good bread-making properties due to the addition of spelt flour, but will also be high in various vitamins and trace elements, and loaves baked from it will have a pleasant goldish colour of the crust. Since its ash content will be less than 0.60%, this flour can be named Type 600 wheat-spelt flour.

Keywords: wheat flour, spelt flour, flour mixtures, rheological properties

Introduction. Formulation of the problem

Today, there is considerable interest to alternative crops [1] due to consumers' concern for healthy nutrition and useful properties of food [2]. Among other elements of a healthy diet, spelt wheat can gain interest and popularity.

Spelt has the same genome as *Triticum aestivum*, so it can be considered an ancient relative of bread wheat [3]. Compared to bread wheat, spelt has higher concentrations of Fe, Zn, Cu, Mg, and P elements, which are naturally concentrated in fine bran and coarse bran [4]. Ranhotra et al. found that spelt grain was higher in P (by 19%), Fe (by 20%), K (by 7%), and Zn (by 91%) than hard red winter wheat [5]. Sometimes, grains may even contain more carotenoids than wheat bread has, which causes a darker colour of spelt wheat bakery products [6].

Due to all its properties, spelt is actively used in the manufacture of bakery or pasta products, different semi-products. Alternative medicine suggests including spelt wheat in the diet of patients who suffer from a range of diseases: from allergies [2,5] and colitis ulcerosa [7] to high blood cholesterol [8], depression, and cancer. Zieliński et al. found that despite the wide use of spelt, its gluten proteins can provoke wheat allergy and gluten enteropathy [2].

Often spelt flour can be purchased in health food shops [2] at a price up to 50% higher than that of its common wheat equivalent [9]. That is why it is highly advisable to use a mixture of spelt wheat and bread wheat flour to make bakery products. It is necessary to understand how much the addition of spelt flour will relax the dough without affecting its baking properties, and increase its biological value at an affordable price.

Analysis of recent research and publications

Now, in Europe, more than 10 percent of the agricultural land is used for organic production. The available literature data indicate that organic farming of cereal crops significantly increases every year, and the main crops cultivated are bread wheat and hulled wheat. With the increasing demand for diverse and high-quality food, the hulled wheat species (also termed spelt) have are drawing more and more interest [10,11].

Hulled wheat species are among the most ancient cereal crops. Spelt contains all the basic components necessary for people, and is high in protein, the amount of which depends on the agro-climatic conditions of cultivation [12,13]. As a result, in literature, data of a different protein content can be found, and most studies agree that spelt is higher in protein than modern wheat: from 7.5–10.8% [2] up to 12.49–19.48% [13]. Abdel-Aal found 15.4% of protein during the experimental milling of whole grain spelt flour, but only 15.0% of it in commercially milled whole grain spelt flour [7]. It has often been experimentally confirmed that there is almost no difference between the amounts of protein in spelt and modern wheat, and in some cases, researchers reported a lower protein content [2,5].

Not only the amount of protein, but also the characteristics of gluten are significant technological quality indicators closely connected with the baking quality of cereal grains. Spelt typically has a higher yield of wet gluten [14,15] which tends to be more extensible and less resilient than gluten of common wheat [5,16,17]. Lacko-Bartošová and Rédlová reported that wet gluten in different spelt wheat varieties ranged from 31.01% to 39.50% [18].

Hulled wheat species are a typical example of an underused plant. They are quite unknown and undervalued in commercial production. There are significant technological differences in processing spelt and common wheat [19]. Tough spelt hull makes it less easily processable than modern wheat varieties. As a result, the yield of spelt flour is about 65% [2]. Smaller yields per unit area, lower yield of flour, and processing difficulties make spelt flour more expensive than bakery wheat flour [9].

During kneading, dough from spelt flour is characterised by low stability, it is less elastic, and highly extensible. After kneading, it is very soft and sticky. That is why handling spelt dough is more difficult [14,16,20,21]. Although spelt behaves differently from common wheat at different stages of the technological process [14], its use in bread production is possible. Bojňanská and Frančáková say that bread with spelt flour added has an excellent taste, a strong bread aroma, and a longer shelf life [13].

To use spelt flour in real technological conditions, ascorbic acid should be added to it because of the strength of the gluten structure and the reduced extensibility of dough [13]. But Schober et al. concluded that increasing the rest period of spelt dough to several hours would make using ascorbic acid unnecessary [14].

The wheat flour types, which are widely used in Europe, are based on how much bran remains in flour after milling: the less bran, the lighter and whiter the flour; the more bran, the greater amount of healthy substances remains in the flour. In Ukraine, wheat flour with the ash content not higher than 0.55% is called top-grade flour, and it almost corresponds to the European standards: Type 55 (France), Type 550 (Germany). This flour is white, contains the smallest amount of protein, and is used for most bakery products such as pan bread, croissants, or biscuits. Straight Grade flour with the ash content <0.65% (Type 650) is used to make baguettes. First grade flour, or Type 750, with the ash content <0.75% is ideal for baking rolls and loaves. Wheat flour with the ash content 0.45%, used for biscuits, and cakes, belongs to Type 450. Ukrainian top-grade flour, which is the most demanded, can be equalled to Type 550 patent flour. However, recently, straight flour (Type 650) has grown in popularity, too.

Our analysis of the quality of commercial flour produced in Ukraine in 2016–2020 has shown that neither the protein-protease nor carbohydrate-amylase flour complexes are optimal for bread production, and both require correction. This is due to various factors, one of which is the change in the agro-climatic conditions of grain growing, especially in the southern regions of Ukraine.

Therefore, the **purpose of this** work is studying the possibility of using spelt flour to correct the baking parameters of wheat flour, and establishing the optimal formulation of the wheat-spelt mixture. The research **objectives** were:

– to study the physicotechnological and chemicotechnological quality characteristics of wheat flour and spelt flour;

– to determine the rheological properties of dough and the parameters of the baking test for wheat flour, spelt flour, and their mixtures;

– to establish and give reasons for the optimal ratio of wheat flour and spelt flour in the wheat-spelt flour blend.

Research materials and methods

Samples. Eleven flour samples have been investigated: top-grade wheat flour, spelt flour, and 9 mixtures of them, obtained by mixing in different ratios (from 10 to 90%). The top-grade wheat flour was manufactured industrially at the milling plant *TM Amina* by processing common wheat grown in the Nikolayev Region in 2017–2018. Spelt flour was obtained from spelt (hulled red winter wheat) grown in the Odessa Region in 2017–2018 and milled in laboratory conditions.

Experimental milling. Water-thermal treatment (tempering stage) of the spelt grain prior to its grinding was carried out by moistening to 15.0% for 16 hours. Spelt flour was obtained (in the form of straight flour, for a higher level of transition of biologically active components) by grinding in a Bühler laboratory flour mill (MLU–202). The soft grains of the spelt made it necessary to use 120 µm sieves (instead of standard 95 µm) for better sieving. Besides, bran was sieved on a 150 µm sieve, and its flour was added to the total flour.

Flour quality analysis. The moisture content was determined according to ISO 712. The protein content in the food material was determined by measuring the nitrogen content of the material and multiplying its value by the N factor, which was 5.70 for all the flours. The classical procedure to determine nitrogen was the Kjeldahl method described in ISO 20483. The ash content of flour is defined as the residue remaining after controlled incineration of the flour. This method is described in ISO 2171. The whiteness of flour was studied in accordance with GOST (State Standard) 26361 on a device Blick-M.

Wet gluten was washed out according to GOST 27839, by the handwashing of dough obtained from 25 g of flour with 14 ml of water. The gluten deformation index (GDI) was measured on a gluten deformation meter IDK-M. The Falling Number method was performed according to ISO 3093. The Zeleny test was performed according to ISO 5529.

The rheological properties of the dough were determined with an alveograph (Chopin (NG), France) following the AACC method ISO 27971. The Chopin Alveograph is a tool commonly used overseas to help determine the baking potential of wheat by a complex of parameters. A computer software program automatically recorded the following Alveograph parameters: resistance to extension (P), dough extensibility (L), curve configuration ratio (P/L ratio), deformation energy (W), and elasticity (P200/P ratio).

When kneading the combined dough, a Mixolab meter was used to determine the rheological properties of the dough (at a constant temperature following the steps of heating, holding at a high temperature, and subsequent cooling) and its water absorption capacity (WAC). Mixolab allows simultaneous evaluation of protein-proteinase and carbohydrate-amylase complexes within 45 minutes in accordance with the international standard ICC 173/1. The Mixolab test has shown the following parameters: torque C1 is the maximum point of the first mixing phase, torque C2 shows protein weakening, torque C3 indicates the rate of starch gelatinisation, torque C4 shows the amylolytic activity and stability of hot gel, torque C5 shows its starch retrogradation in the cooling phase, C3–C4 show amylase activity and are linked to the Falling Number. Slope α (between the end of the 30°C period and C2) indicates the rate of protein weakening when it is heated, slope β (between C2 and C3) indicates the rate of pasting (gelatinisation), slope γ (between C3 and C4) indicates the rate of enzymatic (α–amylase) degradation.

A baking test of the laboratory bread was carried out to evaluate comprehensively the baking properties of flour according to the method provided for in State Standard 27669 (in terms of 100 g of flour). The amount of water needed for dough formation was determined based on the moisture content of the flour. Yeast (3 g), sugar (4 g), and salt (1.3 g) were added according to the formulation. The dough was fermented in a thermostat at 31±1°C for 180 minutes. Bread was baked in a laboratory oven at 220–230°C, with humidification of the baking chamber for 20–25 minutes.

Sensory analysis was carried out by such parameters as: taste, smell, appearance and colour of the crust and crumb, tactile and auditory impressions. Each parameter was rated on a five-point marking scale, and the overall score was calculated as the arithmetic mean of all parameters.

Results of the research and their discussion

Table 1 shows the results of all physico-technological and chemical analyses in our research. If the conditions of milling are the same, the quality of milling (the flour yield, ash content, and whiteness) is determined by the morphological parameters of grain [22]. Commercial flour was obtained in a factory with the average output of top-grade flour about 60.0% and the total flour yield about 78.0%. Many authors, such as Abdel-Aal et al., Marconi et al., in their studies noted that the yield of spelt grain flour was lower than that of common wheat flour, which indicated poorer milling properties of spelt. In our case, spelt flour, obtained by our improved scheme, showed a lower total flour yield (73.2%) [16,17].

Table 1 – Quality characteristics of wheat and spelt flour (n=3, p=0.95)

Indicator	Wheat flour	Spelt flour
Ash,%	0.52	0.63
Whiteness, un.	60.2	58.0
Protein,%	11.5	14.2
Wet gluten,%	26.0	36.5
GDI, un.	60	95
Zeleny test, ml	41	14
FN, sec	424	245

Note: GDI – gluten deformation index, FN – Falling Number

Ash represents the mineral content of the flour, individual elements of which may exist in various forms in combination with other flour constituents. Common wheat flour has shown the standard values of ash (0.52%) and whiteness (60.2 un.) for top-grade flour. Whiteness of flour depends on many factors: from the variety of flour to the percentage of bran and endosperm particles [23]. The higher ash content in spelt flour (0.63%) and, respectively, lower whiteness (by 2 un.) result from the grinding characteristics and softness of grain.

The researched spelt flour was higher in proteins (14.2%) due to the higher protein content in the aleurone layer [13]. This is in good agreement with other data in which spelt has always been superior to common wheat [24].

Wet gluten is a cohesive visco-elastic substance obtained after washing out the starch from dough [26]. The wet gluten content, gluten deformation index (GDI), and Zeleny test are indicators that indirectly characterise the baking quality of flour. Wheat flour has shown almost the same amount of wet gluten (26.0%) as for food-grade wheat (minimum 25%) [13]. Spelt flour was by 10.5% higher in gluten than wheat flour. This is confirmed in many previous studies by Lacko–Bartošová and Rédlová, Bojňanská and Frančáková, Zielinski et al., who found that wet gluten content in samples ranged from 30.0% to 39.5% depending on the variety or line [13,18]. The quality of spelt gluten (GDI) is 90–120 un., which means weak quality [25]. The gluten deformation index of our spelt flour was 95 un., and that is typical of spelt grain. The Zeleny test shows the ability of protein molecules to swell in a slightly acidic environment. The Zeleny test resulted in a proportion of sediments of 41 ml for common wheat flour, which, based on the published data, suggests average baking quality (36 ml to 45 ml), and 14 ml for spelt flour, which signifies its weak quality.

The Falling Number (FN) is the most common criterion, the indicator of enzymatic (alpha-amylase) activity depending on the amount of grains entering the germination process [27]. The upper limit of the FN standard is not regulated. Too high FN values (>300 sec.) for common wheat flour indicate that the activity of native enzymes in flour is lowered, and as a result, the bread will have insufficient volume and gas formation. Common wheat flour has a very high FN=424 sec, which has been typical in recent years of the southern regions of Ukraine [28]. On the contrary, the FN of spelt flour is 245 sec, a good and optimal result for bakery (Table 2 and Fig. 1). Flour strength (W) is a key indicator of flour quality [27]. Top-grade flour is the benchmark for common bakery wheat, and according to our results of determining the rheological properties, it has very high strength (W) and elasticity (Ie). Wheat with $W=280\cdot10^{-4}J$ is strong wheat with high baking properties ($W>250\cdot10^{-4}J$). As a result of insufficient extensibility L=66 mm and a high value of P=109 mm, we obtain the suboptimal curve configuration P/L=1.65 for baking purposes (P/L=0.8–1.2) [29].

Table 2 – Parameters of the rheological test on the alveograph

Parameter	Wheat flour	Spelt flour
$W\cdot10^{-4}J$	280	110
P, mm	109	50
L, mm	66	95
P/L	1.65	0.56
Ie,%	60.1	39.5
G	18.1	21.2

Spelt flour (Table 2, Fig. 1) has low strength $W=110\cdot10^{-4}J$, low elasticity Ie=39.5%, and low baking capacity. The best quality wheat flour samples can have the Ie index 60% to 65.0%, and even 70.0%. Flour samples of medium and satisfactory quality have an Ie index below 60.0% [27]. Spelt flour has a lower P/L ratio 0.56 and unsuitable (fluid, sticky) dough consistency. Our results are consistent with those of many authors (Abdel-Aal et al., Schober et al., Zanetti et al., Pruska–Kędzior et al., Bonifácia et al.), who find dough from spelt flour to be very soft and sticky, and handling spelt dough to be more difficult [7,14,15,20,21].

Rheological analysis of flour confirms the need for mixing spelt and top-grade wheat flour to relax the dough, achieve greater extensibility and the optimal P/L ratio for baking. Therefore, the rheological properties of the Mixolab dough and the bread baking performance were further investigated not only for the initial samples of wheat and spelt flour, but also for their mixtures.

Water absorption capacity (WAC) is an important quality parameter related to the amount of bread that can be made from a given weight of flour. In our earlier studies, it was established that for Ukrainian commercial flour, this parameter was 56–60%. The WAC of wheat flour was much higher (59.2%) despite its lower ash content and lower protein content, due to the hardness of wheat grain and a greater degree of starch damage, unlike soft spelt (Table 3). The mixing index (Fig. 2A, F) in two samples was lower (2) than recommended for bread baking (3–5). For wheat flour, this is the result of a low protein and gluten content, for spelt flour, it is due to weak gluten, which immediately breaks down during kneading and does not form a continuous stable gluten framework. The gluten+ index in commercial top-grade flour showed a high value (8). This indicates too high gluten temperature resistance, which can lead to undermining during baking.

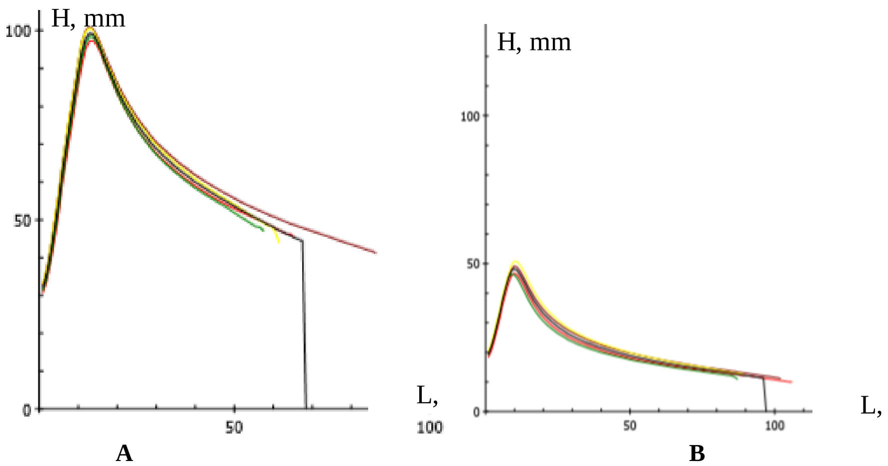

Fig. 1. Graphic data of the alveograph test of wheat flour (A) and spelt flour (B)

Table 3 – Parameters of the Mixolab rheology test

Parameters	Wheat:spelt flour ratio										
	100:0	**90:10**	**80:20**	**70:30**	**60:40**	**50:50**	**40:60**	**30:70**	**20:80**	**10:90**	**0:100**
WAC,%	59.2	59.0	58.6	58.2	56.3	55.3	53.8	52.8	52.4	51.6	50.2
C1, nm	1.136	1.142	1.122	1.114	1.109	1.120	1.107	1.102	1.063	1.120	1.089
C2, nm	0.545	0.556	0.551	0.529	0.511	0.477	0.457	0.441	0.370	0.369	0.332
C3, nm	1.975	2.025	2.000	1.974	2.022	2.065	2.175	2.203	2.133	2.161	2.165
C4, nm	1.444	1.557	1.657	1.632	1.955	2.003	2.099	2.145	2.069	2.075	2.099
C5, nm	2.716	3.085	3.005	2.995	2.993	2.990	3.133	3.172	3.233	3.125	3.200
α	-0.094	-0.084	-0.082	-0.078	-0.088	-0.080	-0.080	-0.074	-0.068	-0.074	-0.068
β	0.450	0.388	0.368	0.418	0.304	0.262	0.292	0.290	0.298	0.318	0.374
γ	-0.130	-0.114	-0.154	-0.176	-0.044	0.004	-0.006	-0.022	-0.018	-0.024	-0.048

Note: WAC – water absorption capacity

The C2 values below 0.4 nm indicate that dough from this wheat species can be less tolerant to mixing. Protein weakening C2=0.545 nm of wheat flour is significantly higher than 0.4 nm. Spelt flour dough with C2=0.332 nm is very sensitive to temperature conditions and may fall during landing. The viscosity indices of spelt and top-grade flour are almost the same, respectively, the rates of starch gelatinisation C3 at the maximum point are the same, too. The samples differ significantly in amylolytic activity and hot gel stability. Spelt flour has higher C4=2.099 nm, and the difference between C3 and C4 (0.066 nm) means stability of starch gel when heated. Wheat flour, with less amylolytic activity, has more damaged starch. That is why, in the hot state, dough continues to liquefy, and the difference between C4 and C3 is 0.531 nm. According to the retrogradation index, two flour samples, despite the different properties of the carbohydrate-amylase complex, have the same values of 8.

The addition of spelt flour leads to a change in the rheological characteristics and profiles of the resulting mixtures (Fig. 2).

The baking experiments have been performed on all flour samples and their mixtures. The results of the experiments are presented in Fig 3. This test is often used to determine differences in the quality of flour [30]. The volume of a loaf and its specific volume are very important characteristics of bread making quality [18]. Bread from top-grade flour has a good, but not high loaf volume of 430 cm^3, whereas using spelt flour, despite the weaker properties of its protein-proteinase complex, results in an even higher loaf volume, 440cm^3.

According to the results of the sensory evaluation, 5 out of 7 properties of bread made commercial flour had good marks (4 out of 5 points). The exceptions were the colour and the presence of some open coarse texture. The situation for spelt bread was much worse: the shape was more irregular, the surface was knobbly, the crumb was of insufficient elasticity, and the colour was dark (due to peripheral particles), as also reported by Abdel-Aal et al. [16]. The porosity, according to the results of the analysis, was the same for two samples. The porosity of spelt bread is uneven with interspersed large pores, a sweeter taste and a pronounced smell have also appeared. Abdel-Aal et al. and Ranhotra et al. made bread from spelt flour only, and that bread was worse in volume, texture, crumb colour, and had a rather open coarse texture compared to bread from common wheat [5,16].

In the process of kneading, already after adding 30–40% of spelt flour, the stickiness of the dough began to be felt. After 60–70%, the dough was very sticky. In wheat-spelt mixtures (up to 40% of the spelt flour additive), the porosity increased due to an increase in the gas-forming ability, then it remained at the same level, and decreased after 70%. This trend is due to a decrease in the gas holding capacity of spelt flour and wheat-spelt mixtures.

The addition of spelt flour improved the taste, and the smell became more saturated. As a result of a higher protein content and better sugar-forming ability in spelt flour, the colour of the crust of bread became more golden due to a more pronounced Maillard reaction. These characteristics have contributed to the improvement in the score. Due to the greater stickiness of the dough after adding 60–70% spelt flour, the surface of the bread became knobbly. The crumb became greyer and less elastic. The number of large pores increased, and they became less even. All these parameters have significantly reduced the integrated sensory evaluation of bread. Respectively, the sensory characteristics of spelt bread were described by Abdel-Aal et al. as moderate [16].

The maximum loaf volume was observed in the mixture with 30–40% of spelt. It is by 1.13–1.16 more than in commercial top-grade flour. According to the results of sensory analysis, the recommended amount of added spelt flour is 20–30%. In Table 3, it is shown how the ash content changes depending on the percentage of spelt added. In the mixture, it will range about 0.55–0.56%. Since its ash content is <0.60%, such flour will be of Type 600.

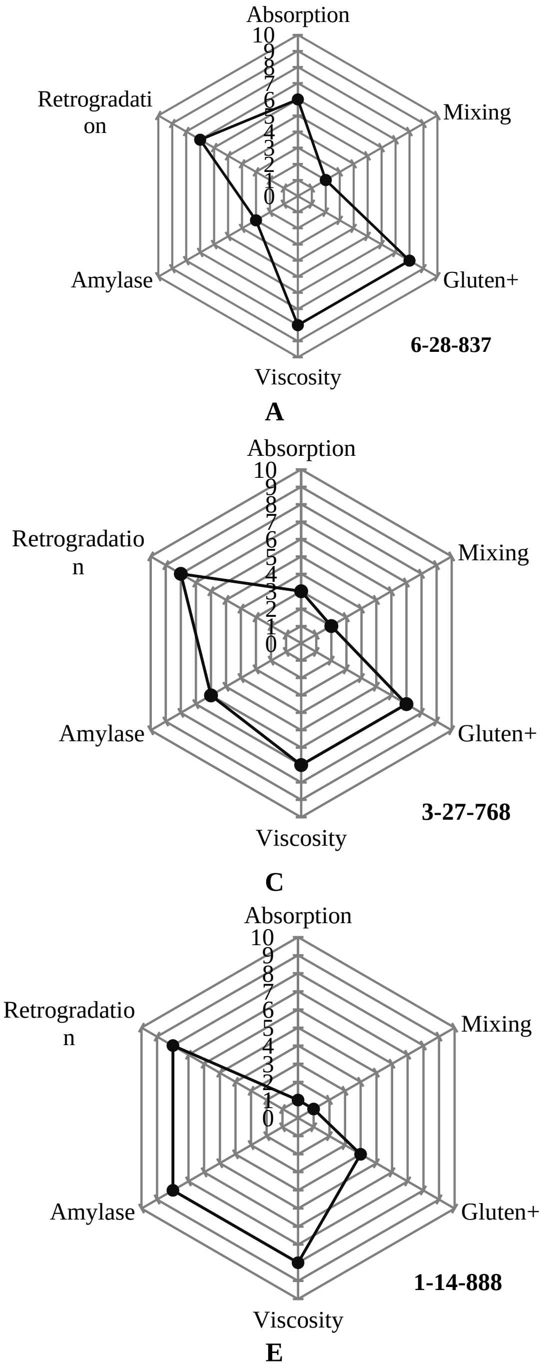

Fig. 2. Graphic data of the Mixolab test of wheat flour, spelt flour, and their mixtures, with the wheat and spelt flour ratios: A – 100:0; B – 80:20; C – 60:40; D – 40:60; E – 20:80; F – 0:100

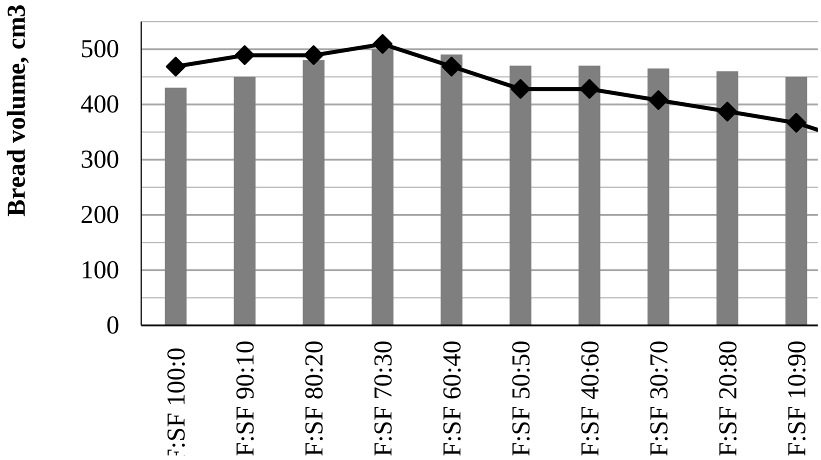

Fig. 3. Bread volume and sensory characteristics of wheat flour (WF), spelt flour (SF), and their mixtures

Table 3 – Calculation of characteristics of wheat-spelt flour

Parameter	Wheat-spelt flour ratio										
	100:0	**90:10**	**80:20**	**70:30**	**60:40**	**50:50**	**40:60**	**30:70**	**20:80**	**10:90**	**0:100**
Ash,%	0.52	0.53	0.54	0.55	0.56	0.57	0.59	0.60	0.61	0.62	0.63
Wholesale price for 1 ton, UAH	6600	7160	7720	8280	8840	9400	9960	10520	11080	11640	12200

Products from spelt flour are becoming more popular due to their pleasant taste and aroma, and they are easily digested by consumers with wheat sensitivity. But from the economic point of view, spelt flour will be quite expensive [9], and from the technological one, it is difficult in use [13]. Therefore, a simple economic cost analysis has been performed: the cost of different proportions of common wheat and spelt flour has been calculated (Table 3).The results of the economic cost analysis have shown that spelt flour should be mixed with bread flour in an amount of 20–30%. This is the optimal solution for spelt flour. It will increase the cost of the end flour by 1.15–1.25 times, but still, it will be more economical (approximately no more than 1.10–1.15 times as expensive) than improving commercial wheat flour from the south of Ukraine with enzyme preparations, and bread will contain more biologically active substances and have a more saturated taste.

Conclusion

According to all the data we obtained in our experiment on the commercial flour from *TM Amina*, it can be concluded that it is typical bakery flour. The results of the experiments correspond to the values characteristic of top-grade flour. Compared to spelt flour, this flour has shown, predictably, lower contents of protein (11.5%) and gluten (26.0%). The rheological analysis has shown high strength $W=280\cdot10^{-4}$J and, indirectly, high baking properties ($W>250\cdot10^{-4}$J). But as a result of insufficient extensibility L=66 mm and a high value of P=109 mm, a suboptimal curve configuration P/L=1.65 for baking purposes (P/L=0.8–1.2) has been obtained. The rheological analysis of flour confirms that spelt should be mixed with top-grade flour to relax the dough, achieve greater extensibility and the optimal P/L ratio for baking based on the results of determining the amylase complex. A conclusion has been made about the high activity of enzymes (FN=424 sec) and, consequently, possible insufficient gas formation. The water absorption capacity of top-grade flour was much higher (59.2%) despite its lower ash and protein contents.

At the same time, spelt flour has more gluten (36.5%) and protein (14.2%). However, its gluten is weak, that is why the dough is highly fluid and has a low ratio P/L=0.56 and baking capacity with $W=110\cdot10^{-4}$J. The dough will be sticky because of low resistance to extension (50 mm) and high extensibility (95 mm). It will have good gas production, but it will not hold it. Therefore, using spelt flour alone is not practical. Such flour will have not only good bread-making properties due to the addition of spelt flour, but will also be high in various vitamins and trace elements, and will result in a pleasant goldish colour of bread crust. The economic and baking analyses have also shown the need for and possibility of wheat and spelt flour mixing. The addition up to 60–70% of spelt flour improved the taste, the smell became more saturated, but with a higher percentage of these parameters, it became worse. The maximum loaf volume was observed in the mixture with 30–40% of spelt (by 1.13–1.16 more than with commercial top-grade flour). According to the results of the sensory analysis, the recommended amount of added spelt flour is 20–30%. In our estimation, considering this, the recommended percentage of spelt flour is 20–30%. It will increase the cost of end flour by 1.15–1.25 times, but still, it will be more economical than improving commercial wheat flour with enzyme preparations. Besides, this flour will not only have high baking properties, but increased biological value, too. Since its ash content will be less than 0.6%, this flour can be named Type 600 wheat-spelt flour.

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ПШЕНИЧНО-СПЕЛЬТОВЕ БОРОШНО ТИП 600 ІЗ ПОЛІПШЕНИМИ ХЛІБОПЕКАРСЬКИМИ ВЛАСТИВОСТЯМИ

Д.О. Жигунов, доктор технічних наук, доцент[1], E-*mail*: dmytro.zhygunov@gmail.com
Ю.С. Барковська, магістр [1], хімік-лаборант[2], E-*mail*: barkovska.yulya@gmail.com
Є.О. Єгоршин, магістр[1], E-*mail*: yevheniiyehorshyn@gmail.com
Г.Д. Жигунова, магістр [1], студент магістратури[3], E-*mail*: hanna.zhyhunova@gmail.com
К.С. Барікян, магістр[1], стажер[4], E-*mail*: kateryna.barikian@gmail.com
[1] Одеська національна академія харчових технологій, вул. Канатна, 112, Одеса, Україна, 65039
[2] ДП Агмінтест Контрол Юніон, Овідіопольска дор., 3, Одеса, Україна, 65036
[3] Вищий інститут агробізнесу, Бульвар Вобан, 48, Лілль, Франція, 59014
[4] Хемельтер Мюле Доктор Кордесмайєр Лтд. & Ко, Зуренбургштрассе, 69, Райне, Німеччина, 48429

Анотація. У роботі наведено результати порівняльних досліджень показників якості пшеничного борошна вищого сорту, спельтового борошна та їхніх сумішей, отриманих шляхом змішування в різному співвідношенні (від 10 до 90%). Встановлено, що пшеничне борошно має нижчий вміст білка (11.5%) і клейковини (26.0%) проти (14.2%) та (36.5%), відповідно, ніж у спельтовому борошні. За реологічним аналізом, тісто з пшеничного борошна володіє високою силою $W=280\cdot10^{-4}$J і, високою пружністю P=109мм, але внаслідок недостатньої розтяжності L=66мм має неоптимальну конфігурацію кривої P/L=1.65 для хлібопекарських цілей (P/L=0.8–1.2). Навпаки, спельтове борошно має показник $W=110\cdot10^{-4}$J, низький опір до розтягування P=50 мм, високу розтяжність L=95 мм, низьке значення коефіцієнту конфігурації P/L=0.56, тісто з нього дуже рідке та ліпке. Тому для надання пшеничному тісту певних технологічних властивостей, запропоновано змішування пшеничного та спельтового борошна. Встановлено, що додавання спельтового борошна в кількості 30–40% збільшує об’єм хліба в 1.13–1.16 рази з 440см^3 до 480–490см^3 і його пористість від 78% для пшеничного борошна до 81% у пшенично-спельтовій суміші. Найкращу комбінацію сенсорних характеристик (форми, стану і кольору поверхні, еластичності і кольору м'якушки, характеру пористості, смаку та аромату хліба) отримано при додаванні спельтового борошна в кількості 20–30%: це співвідношення і рекомендується при виробництві пшенично-спельтового борошна. Це збільшить вартість борошна для кінцевого використання в 1.15–1.25 рази, але, з огляду на необхідність коригування комерційного пшеничного борошна ферментними препаратами, збільшення вартості буде менше. Таке борошно володітиме не тільки хорошими хлібопекарськими властивостями завдяки додаванню спельтового борошна, але й високим вмістом різних вітамінів і мікроелементів, матиме приємний золотистий колір скоринки. Оскільки вміст золи в ньому складатиме менше 0,60%, таке борошно можна назвати «пшенично-спельтовим борошном типу 600».

Ключові слова: пшенично борошно, спельтове борошно, мучна суміш, реологічні властивості.

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