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ELUCIDATION OF THE MECHANISM THAT FORMS BREADBAKING PROPERTIES OF THE SPELT GRAIN

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Теоретично обґрунтовано та експериментально підтверджено технологічні властивості зерна 16 сортів і ліній пшениці спельти. Проаналізовано відмінності між якістю хліба з борошна вищого сорту та обойного, показано актуальність диференційованого підходу до технологічних властивостей борошна для його виробництва. На основі досліджень фізико-хімічних, органолептичних показників хліба підтверджено можливість перспективного використання зерна пшениці спельти в технології хлібопекарської продукції для розширення асортименту і підвищення якості виробів

Ключові слова: пшениця спельта, хлібопекарські властивості, якість хліба, вуглеводно-амілазний комплекс

Теоретически обоснованы и экспериментально подтверждены технологические свойства зерна 16 сортов и линий пшеницы спельты. Проанализированы различия между качеством хлеба из муки высшего сорта и обойной, показана актуальность дифференцированного подхода к технологическим свойствам муки для его производства. На основе исследований физико-химических, органолептических показателей хлеба подтверждена возможность перспективного использования зерна пшеницы спельты в технологии хлебопекарной продукции для расширения ассортимента и повышения качества изделий

Ключевые слова: пшеница спельты, хлебопекарные свойства, качество хлеба, углеводно-амилазный комплекс

1. Introduction

Grain crops are important in human nutrition because they provide 40–75 % of total carbohydrate intake [1].

Spelt (*Triticum spelta* L.) is one of the oldest species of the *Triticum* family with the A^uBD genome. Its crops dominated the fields for a very long time [2]. Based on the ancient spelt, all modern high-yielding wheat varieties with high potential of yield, resistant to disease agents and extreme weather conditions, were grown. From the nineteenth century, after growing the first high-quality filmless varieties of winter wheat on the territory of Ukraine, a sharp cut in

the spelt sown areas began to take place. Since then, mainly enthusiasts and amateurs have continued to cultivate spelt. It remained cultivated just on small areas in mountainous regions of Europe and Asia. However, a complete cessation of cultivation did not occur because the spelt grain never lost its attractiveness [3].

One of the lines for improving efficiency of material and technical resources is the use of the plant varietal potential. However, varieties have diverse morphoagribiological attributes and properties, genetic potential of productivity, reaction to conditions of cultivation and adaptivity. Therefore, they differ in product yield and quality [4]. Consequently, technological properties and biochemical composition of the grain depend on the variety.

Since data on the use of spelt grain in bakery are scanty, it is important to expand studies to provide scientific substantiation and its rational use, to develop new formulations to expand the range of bakery products.

2. Literature review and problem statement

Technological properties of wheat grain depend on the content and properties of its main components and biochemical characteristics. The most important indicator of grain quality is the baking quality. Culinary estimation of bread depends on a number of baking indicators. The main of them are the content of protein, gluten, quality, dough dilution according to the farinograph indicator, specific work of dough deformation according to the alveograph indicator [5].

Baking properties of the wheat grain are of polygenic nature. For example, genes are localized in chromosomes of 1D, 2A, 2B, 2D, 3A, 3B, 3D, 4A, 4B, 4D, 5A, 5B, 5D genomes. The very low quality of the bread is controlled by the genes found in 1D, 2A, 2B, 3D, 6B, 7D chromosomes. The greatest influence on the bread volume, its surface and porosity is exerted by the complex of genes localized in the chromosomes of B genome.

Proteins in living organisms perform a number of functions, and their deficiency results in a violation of normal functioning of all systems. As usual, the content of protein and gluten correlates with the bread quality. The minimum protein content at which flour is capable of forming dough is 7.5 % but to that end, flour with protein content of more than 11 % is used. It is different for different varieties of wheat. Usually, baking properties worsen with an increase in protein content in winter wheat grain above 17 % but the correlation coefficient between these variables varies from 0.63 to 0.86. This suggests that as the protein content in the grain increases to more than 17 %, the bread volume may increase or decrease. It is believed that the increase in protein content above 19 % by the application of selective and genetic methods does not worsen baking properties of grain which contributes to obtaining of quality bread. Protein content in wheat may vary from 8 % to 25 % depending on the conditions of cultivation [6].

Synthesis of gluten-forming wheat proteins is localized in 1A, 1B, 1D, 6A, 6B and 6D chromosomes [7]. Gluten content is also related to the baking properties since there is a close direct correlation between the content of protein and gluten in the grain (r=0.97) [8].

It is supposed [6] that quality of gluten is a varietal feature manifesting itself to a greater extent than its content in the grain. Disparities between strong and weak gluten depend on the internal protein structure, that is, on the density of intra- and intermolecular bonds and its aggregate state. Besides, cultivation conditions affect quality of gluten, so varieties of strong wheat usually give grain with gluten having unsatisfactory physical properties.

Typically, amount of gluten and its elastic properties affect formation of bread volume. However, it is not always possible to obtain high-quality bread using flour obtained from a number of wheat varieties containing more than 40 % gluten. There are cases of high flour strength (w=381) at gluten content of 23.0 %. Volume of bread baked of Saratov-29 flour with gluten content of 16.9 and 25.0 % was 514 and 524 cm^3, respectively [9].

Gluten quality is determined not by the chemical composition, but by certain structural features of the proteins forming it. Amino acid composition of the strong and weak wheat is the same. That is why quality of gluten is one of the main indicators characterizing suitability of flour for production of bakery and confectionery products [10].

Spelt usually features high content of gluten but it is more yielding and less elastic compared to gluten of soft wheat [11]. Its content significantly depends on the variety [12]. The level of this indicator in spelt ranges from 10.8 % to 30.6 % [13].

Quality of spelt gluten is 90°120 units [14] and corresponds to the second or third quality group, that is satisfactorily and unsatisfactorily weak [15]. Therefore, dough prepared of such flour is heavy and dark. It is better to use it as an additive to rye or wheat flour as well as in preparation of shortbread and some other types of dough [16]. However, biological value of spelt gluten is much higher than that of soft wheat since it contains more easily digestible ingredients [17]. Spelt dough is very soft and sticky after kneading, it is more difficult to process it and the bread volume is usually smaller than that of wheat dough [3].

Rheological properties of dough prepared of spelt flour depend on the viscoelastic properties of the gluten matrix which are determined by the qualitative and quantitative composition of the fractions of monomeric gliadin and polymeric glutenin. There are significant differences between the spelt and soft wheat in the number of fractions and molecular weight of α-, β-, γ- and ω-gliadin and low molecular glutenin subpoints [18].

In addition to protein-proteinase parameters, formation of the bread quality is affected by the carbohydrate-amylase complex of grain, content of fat and lipoids, pentosanes, and enzymes [11]. Destruction of starch molecules increases the water absorption capacity of flour and lipids cause formation of cement-forming strength of the gluten framework during dough fermentation which improves bread quality.

Consequently, technological properties of spelt grain are very similar to those of soft wheat but this grain usually contains more protein and gluten. This enables production of high-quality bakery products, but the literature does not sufficiently cover formation of technological properties of varieties and lines of spelt grain obtained by hybridization of *Triticum aestivum/Triticum spelta*.

3. The aim and objectives of the study

The study objective was to find out the mechanism of forming baking properties of grain of new varieties and lines of spelt to determine suitability to processing of various flour types.

To achieve this goal, the following tasks were solved:

– to determine content of protein and gluten in spelt grains and indicator of gluten deformation depending on variety and line;

– to study the hydrocarbon-amylase complex of spelt grain (fall number and gas-retaining ability);

– to determine bread volume and organoleptic quality characteristics of bread baked of different flour types;

– to establish a correlation of the grain baking properties with the bread quality.

4. Materials and methods used for studying quality of spelt grain and bread, physical-chemical, and organoleptic indicators

4. 1. Studied materials and equipment used in the experiment

Experimental part of the work was conducted in the laboratory of technology of storage and processing of grain at Uman National University of Horticulture (Ukraine). We used grain of spelt varieties: Schwabenkorn (Austria), NSS 6/01 (Serbia), Swedish 1 (Sweden). Lines obtained by hybridization of *Tr. aestivum/Tr. Spelta*: LPP 1197, LPP 3117, LPP 1304, LPP 1224, LPP 3122/2, P 3, LPP 3132, LPP 3373, LPP 1221. Lines NAK 34/12-2 and NAK 22/12 obtained by hybridization of *Tr. aestivum*/amphiploid (*Tr. durum/Ae. tauschii*). Line TV 1100 obtained by hybridization of *Tr. aestivum* (Kharkivska 26 variety)/ *Tr. kiharae* with a selection of winter forms. Grain was grown in conditions of the right-bank forest-steppe zone of Ukraine. As a standard (check) sample, Zoria Ukrainy (st) zoned spelt variety was used.

The materials and methods used to conduct the study are described in more detail in [19].

5. Results obtained in the study of indicators of grain and flour quality

It has been determined that protein content in spelt grain varies in a range from 14.0 to 22.5 % depending on variety or line (Table 1). In the grain of varieties, it was from 15.0 % to 17.6 % or 22–33 % less in comparison with the standard sample having 22.5 %. The content of protein in the grain of lines obtained by hybridization of *Triticum aestivum/Triticum spelta* was 12–38 % lower compared to the standard sample. Its highest content was formed in the grain lines P 3, LPP 3132, LPP 3373, LPP 1221 (16.4–19.8 %), and the lowest in LPP 3117, LPP 1224 and LPP 3122/2 (14.0–15.1 %) lines. Protein content in the grain of the introgressive lines was from 14.6 to 18.4 % or 18–35 % lower than in the standard sample.

One of the main indicators of the bread-baking properties of wheat grain is gluten content which represents protein complex. The content of gluten in grain of spelt was found to be 29.2 to 44.9 % depending on variety or line. None of the varieties exceeded the standard sample which had 44.9 %.

The content of gluten was very high (more than 36.0 %) in the spelt grain of Zoria Ukrainy, Schwabenkorn and NSS 6/01 varieties and LPP 1221 and TV 1100 lines, high (31.0–35.9 %) in Swedish 1 and low (21.0–25.9 %) in LPP 3117 and LPP 1197 lines. In the grain of other varieties and lines, this indicator was at an average level of 26.0–30.9 %. Origin of varieties and lines did not affect the content of gluten because there was grain with high and medium gluten contents in each group of the investigated spelt forms.

Table 1

Content of protein and gluten in spelt grain depending on variety and line, %

Variety, line	Content of			
	protein		gluten	
	in grain	± to the standard	in grain	± to the standard
Zoria Ukrainy (st)	22.5	0.0	44.9	0.0
Swedish 1	15.0	–7.5	31.6	–13.3
NSS 6/01	15.8	–6.7	42.1	–2.8
Schwabenkorn	17.6	–4.9	40.1	–4.8
LPP 3122/2	14.0	–8.5	32.0	–12.9
LPP 3117	14.1	–8.4	29.2	–15.7
LPP 1197	14.6	–7.9	29.2	–15.7
LPP 1224	15.1	–7.4	31.6	–13.3
LPP 1304	15.4	–7.1	30.8	–14.1
P 3	16.4	–6.1	32.8	–12.1
LPP 3132	16.5	–6.0	32.9	–12.0
LPP 3373	17.6	–4.9	35.2	–9.7
LPP 1221	19.8	–2.7	43.6	–1.3
NAK34/12-2	14.6	–7.9	29.2	–15.7
NAK 22/12	17.4	–5.1	34.8	–10.1
TV 1100	18.4	–4.1	36.8	–8.1
LSD_{05}	0,8	–	1.6	–

Four of 16 varieties and lines of spelt under study had a satisfactorily weak gluten and in the rest, it was unsatisfactorily weak (Fig. 1). It should be noted that the grain of NAK 34/12-2 line had gluten content of 29.2 %. The deformation index was 86 units which is not typical for spelt. It has led to recombigenase in the wheat genome as a result of hybridization with the amphiploid (*Triticum durum/ Ae. tauschii*). Grain of the Swedish 1 variety (101 units) and LPP 3132 line (101 units) was close to the indicator of satisfactorily weak gluten.

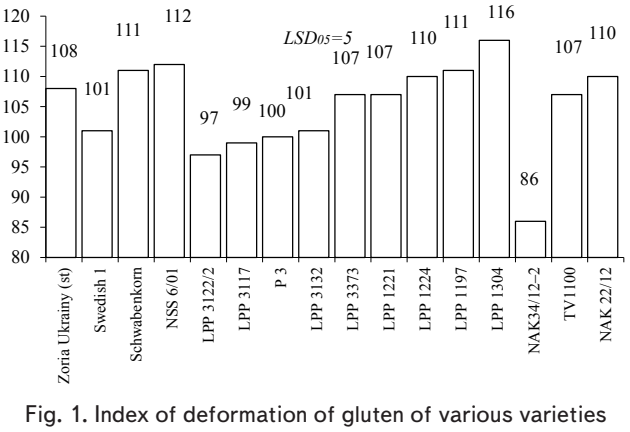

Fig. 1. Index of deformation of gluten of various varieties and lines of spelt, units

Strength of flour of the studied spelt varieties and lines was within 97–248 min (Fig. 2). Grain of the Schwabenkorn variety and LPP 3117, P3, NAK 34/12-2 lines had the highest flour strength (129–248 min). Swedish 1 and NSS 6/01

varieties and LPP 1221, NAK 22/12 lines had the lowest flour strength (40–45 min).

Wheat flour is considered to be of very high strength if a dough ball remans stable in water for more than 150 min. Respective figures are 100–150 min for high strength, 60–100 min for medium strength, 30–60 min for low strength and ≤30 min for very low strength.

Very high strength (248 min) of flour had the NAK34/12-2 line. Values 121, 129 and 132 min were observed, respectively, for Schwabenkorn variety and LPP 3117 and P 3 lines which were characterized by high flour strength. Flour of spelt of LPP 1224, LPP 3373, LPP 3132 lines and Zorya Ukraine variety had average values (between 62 and 97 min). The rest of the studied samples had low flour strength of 40–57 min which is 41–59 % lower than that of the standard sample.

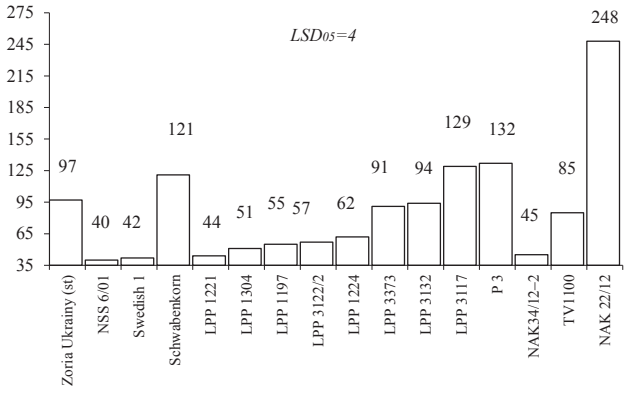

Fig. 2. Strength of spelt flour of various varieties and lines as determined by stability of dough balls in water, min

Between the index of gluten deformation and strength of spelt flour, a high correlation was established (r= =−0.80±0.007) which is described by the regression equation y=−2.9508x+386.37 where y is the flour strength (min), x is the index of gluten deformation (units) (Fig. 3).

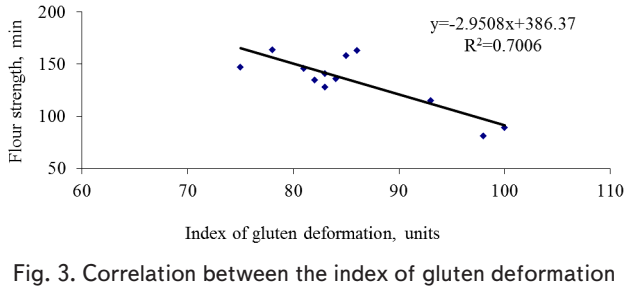

Fig. 3. Correlation between the index of gluten deformation and the flour strength

The fall number indicator of the dough prepared of flour of spelt of Zoria Ukrainy variety was 412 s (Fig. 4).

The vast majority of varieties and lines of spelt had lower values which varied from 394 to 416 s, however difference between them was insignificant. Indicators of three lines (LPP 3117, NAK34/12-2, NAK 22/12) were 389, 379 and 388 s, respectively that was 6–8 % lower than those of the standard sample.

Consequently, activity of alpha-amylase in the grain of the studied spelt varieties and lines was low. Therefore, this enzyme did not worsen the grain baking properties.

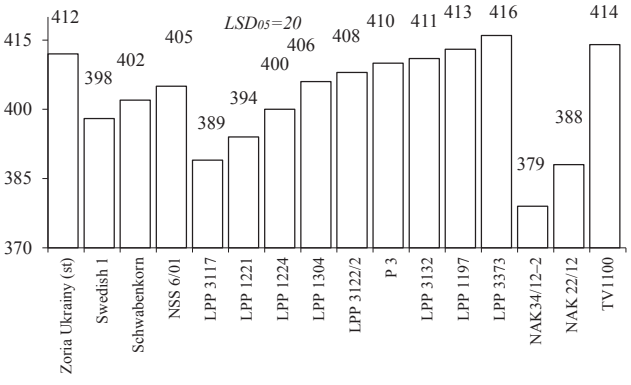

Fig. 4. Fall number of grain of various varieties and lines of spelt, s

The gas-holding capacity is considered very high if this indicator is ≥475 cm^3, high at 425–474 cm^3, average at 375–424 cm^3, low at 325–374 cm^3, very low at ≤323 cm^3.

The gas-holding capacity of dough prepared of spelt flour at fermentation period of 30 min was very low for all studied varieties and lines and was within the range of 95–230 cm^3/100 g (Table 2).

Table 2

Gas-holding capacity of dough prepared of flour of spelt of various varieties and lines depending on the fermentation period, cm^3/100 g

Variety, line	Fermentation period, min					
	30	60	90	120	150	180
Zoria Ukrainy (st)	215	450	555	420	390	185
Swedish 1	95	487	369	325	270	105
Schwabenkorn	118	400	417	386	342	234
NSS 6/01	110	425	450	408	255	207
LPP 1304	189	356	287	174	150	113
LPP 1221	174	405	321	214	163	120
LPP 3373	187	418	342	213	174	116
P 3	142	297	408	374	302	243
LPP 1197	115	396	410	378	210	117
LPP 3122/2	138	289	413	387	203	176
LPP 3117	110	485	415	367	300	180
LPP 1224	110	389	420	375	296	115
LPP 3132	115	395	487	390	241	141
TV 1100	208	416	348	285	197	123
NAK 22/12	230	434	404	327	201	104
NAK34/12–2	138	364	498	513	402	341
LSD_{05}	*6*	*18*	*21*	*13*	*11*	*8*

At fermentation period of 60 min, the very high gas-forming capacity was observed in the Swedish 1 variety and the LPP 3117 line with 487 and 485 cm^3/100 g, respectively. In spelt of Zoria Ukrainy variety and NSS 6/01 and NAK 22/12 lines, the studied indicator corresponded to 450, 425 and 434 cm^3/100 g, respectively, that is, the gas-holding capacity was high. The average figure of 395–418 cm^3/100 g was observed in the Schwabenkorn variety and LPP 1197, LPP 1224, LPP 3132, LPP 3373, LPP 1221, TV 1100 lines. Two lines had a low gas holding capacity of 356–364 cm^3/100 g and the rest were characterized by a very low indicator.

Maximum dough gas-holding capacity was after 90 min of fermentation. For example, a very high gas-holding capacity was found in the Zoria Ukrainy variety and LPP 3132, NAK 34/12-2 lines. High indicator of 450 cm^3/100 g was observed in the NSS 6/01 line. Average figures (404–420 cm^3/100 g) were found in seven lines. The Swedish 1 variety and LPP 3373 and TV 1100 lines had 369 and 348 cm^3/100 g gas-holding capacity, respectively. The smallest fermentation period (287 and 321 cm^3/100 g) was in the LPP 1304 and LPP 1221 lines. However, after fermentation of dough during 120 min, gas-holding capacity was the highest in the NAK34/12-2 line and amounted to 513 cm^3/100 g.

Among the investigated spelt forms, high volume of bread baked of prime flour was observed for Zoria Ukrainy variety and NAK34/12-2 line: 523 and 484 cm^3, respectively, or 7.0–7.6 points (Table 3). Average figures were found in Swedish 1 variety and LPP 3132, LPP 3117 lines. Their values were within 454–462 cm^3.

Table 3

Volume of bread of prime and dark flour of various spelt varieties and lines

Variety, line	Volume of bread baked of							
	prime flour				dark flour			
	cm^3	± to st.	points	± to st.	cm^3	± to st.	points	± to st.
Zoria Ukrainy (st)	523	–	7.6	–	470	–	5.8	–
Schwabenkorn	372	–151	3.6	–4.0	302	–168	1.0	–4.8
NSS 6/01	384	–139	3.6	–4.0	311	–159	1.0	–4.8
Swedish 1	454	–69	5.6	–2.0	417	–5.3	5.2	–0.6
LPP 1304	303	–220	1.0	–6.6	283	–187	1.0	–4.8
LPP 1224	318	–205	1.0	–6.6	282	–188	1.0	–4.8
LPP 1221	347	–176	3,2	–4,4	294	–176	1,0	–4,8
P 3	364	–159	3.4	–4.2	300	–170	1.0	–4.8
LPP 3122/2	374	–149	3.6	–4.0	270	–200	1.0	–4.8
LPP 1197	380	–143	3.6	–4.0	305	–165	1.0	–4.8
LPP 3373	380	–143	3,6	–4,0	328	–142	3,0	–2,8
LPP 3132	460	–63	5.8	–1.8	399	–71	3.8	–2.0
LPP 3117	462	–61	5.8	–1.8	401	–69	3.0	–2.8
NAK 22/12	330	–193	3.0	–4.6	281	–189	1.0	–4.8
TV 1100	382	–141	3.6	–4.0	302	–168	1.0	–4.8
NAK34/12–2	484	–39	7.0	–0.6	392	–78	3.8	–2.0
LSD_{05}	*21*	–	*0.2*	–	*17*	–	*0.1*	–

Low bread volume (380-384 cm^3) was obtained for NSS 6/01 variety and LPP 1197, LPP 3373, TV 1100 lines. The rest of varieties and lines of spelt have given volume of bread of prime flour varied from 303 to 374 cm^3 which corresponded to a very low indicator (1.0–2.6 points).

Volume of bread baked of dark flour was 10–20 % lower compared with the volume of bread baked of prime flour. The average volume was obtained for the bread baked of dark flour of Zoria Ukrainy variety: 470 cm^3, low volume was observed for flour of Swedish 1 variety and LPP 3132, LPP 3117, TV 1100 lines which corresponded to 2.8–3.2 points. The rest of wheat forms have shown very low values of 270–328 cm^3 or 142–200 cm^3 less in comparison with the standard sample.

It was calculated that flour strength had the highest influence on the volume of bread baked of dark flour because a direct significant correlation (r=0.67 ±0.007) was established between these indicators. For the prime flour, a high correlation (r=0.71 ±0.005) was found which is described by the following regression equations: y=0.84432x+321.4 for the bread of prime flour; y=0.84432x+321.4 for the bread of dark flour where y is the volume of bread, cm^3; x is strength of flour, min.

Indicator of convexity of form of the bread baked of the prime flour was the highest for spelt of Zoria Ukrainy variety and NAK 34/12-2 line: 0.49 and 0.54, respectively which corresponded to 5.0 points (Table 4). The Swedish 1 variety and five lines were within the range of 0.30–0.43 or 4.0–5.0 points. For the rest of the studied forms, the indicator of convexity of bread form was significantly less than for the standard sample (0.08–0.29) corresponding to 2.0–4.0 points.

Indicator of convexity of the bread baked of dark flour of spelt of Zoria Ukrainy variety was 0.37 which corresponded to 4.0 points. Significantly higher indicators were found for P 3, NAK34/12-2, LPP 3122/2 lines: 0.38–0.51 (1.0–5.0 points). In the Swedish 1 variety and five lines, the indicator of bread convexity varied from 0.27 to 0.37 or from 3.0 to 4.0 points. In other varieties and lines, it was significantly less than in the standard sample: 0.07–0.21.

Between convexity of the form bread baked of prime flour and the bread baked of dark flour, a high direct correlation was established: (r=0.71±0.007–0.72 ±0.009). It is described by the following regression equations: y=0.0019x+0.1053 for the bread baked of prime flour; y=0.0018x+0.0927 for the bread baked of dark flour where y is convexity of bread; x is the strength of flour, min.

However, the index of gluten deformation had the strongest influence on convexity of bread since there is a very high inverse correlation between these indicators (r= =–0.90±0.006–0.91±0.009) described by the following regression equations: y=–0.0167x+2.0281 for the bread baked of prime flour; y=–0.016x+1.935 for the bread baked of dark flour where y is convexity of bread; x is index of gluten deformation, units (Fig. 5).

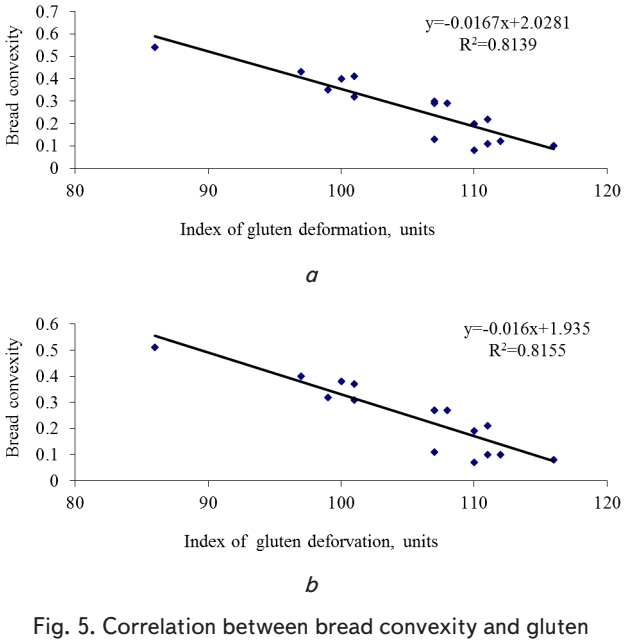

Fig. 5. Correlation between bread convexity and gluten deformation index of spelt: bread baked of prime flour (*a*); bread baked of dark flour (*b*)

Estimation of surface of the bread baked of prime flour of various spelt varieties and lines was made according to the following indicators: crust color, crust surface, surface glossiness.

According to the indicator of the bread crust color, all studied varieties and lines had an estimate of 9 points (Table 5). Crust surface of the bread baked of Swedish 1 variety and LPP 3117, LPP 3122/2, P 3, LPP 3132, NAK 34/12-2 lines was estimated at 9 points. The variety of spelt taken as standard and the rest of varieties and lines have got 7 points each. Gloss covered the entire surface of the bread baked of flour of Zoria Ukrainy, Schwabenkorn varieties and LPP 3373, LPP 1221, NAK 22/12, TV 1100 lines had estimate of 9 points. In the bread baked of flower of LPP 1304, LPP 1224, P 3, LPP 3132 lines, gloss covered only 50 % of the crust surface and in the bread baked of the rest of forms, 25 % of the crust surface were covered with gloss which corresponded to 5 and 3 points, respectively.

Elasticity, aroma, taste, pore size, pore distribution uniformity, consistency during crumb chewing were very high and had estimate of 9 points each irrespective of the variety and the line but the remaining indicators varied significantly.

Table 4

Convexity of the form bread baked of various varieties and lines of spelt

Variety, line	Convexity of bread baked of							
	prime flour				dark flour			
		± to st.	points	± to st.		± to st.	points	± to st.
Zoria Ukrainy (st)	0.49	–	5.0	–	0.37	–	4.0	–
Schwabenkorn	0.12	–0,37	3.0	–2.0	0.10	–0.27	2.0	–2.0
NSS 6/01	0.22	–0.27	3.0	–2.0	0.21	–0.16	3,0	–1,0
Swedish 1	0.32	–0,17	4,0	–1,0	0,31	–0,06	4.0	0.0
LPP 1304	0,10	–0.39	3.0	–2.0	0.08	–0.29	1.0	–3.0
LPP 1224	0.11	–0.38	3.0	–2.0	0.10	–0.27	2.0	–2.0
LPP 1221	0.20	–0.29	3.0	–2.0	0.19	–0.18	2.0	–2.0
P 3	0.29	–0.20	4.0	–1.0	0.27	–0.10	3.0	–1.0
LPP 3122/2	0.30	–0.19	4.0	–1.0	0.27	–0.10	3,0	–1.0
LPP 1197	0.35	–0.14	4.0	–1.0	0.32	–0.05	4.0	0.0
LPP 3373	0.40	–0.09	5.0	0.0	0.38	0.01	4.0	0.0
LPP 3132	0.41	–0.08	5.0	0.0	0.37	0.00	4.0	0.0
LPP 3117	0.43	–0.06	5.0	0.0	0.40	0.03	5.0	1.0
NAK 22/12	0.08	–0.41	2.0	–3.0	0.07	–0.30	1.0	–3.0
TV 1100	0.13	–0.36	2.0	–3.0	0.11	–0.26	2.0	–2.0
NAK34/12–2	0.54	0.05	5.0	0.0	0.51	0.14	5.0	1.0
LSD_{05}	*0.02*	–	*0.2*	–	*0.01*	–	*0.2*	–

Table 5

Quality of the bread baked of prime flour of various spelt varieties and lines

Variety, line	Bread surface, points			Indicators of bread crumb, points							Overall estimate	
	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	points	%
Zoria Ukrainy (st)	9	7	9	5	9	9	9	5	9	9	8.0	89
Swedish 1	9	9	3	5	9	9	9	3	9	9	7.2	80
Schwabenkorn	9	7	9	9	9	9	9	7	9	9	8.2	91
NSS 6/01	9	7	3	7	9	9	9	5	9	9	8.2	91
LPP 1197	9	7	3	5	9	9	9	3	9	9	7.4	82
LPP 3117	9	9	3	9	9	9	9	3	9	9	7.6	84
LPP 1304	9	7	5	5	9	9	9	7	9	9	7.8	87
LPP 1224	9	7	5	5	9	9	9	7	9	9	7.8	87
LPP 3122/2	9	9	3	9	9	9	9	5	9	9	8.0	89
P 3	9	9	5	5	9	9	9	7	9	9	8.0	89
LPP 3132	9	9	5	5	9	9	9	5	9	9	8.0	89
LPP 3373	9	7	9	5	9	9	9	5	9	9	8.0	89
LPP 1221	9	7	9	7	9	9	9	7	9	9	8.2	91
NAK34/12–2	9	9	3	9	9	9	9	7	9	9	8,2	91
NAK 22/12	9	7	9	9	9	9	9	3	9	9	8,2	91
TV 1100	9	7	9	9	9	9	9	5	9	9	8.4	93
LSD_{05}	1	1	1	1	1	1	1	1	1	1	0.4	–

*Notes: * – 1 – crust color; 2 – crust surface; 3 – gloss surface area; 4 – crumb color; 5 – elasticity; 6 – aroma; 7 – taste; 8 – pore size; 9 – uniformity of pore distribution; 10 – consistency*

For example, by color, 9-point estimate was given to the bread baked of flour of LPP 1197, LPP 1224, NAK 34/12-2, NAK 22/12 lines and the Schwabenkorn variety. Crumb of the bread baked of flour of NSS 6/01 variety and LPP 3132 line was light with a yellow shade and had estimate of 7 points. For the rest of studied weat forms, it was light yellow which corresponded to 5 points.

By the indicator of the crumb pore size, spelt forms varied greatly. For example, the bread baked of flour of Swedish 1 variety and LPP 3117, LPP 3122/2, P3, LPP 3132, NAK34/12-2 lines had fine thin-walled pores among which quantity of middle thick-walled pores amounted to 25 %, which corresponded to 7 points. The indicator corresponding to 5 points (50 % of middle thick-walled pores) was found in Zoria Ukrainy and Schwabenkorn varieties and LPP 1224, LPP 3373, LPP 1221, TV 1100 lines. The rest had the worst estimate of the crumb pore size and made up 3 points.

The overall estimate of quality of the bread baked of prime flour was very high in three varieties and eight lines of spelt: 8.0–8.4 points or 89–93 % of the maximum value. Lower values were found in LPP 1197, LPP 3117, LPP 3122/2 – 7.6–7.8 lines. Estimate of the bread baked of flour of NSS 6/01 variety and LPP 1304 line was 7.2–7.4 points, which was significantly lower than for the standard sample but remained high.

The indicator of crust surface of the bread baked of flour of Swedish 1 variety and LPP 3117, LPP 3122/2, P 3, LPP 3132, NAK34/12-2 lines was the highest: 9 points (Table 6). Surface of the bread baked of flour of the remaining varieties and lines was quite smooth with lone bubbles and cracks that did not cross the entire surface (estimate of 7 points).

Indicators such as elasticity, smell, taste, uniformity of pore distribution in the bread baked of dark flour of the studied varieties and lines were the highest: 9 points.

Pores size in the bread baked of dark flour of spelt of Swedish 1 variety and five lines (LPP 3117, LPP 3122/2, P 3, LPP 3132, NAK34/12-2) had an estimate of 9 points. For the rest of bread samples, this indicator estimate was 7 points.

The overall estimate of quality of the bread baked of dark flour was very high: from 8.3 to 9.0 points. The bread baked of flour of Swedish 1 variety and LPP 3117, LPP 3122/2, P 3, LPP 3132, NAK34/12-2 lines had estimate of 9.0 points and the rest of spelt forms had the overall estimate lower by 8 %.

6. Discussion of results obtained in the study of quality indicators of the bread baked of the spelt flour

The technology of preparing dough from the spelt flour differs from that known for flour of soft wheat in which starch grains are firmly bound to the protein matrix. This reduces the attack ability of starch by enzymes. Therefore, fermentation of dough prepared of spelt flour lasts for a shorter time compared with soft wheat [23]. In addition, 20 % less carbon dioxide is formed during fermentation [24]. Although studies by other scientists [25] suggest that the bread baked of spelt flour has a high volumetric yield, regular shape, cream color of crust with pleasant taste and aroma. Its crumb has a granular and somewhat coarse structure compared with the bread baked of soft wheat. Products of spelt flour have crispy crust and dense crumb [26]. Obviously, the above-mentioned feature of connection between starch and protein is not inherent to all varieties and forms of spelt.

According to calculations, glossiness and the overall quality of the bread baked of prime flour are most affected by protein content. A direct high correlation was established between these indicators: r=0.83±0.007–−0.84±0.005 (Table 7).

Table 6

Quality of bread baked of dark flour of various spelt varieties and lines

Variety, line	Indicator, points						Total estimate	
	1*	2*	3*	4*	5*	6*	points	%
Zoria Ukrainy (st)	7	9	9	9	7	9	8.3	92
Schwabenkorn	7	9	9	9	7	9	8.3	92
NSS 6/01	7	9	9	9	7	9	8.3	92
Swedish 1	9	9	9	9	9	9	9.0	100
LPP 1197	7	9	9	9	7	9	8.3	92
LPP 1304	7	9	9	9	7	9	8.3	92
LPP 1224	7	9	9	9	7	9	8.3	92
LPP 3373	7	9	9	9	7	9	8.3	92
LPP 1221	7	9	9	9	7	9	8.3	92
LPP 3117	9	9	9	9	9	9	9.0	100
LPP 3122/2	9	9	9	9	9	9	9.0	100
P 3	9	9	9	9	9	9	9.0	100
LPP 3132	9	9	9	9	9	9	9.0	100
NAK 22/12	7	9	9	9	7	9	8.3	92
TV 1100	7	9	9	9	7	9	8.3	92
NAK34/12–2	9	9	9	9	9	9	9.0	100
LSD_{05}	*1*	*1*	*1*	*1*	*1*	*1*	*0.4*	–

*Notes: * – 1 – crust surface; 2 – crumb elasticity; 3 – aroma; 4 – taste; 5 – pore size; 6 – uniformity of pore distribution*

The content of gluten affected these indicators somewhat less: r=0.63±0.006–0.64±0.009. A substantial inverse correlation was established between the crust surface and protein and gluten content: r=–0.53±0.007–0.54±0.004.

Table 7

Correlation between baking qualities of wheat grain and the bread quality

Indicator	Protein content, %	Gluten content, %	Index of gluten deformation, units	Flour strength, min
Bread baked of prime flour				
Volume, cm^3	0.17	0.11	–0.57	0.71
Glossiness, points	0.84	0.64	0.41	–0.25
Crust surface, points	–0.53	–0.54	–0.87	0.57
Pore size, points	–0.21	–0.30	–0.84	0.61
Overall estimate, points	0.83	0.63	–0.82	0.69
Bread baked of dark flour				
Volume, cm^3	0.24	0.12	–0.41	0.64
Crust surface, points	–0.51	–0.54	–0.85	0.55
Pore size, points	–0.51	–0.54	–0.85	0.57
Overall estimate, points	–0.50	–0.52	–0.83	0.60

All indicators of bread quality were influenced by the index of gluten deformation. For example, according to the overall estimate, there was a strong inverse correlation (r= =–0.82±0.007-0.87±0.008) between this indicator, crust surface and pore size. An essential correlation was established with the volume of bread (r=–0.57±0.008) and a moderate direct correlation with the bread glossiness (r=0.41±0.009). The bread volume was most influenced by flour strength since a strong direct correlation was found (r=0.71±0.005) and a significant correlation was found for the bread crust surface, pore size and overall estimate.

Similarly, index of gluten deformation and flour strength influenced quality of the bread baked of dark flour. However, an essential inverse correlation between the crust surface, pore size, overall estimate of the bread quality and content of protein and gluten r=–0.50±0.007-0.54±0.005 was found.

It should be noted that the correlations found between baking indicators are valid for the varieties and lines of spelt used in the experiment. However, these parameters may differ for new genotypes of this crop. Therefore, the study of technological properties of grain of new forms of spelt with altered selection and genetic properties is promising.

7. Conclusions

1. Protein content in spelt grains varies from 15.0 % to 22.5 % for varieties and from 14.0 % to 19.8 % for lines. Gluten content does not depend on the origin of varieties and lines. It amounts to 31.6–44.9 % in grain varieties and 29.2–43.6 % in lines. Technological properties of grain of introgressive lines are similar to those of grain of interspecies spelt lines.

2. Gluten deformation index for grain of spelt varieties and lines varies from 97 to 116 units and the fall number from 389 to 416 s. Baking properties of spelt differ from soft wheat since the maximum gas-holding capacity of the dough prepared of spelt flour comes after 60–90 minutes of fermentation and then rapidly decreases. Dough prepared of flour of Zoria Ukrainy, NSS 6/01 and NAK34/12-2 varieties had the highest stability during fermentation.

3. Volume of the bread baked of prime flour was from 303 to 523 cm^3 which corresponded to 1.0–7.6 points and that for dark flour 270 to 470 cm^3 depending on the spelt variety and line. Its quality was high in all samples: 7.2–8.4 points or 80–93 % of the maximum value. The bread baked of flour of Zoria Ukrainy variety and LPP 3132, NAK34/12-2 and TV 1100 lines was of the highest quality. The overall estimate of quality of the bread baked of dark flour was very high (8.3–9.0 points), while bread baked of flour of Swedish 1 variety and LPP 3117, LPP 3122/2, P 3, LPP 3132, NAK34/12-2 lines had the highest quality: 9.0 points.

4. Glossiness of bread surface and its overall estimate were influenced by protein content in the grain. Gluten content affected bread quality somewhat less. Besides, crust surface, pore size and overall estimate of the bread quality were also affected by the gluten deformation index. The bread baked of flour of Zoria Ukrainy variety and LPP 3132, NAK34/12-2 and TV 1100 lines had the highest overall culinary estimate.

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