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INVESTIGATION OF QUALITY INDICATORS OF WHOLEMEAL INDUSTRIAL-MADE FLOUR

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Abstract. The article shows the benefits of consuming wholemeal products. However, the level of consumption of these products is low. The reason is primarily the low quality of products: the rough structure of the crumb, rapid hardening. Therefore, there is a need to improve the quality of bread from wholemeal flour. The indicators of quality of wholemeal flour produced by national enterprises are investigated in the work. Analysis of packaging and labeling of test samples of wholemeal flour (according to the manufacturer) showed that some of them are produced in accordance with GSTU 46.004-99 ("Wheat flour. Specifications"), and the quality of other samples is controlled by the manufacturer's own specifications. It should be noted that there are no Ukraine's standards for wholemeal wheat flour. Standard GSTU 46.004-99 ("Wheat flour. Technical conditions") apply only to wheat graded and dark flour. It was found that the ash content of the studied samples of whole-meal flour (WMF) from wheat and spellta grain is in the range of 0.80–1.46%; paricle size: the residue on the sieve No. 067 – within 0.1–1.7%, the passage of the sieve No. 38 – within 12–34%. The influence of particle size and gluten of wheat and spelta whole-meal flour on its baking properties has been studied. It has been found increasing the volume and porosity of the bread while the particle size decreases. The largest bread volume (400–460 cm^3) and porosity (67–68%) had the samples of flour with the smallest particle size (sieve residue No. 067 not more than 1 %, sieve passage No. 38 more than 15–20 %). For samples with a larger particle size (sieve passage No.38 – not more than 15–20 %), the volume of bread and its porosity decreased by 1.2–1.3 and 1.1–1.2 times, respectively. Analysis of gluten quantity and quality effect showed that a rather high quality of wholemeal bread from wheat WMF can be obtained with a crude gluten content in flour of at least 24–26% with a gluten quality of Gluten deformation index (GDI) in a range of 60–80 units. For the production of bread from spelta WMF it is recommended to use WMF with a crude gluten content of at least 30% with a gluten quality GDI in a range of 60–100 units.

Key words: wholemeal flour, wheat, spelta, milling, baking properties, quality indicators, rheological properties.

Introduction. Formulation of the problem

A large number of current world global and national regulations about healthy lifestyle promotion ensure human rights about keep and increase human health [1,2]. In this context, it is especially important to introduce innovations in the food processing industry, which requires newly created or improved innovative technologies and the production of food products with new consumer and quality functional properties [3].

The products of mass consumption, that keep a leading place in the daily diet of the population of our country, are bakery. But due to the refined composition of the main component of their recipe – wheat flour of the highest grade – the biological value of bread is reduced. Grain processors face the task of creating a rather simple and reliable enrichment technology that will ensure the preservation of natural nutrients in wheat flour [4].

Analysis of recent research and publications

More and more research confirms that regular consumption of whole grains can help reduce the risk of many diseases, especially chronic ones, such as certain types of cancer, type 2 diabetes, etc. [5-10]. However, despite the proven benefits of WGF

products, their consumption is still much lower than the recommended level [11-15]. Kuznetsof et al. [16] consider the main reasons for this a traditional taste preferences, the complexity of cooking from WMF, their price, weak range availability in trade network. A constraining factor in the production of wholemeal flour is the lack of efficient technology that could be easily implemented in modern high-performance mills, as traditional outdated technology is based on the use of low-performance energy-intensive stone millstones [17-21]. However, the development of modern industrial technology for the production of WMF in mills is urgent.

Currently, global research on WMF is carried out in the following aspects:

- unification and standardization of the term "whole grain product", including "whole meal flour" [22-25]. Moreover, the United States has already standardized at the state level the definition of the term WMF and the requirements for the size of its particles [25];
- increasing the shelf life of WMF [37-38];
- improvement of baking properties of WMF [39-42];
- development of effective industrial technology, its structure and selection of modes equipment of pre-treatment department (modes of tempering stage, the degree of grain surface cleaning) and grinding department (type of grinding equipment, particle size of grinding products, etc.) [26-36].

There is an interest on the part of small enterprises and farms in millstones [35,36], despite the WMF baking properties lowering proved by scientists [31-33,38]. Some scientists consider more promising way as the multithreaded classical grinding of prepared grain in roller machines with the combination of all product streams at the end of grinding to recombine the chemical composition of whole grains [34]. However, there is no clearly established nature of the impact of the grain grinding system on the WMF baking properties [33].

Thus, the analysis of the quality of WMF, which is produced by national enterprises, and its bakery properties is relevant.

The purpose of the work is to substantiate the requirements for quality indicators of wholemeal wheat and spelta flour.

To achieve this goal it is necessary to solve the following **tasks**:

- to study the quality indicators of WMF produced by national enterprises;
- to determine the physico-chemical parameters of bread from the studied samples of WMF;
- to establish the rheological properties of the dough obtained from the studied samples of WMF.

Research materials and methods

The study examined wolemeal flour from wheat and spelta grain, made in industrial conditions according to different technological schemes (Table 1). Moreover, according to the manufacturer's information on the package, samples No. 1-8 are made in roller machines, No. 9-13 – in stone grinding systems. Most of the studied samples, except for samples No. 3, 6, 9, were studied during 2020 and 2021, monthly in 3 parallels (results are averaged).

Technological properties of grain and flour were determined using standardized methods.

The moisture content was determined according to ISO 712. 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 to 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 GDI was measured on a gluten deformation meter IDK-M.

The study of the baking properties of flour was carried out using the direct method, ie the evaluation of the quality of flour by trial baking.

Table 1 – Information on the studied samples of WMF

Sample No.	Product Name	Manufacturer, year	Grinding type	Standard document indicated on packing
1	Wheat dark WMF	TM «Kosub», 2020	Roller grinder	GSTU 46.004-99
2	Wheat dark WMF	TM «Kosub», 2021	Roller grinder	GSTU 46.004-99
3	Wheat organic coarse flour	TM «Ecorod», 2021	Roller grinder	GSTU 46.004-99
4	Wheat WMF	TM «Alta-vista», 2020	Roller grinder	GSTU 46.004-99
5	Wheat WMF	TM «Alta-vista», 2021	Roller grinder	GSTU 46.004-99
6	Wheat WMF	TM «Sto pudov», 2021	Roller grinder	GSTU 46.004-99
7	Wheat dark WMF	TM «Svoya liniia», 2020	Roller grinder	TU U15.6-00952737-006:2002
8	Wheat dark WMF	TM «Svoya liniia», 2021	Roller grinder	TU U15.6-00952737-006:2002
9	Spelta WMF	TM «Lavka tradizii», 2021	Stone grinder*	GSTU 46.004-99
10	Wheat WMF	TM «Lavka tradizii», 2020	Stone grinder*	GSTU 46.004-99
11	Wheat WMF	TM «Lavka tradizii», 2021	Stone grinder*	GSTU 46.004-99
12	Spelta WMF	TM «Zeleny mlyn», 2020	Stone grinder*	GSTU 46.004-99
13	Wheat WMF	TM «Zeleny mlyn», 2021	Stone grinder*	GSTU 46.004-99

* from manufacturer's information

A baking test of the laboratory bread was carried out to evaluate comprehensively the baking properties of flour according to GOST 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. Bread quality estimation was made by physical parameters according to GOST 27669.

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.

Results of the research and their discussion

Analysis of packaging and labeling of test samples (according to the manufacturer) showed that the flour samples No. 1-6, 9-13 are produced in accordance with GSTU 46.004-99 «Wheat flour. Technical conditions», the quality of flour samples No. 7.8 is controlled by own technical conditions of the manufacturer. It should be noted that Ukraine's standards for wholemeal wheat and spelta flour are currently lacking. GSTU 46.004-99 «Wheat flour. Technical conditions» apply only to wheat graded and dark flour.

It was found that the moisture content of the tested samples of WMF did not exceed 15.0%, which meets the requirements for baking wheat flour. The lowest moisture content was observed in samples No. 12 and 13 (Table 2), which is explained by the lack of preliminary tempering of grain before grinding and higher temperatures experienced by the grain when grinding between grindstone, which is consistent with [34]. Higher values of moisture content of other samples of stone grinding flour (samples No. 9-11) indicate the presence of the stage of tempering treatment before grinding, because they are made by one manufacturer. In any case, almost all investigated samples of stone grinding flour, except for sample No. 9, have lower values of moisture than samples of flour obtained after grinding in roller machines. In addition, it can be noted that all samples of the studied flour produced in 2020 have a slightly lower moisture content than the samples of 2021 production.

The ash content of the studied samples of WMF of national production from wheat and spelta grain was in the range of 0.80–1.46%. The maximum ash content is almost at the level of whole wheat or spelta grain in sample No. 4, which is explained by the recombination step correctly performed by the manufacturer, which was neglected by other manufacturers of WMF grinded on rollers, especially for samples No. 3 and 8 ash content is almost twice less than the ash content of whole grain. The same applies to stonegrinded samples No. 9 and 11 (from the same manufacturer). That is, to name these samples of WMF is an error, according to the values of quality indicators, they are really close to the 2nd clear flour. There are unreasonal minimum values of ash content in the stonegrinded samples No. 9 and 11, according to the traditional technology of such milling, which occurs in one stream and in one pass without loss of mass and separation into intermediate products of grinding. Probably there is either information falsification by this manufacturer and flour obtained not with the help of stone grinders, or this type of equipment is used, but only partially: the main technology is performed by classic dark milling using roller machines, but without recombination stage. To confirm one of the assumptions, the particle size of the WMF samples should be determined.

Table 2 – Quality indicators of the studied samples of flour obtained in production conditions (n=3, p≥0.95)

Sample No.	Moisture content, %	Ash content, %	Particle size, %	
			residue on sieve No.067	passage of sieve No.38
1	12.6	1.39	0.5	21
2	13.1	1.00	0.6	13
3	11.5	0.95	–	34
4	12.2	1.46	1.5	29
5	13.2	1.10	0.4	12
6	11.7	1.23	0.1	24
7	12.5	1.22	0.5	22
8	13.5	0.90	–	24
9	13.2	0.80	0.1	17
10	11.5	1.08	0.3	18
11	11.8	0.90	1.7	13
12	10.8	1.01	0.5	12
13	11.5	1.24	0.2	18
GSTU 46.004-99 requirements to quality indicators of wheat dark flour	No more than 15.0	No more than 2.0	No more than 2.0	Not less than 35.0

The particle size of coarse flour (dark wheat flour) according to Ukrainian standards is controlled by two sieves: the residue on the sieve No. 067, and the passage of the sieve No. 38, while in the US use the following requirements for particle size: not less than 90 percent passes through a 2.36 mm (No. 8) sieve and not less than 50 percent passes through a 850 μm (No. 20) sieve [26]. The size of the studied samples of WMF differed sharply even for the same manufacturer, so for samples No. 4, 5 the residue on the sieve No. 067 was in the range of 0.4–1.5%, in samples No. 3, 8 – was absent, and in other samples it ranged from 0.1 to 1.0%. The highest content of fine fraction of flour (sieve passage No.38) within 29–34% was observed in samples No. 3, 4. In samples No. 1, 7 and 8 the content of the corresponding fraction of flour ranged from 20 to 25%, which is less than recommended by GSTU 46.004-99. The lowest content of fine fraction (up to 15%) was observed in samples No. 2, 5, 6, 11, 12.

One of the main guality indicators characterizing the baking properties of wheat flour is the quantity and quality of crude gluten (Table 3). The amount of gluten, as well as its quality depends on the varietal characteristics of the grain, the conditions of its growth, and the particle size of the flour. As for the quality of grain, the approach to the choice of raw materials from different producers is heterogeneous. Some producers get wholemeal flour from high-quality wheat, which leads to higher baking properties and high cost of such flour, others follow the approach of using cheaper weaker wheat. In addition to common bakery wheat, some producers use expensive spelta wheat grain, which increases the nutritional value of bread and also affects the baking properties of flour.

The content and quality of gluten in flour are crucial in determining the structural and mechanical properties of the dough and the baking properties of flour. According to the requirements of GSTU 46.004-99, the gluten content of the dark flour is limited to at least 18 %.

The highest content of gluten was observed in samples No. 5, 6 and 13 – 30 %, in samples No. 3, 8-12 the content of gluten is 27–29 %, in samples No. 1, 2, 4 and 7 the content of gluten ranges from 24 to 26 %.

The largest volume of bread was observed in the samples of wheat wholemeal flour No. 3, 6 and 8 (more than 400 cm^3). This is primarily due to the content and quality of gluten and the particle size of the flour of these samples (residue on the sieve No. 067 is absent or is 0.1 %). The porosity of bread is at the level of 60–68 %.

Good volume of bread (360–380 cm^3) was observed in samples No. 1, 12 and 13. For most of the studied samples of flour (No. 2, 4, 7, 9, 10, 11) the volume of bread amounted to 350 cm^3. The flour sample No. 5 had the smallest volume of bread among the studied samples, because it had the largest particle size (sieve passage No. 38 was 12%).

According to the requirements of GSTU 46.004-99 "Wheat flour. Specifications "for wheat dark flour gluten content should be at least 18%, gluten quality – not less than group II (satisfactory strong, good and rather weak group), so the GDI should be from 35 to 100 units. The quantity and quality of crude gluten in whole wheat flour on its baking properties showed that the best indicators (bread volume, porosity and specific volume of bread) were characterized by samples baked from flour with a gluten content at least of 24–26% and quality (GDI) 60–80 units. The studied samples of bread baked from flour with a specified content of gluten, but with a quality (GDI) of 80–100 units, had a lower volume of 1.2–1.3 and lower in 1.1–1.2 times the porosity. Excessive elasticity of gluten led to the fall of the dough in the oven. The use of flour with a crude gluten content of 24–26% and quality (GDI) of 40–60 units led to the production of bread with low specific volume and low porosity, worse structural and mechanical characteristics due to the increased strength of the gluten complex and reduce its elasticity.

Table 3 – Baking properties of the studied samples of WMF (n=3, p≥0.95)

Sample No.	Gluten		Bread volume, cm^3	Porosity, %	Specific bread volume, cm^3/g
	content, %	quality (GDI), units			
1	25	89	380	64	1.8
2	24	42	350	67	1.6
3	27	95	400	67	2.0
4	24	35	350	60	1.6
5	30	87	320	67	1.5
6	30	67	400	67	1.9
7	26	88	350	57	1.6
8	27	42	460	68	2.1
9	28	79	350	68	1.6
10	29	45	350	60	1.6
11	29	82	350	69	1.7
12	29	60	380	58	1.8
13	30	66	360	57	1.7

Further increase in the content of crude gluten in wheat wholemeal flour in the range of 27–30% did not significantly change the baking properties of the studied samples. For a group of samples with gluten quality (GDI) 40–60 units the volume of bread was from 350–460 cm^3. For samples of flour with gluten quality (GDI) 60-80 units the volume of bread was in the range of 350–360 cm^3, which is 1.2–1.3 times less than samples with similar quality of gluten, but its content in the range of 24–26%.

Studies have shown that a rather high quality of wholemeal bread made from whole wheat flour can be obtained with a crude gluten content in flour of at least 24–26% with a gluten quality (GDI) of 60–80 units.

Similar studies have been conducted for wholemeal spelta flour. Based on these studies, for the production of wholemeal bread from spelta grain, we can recommend flour with a crude gluten content of at least 30% with a gluten quality (GDI) of 60–100 units.

During the grinding of wheat grain, its anatomical parts are destroyed and different fractional sizes are formed: small particles, which consist of small and damaged starch grains, intermediate protein; larger ones are larger starch grains, individual fragments of endosperm cells, and even larger particles (cell complexes), parts of membranes. During the processing of grain into wholemeal flour it is necessary to achieve uniformity of grinding, ie to ensure the same degree of grinding of both central and peripheral particles of the grain. There is a close relationship between the particle size of the flour and the chemical composition of the flour, so the particle size of the flour directly affects its baking properties. According to the requirements of GSTU 46.004-99 "Wheat flour. Technical conditions" the particle size of wheat dark flour is controlled by the residue on the sieve No.067 (not more than 2%) and the passage of the sieve No.38 (not less than 35%).

Analysis of the effect of the particle size of wholemeal wheat and spelta flour on its baking properties showed that flour samples that had a high content of coarse fraction, although the content of fine fraction was sufficient, did not provide a high volume of bread and good porosity. The best baking properties were observed in flour with a lower content of coarse fraction (sieve residue No. 067 not more than 1%).

Determining the rheological properties of the dough allows you to reliably assess the quality of flour, because the properties of the dough are the result of the influence and interaction of all its substances. Thus, water absorption, dough formation time and stability of dough properties during its kneading are related to the content and quality of protein substances, and gelatinization and retrogradation of starch are determined by its content and condition.

The evaluation of the studied flour samples was performed on the basis of the standard protocol "Chopin +" of the Mixolab device. Based on the analysis of the indices of Mixolab profilers, it was found (Table 4) that the index of Water absorption capacity (WAC) of wholemeal flour from different manufacturers varies in a wide range from 1 to 8. This is due to the different particle size of the studied flour samples, different content of peripheral particles in flour, a feature of the milling diagram, ie the number of damaged starch grains. Samples with a higher water absorption index contain have more dietary fiber.

Interpreting the results of the analysis of flour samples on the device Miksolab, we can assume that the higher the water absorption index, the better the technological value of the sample. In general, more water absorption of flour leads to an increase in the specific volume and softness of the crumb, as well as less thickening of starch.

The kneading index depends on the behavior of the dough during kneading, especially on stability. The higher the index, the more stable the dough will be during kneading. For the production of bread in forms it is recommended to use flour with a kneading index value of 4-6. A high value of this parameter means better stability of the protein structure. This dough is characterized by high elasticity. This index directly depends on the protein content of the flour and can predict the volume of bread.

Table 4 – Indices of Mixolab profilers for test samples of wholemeal flour

Sample No.	Indexes					
	WAC	Kneading	Gluten+	Viscosity	Amylase	Retrogra-dation
1	4	4	4	4	8	8
2	1	5	8	8	9	8
3	1	3	2	7	8	8
4	1	6	8	7	9	8
5	7	2	8	8	6	6
6	8	6	7	8	8	8
7	7	5	6	7	5	4
8	8	4	8	7	3	8
9	3	2	8	8	6	8
10	4	3	8	8	7	6
11	3	3	6	8	7	6
12	6	5	6	6	7	7
13	7	4	3	7	2	7

The lowest kneading index (2) have samples No. 5 and 9. In samples No. 3, 8, 10, 11 and 13 the value of the kneading index was was a little higher – 3-4. The highest value of the kneading index (6) was observed in samples No. 2, 4, 6, 7 and 12 – 5-6.

The Gluten+ index depends on the relationships between gluten molecules and has a significant effect on the volume of the final product. High values of the Gluten+ index (8-9) indicate excessive strength or low ability of the protein complex to resist mechanical action (samples No. 2, 4, 5, 8, 9, 10). The values of the Gluten+ index (5-7) are optimal for flour with high

baking properties (samples No. 6, 11). Excessive elasticity of gluten, which can lead to the fall of dough pieces in the oven, and the Gluten+ index with a value below 5 are characterized by samples No. 1 and 3, the quality of crude gluten (GDI) in these samples is 89–95 units. At the same time, obviously, this index is associated with the amino acid composition of the protein, as well as with the modes of grinding systems and the milling diagram.

The Viscosity Index describes the phase where all physicochemical and biochemical processes are most active. At this stage, the main role is played by the structure of starch. The greatest impact is played by the degree of starch damage. While the lower the Viscosity Index, so the higher is the stability of the amylase enzyme test. The low value of the Viscosity Index is characteristic of flour with high amylase activity. In the studied samples the Viscosity index ranged from 4 to 8. The lowest value of the Viscosity Index (4) was observed in the flour sample No. 1, the viscosity index 6 was characterized by the sample No. 11. In other samples of WMF the viscosity index was 7-8.

The Amylase Index characterizes the amylolytic activity of α-amylase and is related to the Falling Number (FN). The high index of amylolytic activity of the device Mixolab corresponds to a high value of the FN. Samples No. 8 and 13 had the smallest value of the Amylase index (2-3), samples of No. 5, 8-12 were characterized by the value of the index 6-7. For other samples of WMF the Amylase index was 8-9.

The Retrogradation Index is directly related to the ability of the final product to resist hardening and retain its marketable appearance. The hardening of bread is directly related to the process of crystallization of starch (mainly the retrogradation of amylopectin), which after baking tends to return to the original form in which it was before baking. As a result, the crumb of products becomes hard and brittle, the crust loses its luster, the organoleptic properties of the product deteriorate. While the higher the value of this index, so the stronger the crystallization of starch. The lowest value of the Retrogradation Index (4) is given in the sample No. 7. For samples No. 5, 10 and 11 the Retrogradation Index had a value of 6, ie bread baked from such flour will retain freshness longer. All other samples of WMF have higher values – 7-8, which indicates a rapid process of hardening of bread.

Conclusion

Wheat and spelta WMF allows to expand the range and increase the nutritional value of end bakery products. There are no standards for wheat and spelta WMF today, so its quality on the national market varies widely. The ash content of the investigated WMF samples from wheat and spelta grain is in the range of 0.80–1.46%; particle size: the residue on the sieve No. 067 is in the range of 0.1–1.7%, the passage of the sieve No. 38 is in the range of 12–34%.

It is proved that a rather high quality of bread from wheat WMF can be obtained with a crude gluten content of at least 24–26% with a gluten quality (GDI) of 60–80 units. For the production of bread from spelta WMF it is possible to recommend flour with the content of crude gluten not less than 30% with quality of gluten (IDK) of 60–100 units.

It has been found that as the particle size of flour decreases, the volume and porosity of the bread increases. The largest volume (400–460 cm^3) and porosity (67–68%) had samples of flour with the smallest particle size (sieve residue No. 067 – not more than 1%, sieve passage No. 38 – more than 15–20%). For samples with a larger particle size (sieve passage No. 38 – not more than 15–20%), the volume of bread and its porosity decreased by 1.2–1.3 and 1.1–1.2 times, respectively.

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ДОСЛІДЖЕННЯ ПОКАЗНИКІВ ЯКОСТІ ЦІЛЬНОЗМЕЛЕНОГО БОРОШНА ПРОМИСЛОВОГО ВИРОБНИЦТВА

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Анотація. У статті показано користь споживання продуктів з цільнозмеленого борошна. Однак рівень споживання цих продуктів є низьким. Причиною є насамперед невисока якість виробів: груба структура м'якушки, швидке черствіння. Тому існує потреба поліпшення якості хліба з оббивного та з цільнозмеленого борошна. У роботі досліджено показники якості цільнозмеленого борошна, виробленого вітчизняними підприємствами. Аналіз пакування та маркування досліджуваних зразків цільнозмеленого борошна (за даними виробника) показав, що деякі з них вироблено згідно з ГСТУ 46.004-99 (Борошно пшеничне. Технічні умови), а якість інших зразків контролюється за власними технічними умовами підприємства виробника. Слід зазначити, що стандарти України на цільнозмелене пшеничне борошно на сьогоднішній день відсутні. Стандарт ГСТУ 46.004-99 «Борошно пшеничне. Технічні умови» розповсюджуються тільки на борошно пшеничне сортове та обойне. Встановлено, що зольність досліджуваних зразків ЦЗБ з зерна пшениці та спельти знаходиться у межах 0,80–1,46 %; крупність: залишок на ситі № 067 – в межах 0,1–1,7%, прохід сита № 38 – в межах 12-34%. Досліджено вплив показників крупності та клейковини цільнозмеленого пшеничного та спельтового борошна на його хлібопекарські властивості. Встановлено, що зі зменшенням крупності часток збільшується об'єм та пористість хліба. Найбільшим об'ємом (400–460 см^3) та пористістю (67–68%) володіли зразки борошна з найменшою крупністю (залишок на ситі № 067 – не більше 1 %, прохід сита № 38 – більше 15–20%). Для зразків з більшою крупністю часток (прохід сита № 38 – не більше 15–20%) об'єм хліба та його пористість зменшувались у 1,2–1,3 та 1,1–1,2 рази, відповідно. Аналіз впливу показників кількості та якості клейковини показав, що досить високу якість формового хліба з пшеничного цільнозмеленого борошна можна отримати при вмісті сирої клейковини у борошні не менше 24–26% з якістю клейковини ІДК – 60–80 од.. Для виробництва формового цільнозмеленого хліба з зерна спельти рекомендовано використовувати борошно із вмістом сирої клейковини не менше 30 % з якістю клейковини ІДК – 60–100 од.

Ключові слова: цільнозмелене борошно, пшениця, спельта, помел, хлібопекарські властивості, показники якості, реологічні властивості.