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SUBSTANTIATION OF THE TECHNOLOGY OF PROCESSING WHEAT GRAINS INTO WHOLEMEAL FLOUR

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Abstract. The article presents and briefly discusses the benefits of consuming wholemeal products, including wholemeal flour. The production technologies of wholemeal flour have been classified, and their advantages and disadvantages analysed. The academic community's research results are contradictory: researchers disagree about whether recombined wholemeal flour is higher in its biological and nutritional value than ordinary flour or not, nor their findings allow definitely recommending this or that technology of its production as effective. Therefore, it is important to develop a new technology of producing wholemeal flour for flour mills. This technology would incorporate the advantages of existing grinding methods and at the same time minimise their negative impact on the gluten complex quality and the nutrient content. The purpose of the study is to give reasons for the structure of the combined technological scheme of milling and the optimum modes of wholemeal flour production. The properties of industrially produced wholemeal flour samples have been studied. The findings allow concluding that the quality of these flour samples varies greatly. This is due to differences in the manufacturing technologies and the vagueness of the very concept of wholemeal flour, which should be defined by regulations along with quality requirements prescribed. Such parameters as ash content and flour particles size (which directly depend on how well the milling scheme is build up and whether all anatomical particles get into the flour) have a significant effect on the baking performance. The laboratory milling was performed following the principle of 100% grinding of grain. Three variants of the combined technological scheme of milling have been studied. The best baking performance resulted from using four roller systems for the primary grinding of the bran products and two millstone systems for the final milling. This allowed obtaining wholemeal flour with smaller particles: the residue on sieve No. 067 was 1.4%, and the outsiftings from sieve No. 38 were 40%. Using more grinding systems is impractical: it will allow obtaining even finer particles, but milling will become too energy-intensive and material-consuming.

Keywords: wholemeal product, wheat, wholemeal wheat flour, milling, quality.

Introduction. Formulation of the problem

To solve the problem of preserving and improving people's health most effectively, the Cabinet of Ministers of Ukraine has adopted the intersectoral comprehensive program *Health of the Nation*. It is aimed at expanding the range and increasing the production of organic foodstuffs and products enriched with substances recommended by the leading nutrition experts to prevent alimentary problems [1]. Traditionally, in Ukraine, the leading food of mass consumption is bakery products. However, their biological value is reduced due to the refined composition of the main recipe component, high-quality (patent) wheat flour. Therefore, a promising direction of research is creating quite a simple and reliable enrichment technology that ensures preservation of important natural nutrients in flour [2].

Analysis of recent research and publications

Food made from whole grains has a number of health benefits: it reduces the risk of cardiovascular disease [3] and obesity [4], lowers systolic blood pressure [5,6], etc. However, the unique sensory characteristics of wholemeal products make consumers prefer traditional varieties of bread and bakery goods [7,8,9]. The world's academic community constantly revise the term "whole product" [10]. As a result, there is still no universal definition of it either abroad or in Ukraine.

In the research [11], it is noted that wholemeal wheat flour (WWF) is flour made from wheat and containing all anatomical parts of the original grain in the same ratio. However, despite the growing demand for WWF, appropriate processing methods for its production have not been established yet [12]. This complicates analysis and interpretation of research results. Besides, in Ukraine, there are no state standards for the quality parameters of wholemeal flour.

As noted in [13,14], WWF can be produced both in mills (WWF proper and recombined flour) and in specially equipped production facilities (reconstituted or replicated flour). The technological process of WWF production in mills can be classified by its organisation and complexity as follows:

– single-stream (simple) milling: all anatomical parts of the grain move together from the beginning to the end of the technological process. The structure of milling is similar to low milling, but without sorting out intermediate grinding products, which overloads the grinding equipment [15,16];

– multiple-stream (complex) milling: is structurally close to single-grade milling and multi-grade milling. Different streams of intermediate products of grinding are processed individually. These streams are only formed according to the particle size, but without removing the germ and overtail products. At the last stage, all streams are reunited in the proportion that reproduces the chemical composition of the original grain. This procedure is called recombination [13,17,18]. Production of recombined WWF was officially approved in the United States as early as 1941 [19].

Reconstituted WWF is produced in specially equipped workshops by mixing separate streams of crushed bran, germ, other milling fractions, or grade flour purchased at flour mills, in a ratio that allows reproducing the chemical composition of whole wheat grain. The terms for this process are recombination and reconstitution, but the resulting product is a flour mixture, not the actual WWF [13].

To manufacture real WWF by the single-stream technology, millstones, hammer crushers and disc breakers are most often used [15,16,20], and roller mills to manufacture recombined flour [12,13,16,17,21]. The grinding method determines whether the WWF retains all anatomical parts of the grain, and thus, what its nutritional value is. The size of the flour particles, too, depends on the grinding method chosen and determines the technological and nutritional functionality of the flour [13,22]. Thus, the research [13] proved that millstone-produced WWF has a more homogeneous and even particle size distribution than recombined flour. This may be due to the specific chemical composition of the particles that form the grain coating: they are highly elastic [23], which becomes more pronounced during crushing with a roller mill. Other scientists have found that flour ground using millstones has a higher level of damaged starch than flour obtained by other grinding methods [15].

Besides, the method of grinding affects not only the physical properties of WWF, but also its chemical composition and biological value. This is related, in particular, to the temperature that the grain reaches during grinding. Thus, the study [24] showed that the highest temperatures were observed during grinding wheat with burr mills, the temperature of which reached 90°C due to friction. This led to significant damage to starch, protein, enzymes, amino acids, unsaturated fatty acids, as compared to other grinding methods [24]. On the other hand, in a roller mill, the grain was as hot as 35°C, and in a hammer crusher, it was of an intermediate temperature within the specified range. Some scientists, on the contrary, attest that millstone-ground WWF loses not as much of its nutrients as grain crushed in a rolling mill does. However, this is only true with very slow grinding, and labile components are insensitive to the temperature that increases the loss of vitamins [24].

Therefore, the contradictory research results do not allow attesting whether recombined WWF has higher biological and nutritional value or not, and or be positive about recommending this or that WWF production technology as effective. Thus, it is important to develop a new technology of producing wholemeal flour for flour mills. This technology would incorporate the advantages of existing grinding methods and at the same time minimise their negative impact.

The purpose of the study is to give reasons for the structure of the combined technological scheme and the optimum modes of wholemeal flour production.

For this purpose, it is necessary to achieve the following **objectives**:

– to investigate experimentally the quality parameters of industrially manufactured WWF of the trademarks *Dobrodiya*, *Kozub*, *Formula Zdorovya*, and *O-la-la!* found in retail chains of Odessa;

– to mill wheat grain into WWF in the laboratory according to different technological schemes;

– to study the technological quality parameters of WWF obtained in the laboratory;

– to carry out trial baking using the WWF samples under study, and to investigate the quality parameters of the bread obtained.

Research materials and methods

The research part of the study was carried out in the laboratory at the Grain Processing Technology Department of ONAFT.

At the first stage of research, the quality characteristics of the industrially manufactured WWF samples present in retail chains of Odessa were defined. TM *Formula Zdorovya* was sample 1, TM *Kozub* – Sample 2, TM *O-la-la!* – Sample 3, TM *Dobrodiya* - Sample 4.

For the laboratory milling, wheat grain of the variety *Kuyalnyk* harvested in 2018 was taken. Its quality characteristics were as follows: moisture 11.5%; protein content 12.0%; crude ash content 1.60%; gluten content 19.4%; gluten quality group II; gluten deformation index 80 un.; bulk density of the grain 810kg/m^3; 1000-kernel weight 42g; vitreosity 55%.

The chemical composition and technological properties of the wheat grain and flour were determined by standardised methods.

The bulk density of the wheat grain was determined according to DSTU 4234-2003 (ISO 7971-2:1995) "Cereals. Determination of bulk density." The so-called "mass per hectolitre," the grain vitreosity was determined according to GOST 10987-76 "Grain. Methods for determining vitreosity," and the 1000-kernel weight according to DSTU ISO 520:2015 "Cereals and pulses. Determination of the weight of 1000 grains."

The moisture content was determined according to ISO 712; the ash content according to ISO 2171; the protein content according to ISO 20483; wet gluten was washed out according to GOST 27839 by handwashing of dough obtained from 25g of flour with 14ml of water. The gluten deformation index (GDI) was measured on a gluten deformation meter IDK-M; the acidity of flour according to GOST 27493-87 "Flour and bran. The method of determining the acidity"; the particle size according to GOST 27560-87 "Flour. Size determination method. Flour and bran. Method of determining the size of particles."

A Mixolab meter was used to determine the rheological properties of the dough (at a constant temperature following the steps of heating, maintaining 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.

A baking test was carried out to evaluate comprehensively the baking properties of flour according to the modified bakery test for 100g of flour. The amount of water needed for dough formation was determined based on the moisture content of the flour. Yeast (3g), sugar (4g), and salt (1.3g) 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.

Laboratory milling. In accordance with the objectives set, a number of millings of wheat grain into WWF were carried out in the laboratory. The milling structure was similar to that of low milling of wheat, but without sorting out the bran particles, thus obtaining 100% flour yield. Roller mills were used as the main grinding equipment, and a millstone grinder as an additional one. The laboratory WWF production schemes were performed in three variants (Fig. 1-3), which differed in the modes of grinding and the number of grinding systems. The technical characteristics of the roller mill used were as follows: diameter of rollers D – 0.22m; length of rollers L – 0.15m; number of flutes per 1cm of the circle of rollers R – 6; flute incline U – 6%; roller differential – 2.5.

According to Variant 1 (Fig. 1), the scheme of laboratory milling is constructed similarly to the scheme of low milling of wheat: on 4 break systems (B1-B4) on a roller mill, with the use of a millstone grinder on a millstone system (BS1) for final grinding of bran products obtained as overtail on B4. The grinding gaps were 0.8mm, 0.5mm, 0.25mm, and 0.10mm for B1-B4 respectively, and 0.10mm for BS1. WWF (Sample 5) was selected by passing sieves Nos.067, 056, and 38.

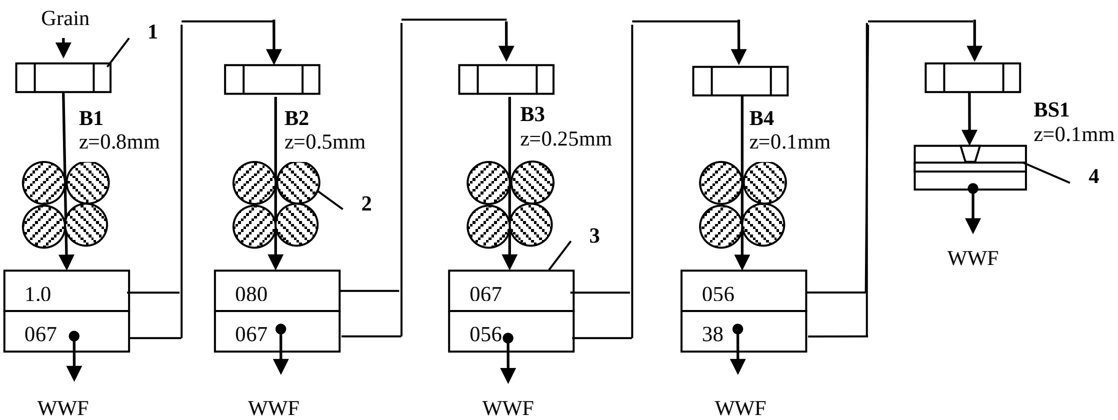

Fig. 1. Diagram of laboratory milling of wheat into wholemeal flour (Variant 1):
1 – magnetic separator, 2 – roller mill, 3 – sifter, 4 – millstone grinder

According to Variant 2 (Fig. 2), the process of laboratory milling of wheat grain is built up, similarly to the previous variant, on four break systems (B1-B4), but a stone grinder is involved for the final grinding of all bran products in two stages (BS1-BS2). The grinding gaps were 0.8mm, 0.4mm, 0.15mm, and 0.05mm for B1-B4 respectively, and 0.15mm and 0.05mm for BS1-BS2. WWF (Sample 6) was selected by passing sieves Nos. 067, 056, and 38.

According to Variant 3 (Fig. 3), the laboratory milling process is built up similarly to the previous variant, but with fewer break systems (B1-B3) and with the use of a millstone grinder for grinding bran products in several stages (BS1-BS2). The grinding gaps were 0.5mm, 0.3mm, and 0.01mm for B1-B3, 0.20mm and 0.10mm for BS1-BS2. WWF (Sample 7) was selected by passing sieves Nos. 067 and 38.

After that, the quality parameters of the WWF obtained in the laboratory according to different milling variants (Samples 5-7) were analysed. The control samples were the industrially manufactured WWF, the quality of which was determined at the initial stage of the study. Then, the rheological properties of the dough were determined with a Mixolab device, and test baking was performed to determine the baking properties of the flour.

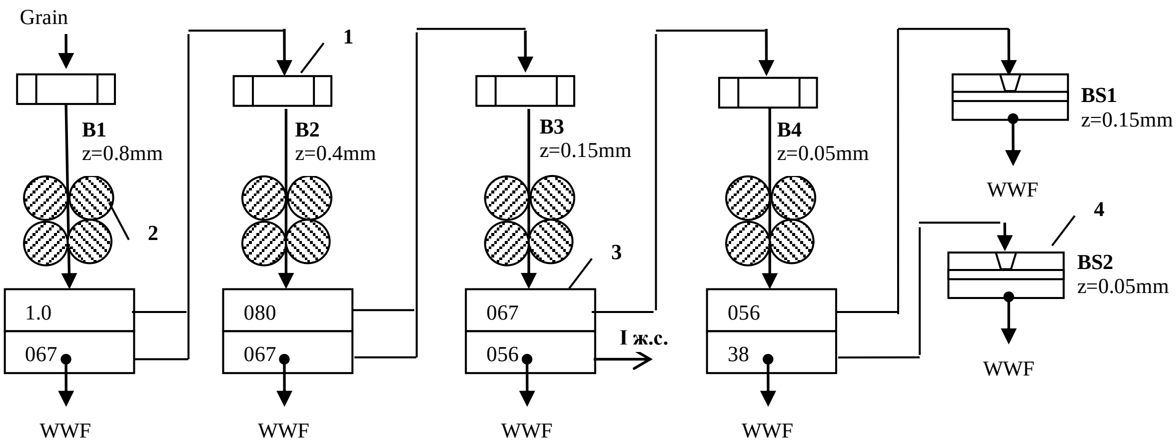

Fig. 2. Diagram of laboratory milling of wheat into wholemeal flour (Variant 2):
1 – magnetic separator, 2 – roller mill, 3 – sifter, 4 – millstone grinder

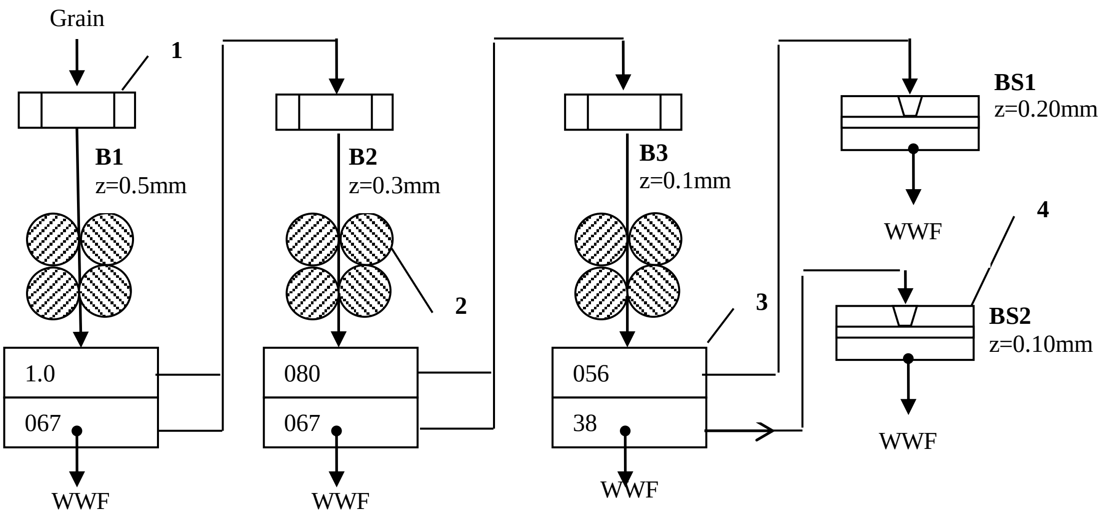

Fig. 3. Diagram of laboratory milling of wheat into wholemeal flour (Variant 3):
1 – magnetic separator, 2 – roller mill, 3 – sifter, 4 – millstone grinder

Results of the research and their discussion

In Variant 1, gradual grinding of grain was used. The overtail fractions from each of the break systems were sent to the next consecutive one for further grinding. In this laboratory milling variant, the operating modes of the systems were as follows: BR_{B1}=17%, BR_{B2}=23%, BR_{B3}=46%, BR_{B4}=32%. On the penultimate grinding system B3, the maximum amount of flour selected was 30%. The load on one millstone system was 23%.

According to Variant 2, the overtail fractions from each break systems were sent to the next consecutive system for further grinding of the intermediate products, except for the 2nd overtail from B3 and B4. These products were directed to BS1 and BS2 respectively. In this variant of laboratory milling, the operating modes of the systems were as follows: BR_{B1}=20%, BR_{B2}=28%, BR_{B3}=52%, BR_{B4}=47%. At the end, on the millstone grinders, a little more flour (38%) was obtained because of the change in the roller mill modes.

According to Variant 3, the overtail fractions of each of the break systems were sent to the next consecutive system for further grinding of the intermediate products, except for B3. The overtail from B3 was sent to BS1 and BS2.

In this variant of laboratory milling, the following operating modes of the systems were used: BR_{B1}=25%, BR_{B2}=43%, BR_{B3}=27%. On the final millstone grinders, the maximum amount of flour selected was 31%, because there was one system fewer in the break process. In this milling, the modes of operation of B1 and B2 were the highest in comparison with other variants because of the harder modes of grinding in the roller mills.

The quality parameters of the WWF obtained in the laboratory (with different grinding schemes used) have been analysed. The industrially manufactured WWF from the retail chains of Odessa have been analysed, too, as control samples (Table 1).

The ash content of the samples of industrial WWF ranged 1.2–1.5%. The highest ash content in the industrial WWF samples (at the level of that in whole wheat grain or slightly below) was found in Sample 2. In Samples 1, 3, and 4, the ash content of flour was 1.2–1.3%, which indicates partial selection of the bran fraction. The ash content of the laboratory samples (5-7) was the same as the ash content of the original grain. This means that during laboratory milling, 100% of the grain passed into the flour, i.e. there was no significant loss of nutrients and bioactive substances.

One of the main characteristics of the baking properties of flour is the quantity and quality of wet gluten. These parameters depend on the varietal characteristics of grain and the conditions of its cultivation and storage, on the scheme and modes of processing the grain into flour. The highest gluten content was observed in Samples 1 and 4–20.4% and 21.6% respectively, the lowest in Sample 2. In the laboratory WWF samples, the gluten content was 19.0–19.2%, i.e. the industrial and laboratory samples were not significantly different. Slight differences were found in their gluten deformation index (GDI): in Samples 1–4, it was 50–63 units, in laboratory samples 5–7, 80–86 units.

Table 1 – Quality parameters of wholemeal flour

No	Product name	Moisture content, %	Size, %		Ash content, %	Gluten		Acidity, °H
			Residue on sieve No. 067	Outsiftings from sieve No. 38		Gluten content, %	Gluten deformation index, units	
1	Wholemeal wheat flour *Formula Zdorovya*	10.6	1.0	56	1.2	20.4	63	2.0
2	Wholemeal flour *Kozub* (wheat)	12.8	1.5	43	1.5	19.6	60	3.9
3	Special low-milled wheat flour *O-la-la!*	12.4	35	26	1.3	20.0	61	5.7
4	Wholemeal wheat flour *Dobrodiya*	14.5	0.01	60	1.2	21.6	50	3.5
5	WWF (laboratory milling, Variant 1)	11.2	1.9	26	1.6	19.2	80	3.8
6	WWF (laboratory milling, Variant 2)	11.3	1.4	40	1.6	19.0	82	3.6
7	WWF (laboratory milling, Variant 3)	11.2	2.5	29	1.6	19.1	86	3.5
	GSTU 46.004-99 (for low-milled flour)	Not more 15.0	Not more than 2.0	Not less than 35	Not more than 2.0	Not more than 18	20-100	–

According to the regulations, the granularity of low-milled flour is controlled with two sieves: by the residue on sieve No. 067, and by the outsiftings on sieve 38. The particle size of the flour samples studied differed: in Samples 1 and 2, the residue on sieve 067 was 1–1.5%, in Samples 5–7 – 1.4–2.5%, in Sample 3 – 35%, only in Sample 4, it was absent. The highest content of the fine flour fraction (outsifting from sieve 38) was within 60%. It was observed in Sample 4. In Samples 1 and 2, the content of this flour fraction was in the range 43–56%. In Sample 3 (industrial WWF) and in Samples 5 and 7 (laboratory WWF), the content of the fine fraction was 26–29%, which is lower than it is recommended by GSTU46.004-99 for low-milled flour. Thus, the largest particles were in Samples 3, 5, 7, and the smallest ones in Sample 4. Other samples had intermediate granularity values.

The effect of the technological process scheme and grinding modes on the rheological properties of wheat dough has been studied using the innovative device Mixolab (Chopin Technologies, France). The findings are summarised in Fig. 4 and in Table 2. Wholemeal flour (Sample 8) was taken as the control. The sample was obtained by 100% grinding in a laboratory mill LZM and sifting through Sieve No. 38 till the outsiftings were fully obtained.

The rheological properties were evaluated according to the Chopin+ protocol, which provides for five temperature ranges during research (Fig. 4). Interval I lasts 8 minutes at 30°C. Interval II lasts 15 min, in this interval the temperature consistently rises from 30 to 90°C. In interval III, the study lasts 8 min at the maximum temperature 90°C. Interval IV takes 10 min and is characterised by a consistent temperature decrease from 90 to 50°C. Interval V lasts 5 min at 50°C (Fig. 4, curve 1).

From the biochemical point of view, the torque in the analysed points of the graph characterises different processes: C1 - dough kneading; C2 – dough dilution; C3 - maximum starch gelation rate; C4, C5 – the start and the end of starch retrogradation in the experiment. The following parameters have been analysed, too: water absorption capacity of the dough (WAC), dough formation time (min), dough stability (min). The data of the integral evaluation of the rheological properties of the dough have been visualised using a graph of dependence of the torque (N·m) on the time (min) in a certain temperature regime (Table 2).

The first phase (C1), the time from the addition of water until the optimal torque, is 4.88 minutes in the control sample. The highest kneading time 5.25 min was observed in Sample 6, which is due to its coarseness. The second phase (C2) is related to mechanical and thermal effect. The torque in the second stage in the control sample of flour was 0.482 N·m. The higher the C2 index is, the better the quality of the protein complex in the flour. The torque in the third phase (C3) in the samples studied ranges from 1.554 N·m (Sample 7) to 1.588 N·m (Sample 8).

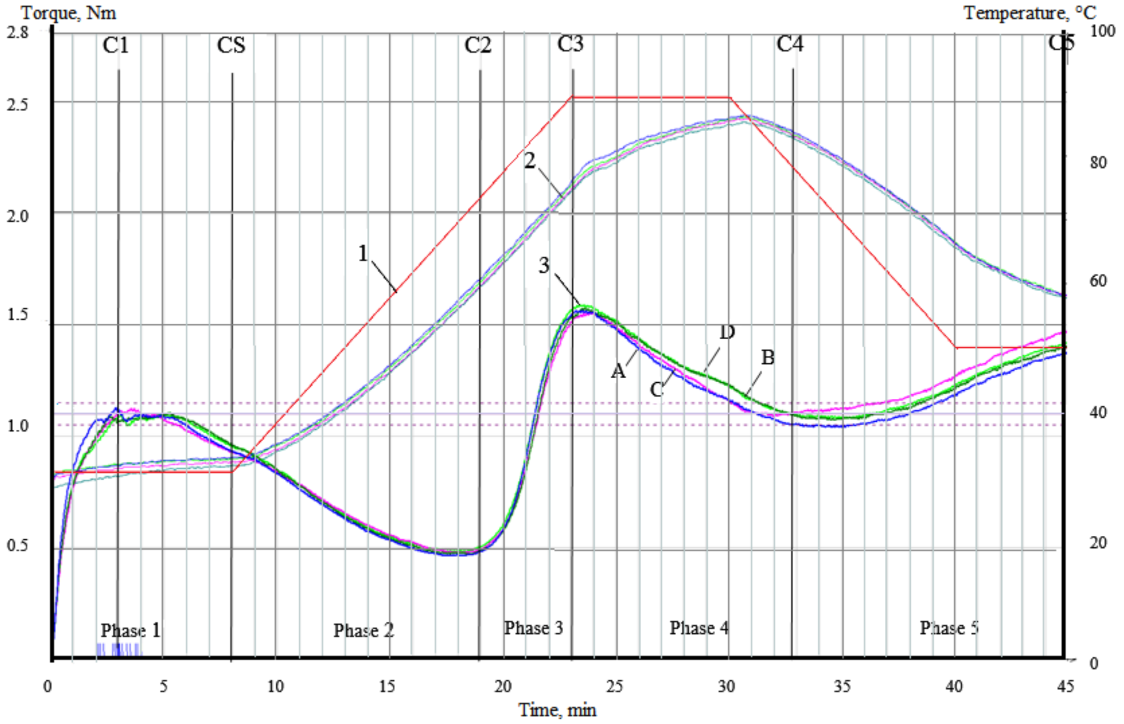

Fig. 4. Mixolab rheologic curve of the laboratory WWF samples:
A ■ – Sample 5; B ■ – Sample 6; C ■ – Sample 7; D ■ – Sample 8 (control); 1- temperature of the dough-making machine; 2 - dough temperature; 3 - torque; C1, C2, C3, C4, C5 - curve points analyzed (torque values)

This stage is characterised by the maximum viscosity and swelling of starch granules. In this phase, there is a steep rise of the curves in the graph, which indicates a high rate of starch gelation. In the fourth phase (C4), the starch viscosity decreases. This is evidenced by the torque values ranging from 1.039 N·m (Sample 5) to 1.089 N·m (Sample 7). The fifth phase (C5) characterises the retrogradation of starch. The higher the torque at this stage is, the faster the retrogradation process. The C5 index for the samples under study is quite low and ranges from 1.362 to 1.655 N·m. This makes it possible to predict that the baked products will be relatively staling-resistant during storage.

A set of indices obtained allows creating a specific Mixolab Profiler graphical profile. This profile is specific to a particular flour sample and visualises its rheological characteristics as six consecutive indices of product quality, thus simplifying comparison and use of the data. Standard ICC protocol No. 173 was used to describe the flour fully and perform a simplified graphical interpretation of the results in the form of index points (Fig. 5).

Table 2 – Parameters of the Mixolab rheological curve of the WWF samples

Parameter	Sample			
	5	6	7	8
WAC, %	70.7	69.5	69.1	69.0
Time, min				
Dough kneading, C1	2.87	5.25	3.55	4.88
Dough dilution, C2	17.58	18.58	18.17	17.45
Maximum starch gelation rate, C3	23.52	23.63	23.85	23.55
Start of starch retrogradation, C4	34.98	34.85	31.97	35.23
End of starch retrogradation, C5	45.02	45.02	45.02	45.02
Torque, N·m				
Dough kneading, C1	1.128	1.104	1.124	1.100
Dough dilution, C2	0.463	0.471	0.477	0.482
Maximum starch gelation rate, C3	1.564	1.575	1.554	1.588
Start of starch retrogradation, C4	1.039	1.071	1.089	1.080
End of starch retrogradation, C5	1.362	1.394	1.465	1.412

The index C1 (water absorption capacity) depends on the ratio of intact and destroyed starch granules in wheat flour, and on the size of the flour particles, which determine the rate and strength of osmotic binding of water to free interstitial protein and attached protein around some individual starch granules. It is considered that the WAC of top-grade wheat flour should be 60–62%, first grade – 62–65%, second grade – 65–70%, low-milled – more than 70%, the WAC of flour for crackers and puff pastry should be 62%, for enriched biscuits 56%, for ordinary biscuits 58%. According to the results of the experiments, the minimum value of WAC (69.0%) was in Sample 8 (control), and the maximum one (70.7%) was in Sample 5, which was obtained according to the multiple-stream version of the technological process. The index C2 (Fig. 5) depends on the behaviour of the dough during kneading and especially on its stability. It is considered that the higher this index is, the more stable the dough piece will be during kneading. This index describes the strength of dough during kneading. The optimal value of this index is 2-4 for flour and bakery products with a small volume, and 4–6 for ones with a large volume. Analysis of the experimental findings has shown that the maximum mixing index was in Sample 6, while Samples 5 and 7 had the lowest C2. The index C3 (gluten index) shows how protein compounds resist a temperature increase to 30–60°C, and is almost independent of the properties of starch. All samples had the gluten index 7, which indicated normal dough elasticity, but could prevent the dough from rising properly during baking.

The index C4 (viscosity index) describes the phase in which the maximum amount of physicochemical and biochemical preparations interact. At this stage, proteins start playing but a smaller part giving way to starch. In all samples, the viscosity index is the same, constant, and at the minimum level – 1.

The index C5 (index of amylolytic activity), which correlates with the Falling Number, in the samples of laboratory flour was 6-7, and the index C6 (index of retrogradation, or thickening of starch in the phase of cooling down from 90 to 50°C) for the laboratory samples was 3–4, which is below the value typical of graded flour (7–8). This indicates that the WWF will need more time to get stale and will retain its marketable appearance longer.

Thus, for this sample of wheat, the different structures of the technological process scheme of obtaining WWF did not significantly affect the change in the rheological curve of the dough. However, taken together, the flour quality and the rheological parameters of the dough influenced its baking performance, which was assessed by the organoleptic and physicochemical parameters of the test-baked loaves (Table 3).

sample is due to the strength of the gluten in the flour (GDI 63units).

The largest specific volume of the test loaf and high porosity were in Sample 4–2.10cm^3/g and 70% respectively, which is almost the level of grade flour. This is due to the particle size of the flour - the outsiftings from sieve 38 were 60%. Besides, this sample had a low ash content, which indicates that during its production part of high-ash bran had been separated and had not got into the flour. Of the laboratory samples, the best baking characteristics were in Sample 6 obtained by laboratory milling variant 2. This is due to the particle size of the flour: the outsiftings from sieve 38 were 40%, and the overtail on sieve 067 was 1.4%, which indicated a more even granulometric distribution. The worst quality was that of flour sample 7 obtained by laboratory milling variant 3. It was due to its particles size, too, as it had the largest particles: the outsiftings from sieve 38 were 26%, and the residue on sieve 067 was 2.5%.

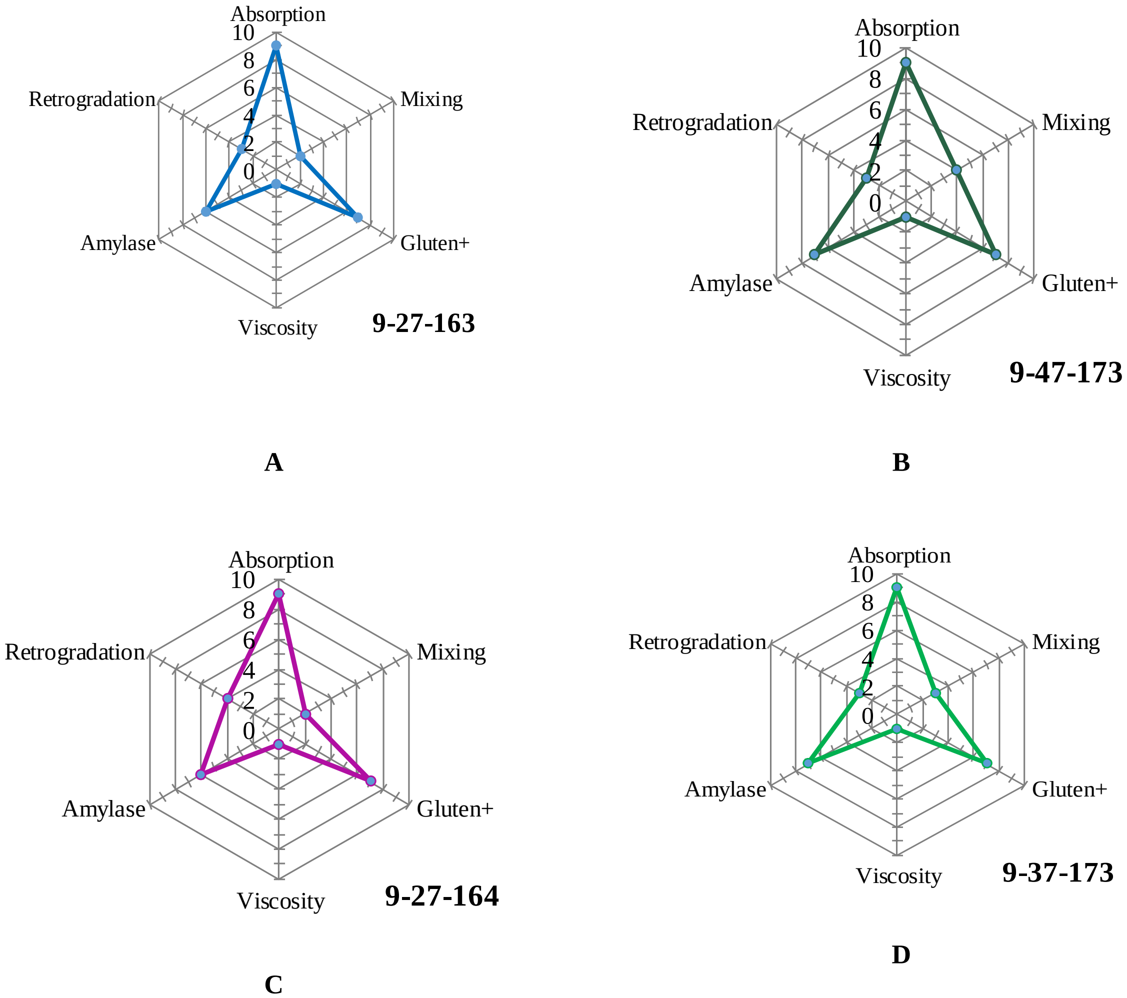

Fig. 5. Mixolab profiles of the WWF samples:
A ■ – *Sample 5; B* ■ – *Sample 6; C* ■ – *Sample 7; D* ■ – *Sample 8 (control);*

Table 3 – Physicochemical parameters of bread from WWF (n=3, p=0.95)

No. of the sample	Product name	Moisture content, %	Porosity, %	Specific volume, cm^3/g	Loaf volume, cm^3
1	Wholemeal wheat flour *Formula Zdorovya*	43.0	63	1.7	360
2	Wholemeal flour *Kozub* (wheat)	45.6	65	1.4	360
3	Special low-milled wheat flour *O-la-la!*	49.5	52	1.0	290
4	Wholemeal wheat flour *Dobrodiya*	43.1	70	2.1	410
5	WWF (laboratory milling, Variant 1)	46.0	58	1.0	310
6	WWF (laboratory milling, Variant 2)	45.6	58	1.2	360
7	WWF (laboratory milling, Variant 3)	49.0	50	1.3	320

The loaves baked from the test samples of WWF differed in appearance, and in condition of the crust surface and of the crumb. The most attractive in terms of the organoleptic parameters and appearance is the test-baked bread from flour sample 1. The volume of the sample 1 loaf was low and amounted to 360cm^3, the porosity was 63%. Since the granularity of the flour meets the quality requirements (the outsiftings from sieve No. 38 were 56%), the low loaf volume in this

Conclusion

The results of the research on the properties of industrial WWF samples allow us to conclude that their quality varies greatly due to differences in their manufacturing technologies and lack of unification of the very concept of wholemeal flour, which should be defined by regulations with quality requirements prescribed.

The laboratory milling was performed following the principle of 100% grinding of grain. Three variants of the combined technological scheme have been studied. The best baking performance resulted from using four roller systems for the primary grinding of the bran products and two millstone systems for the final milling. This allowed obtaining wholemeal flour with smaller particles: the residue on sieve No. 067 was 1.4%, and the outsiftings from sieve No. 38 were 40%. Using more grinding systems is impractical: it will allow obtaining even smaller particles, but milling will become too energy-intensive and material-consuming.

Further research into the technology of wholemeal flour production should focus on proving the advantages of the recommended parameters of wheat grain quality and on explaining the choice and the percentage of processing additives introduced into flour.

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ОБҐРУНТУВАННЯ ТЕХНОЛОГІЇ ПЕРЕРОБКИ ЗЕРНА ПШЕНИЦІ В ЦІЛЬНОЗМЕЛЕНЕ БОРОШНО

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Анотація. У статті показано корисність цільнозмелених продуктів, у тому числі цільнозмеленого борошна. Наведено класифікацію технологій виробництва цільнозмеленого борошна, проаналізовано їхні переваги та недоліки. Суперечливі результати досліджень наукової спільноти не дозволяють стверджувати, що рекомбіноване цільнозмелене пшеничне борошно має більш високу біологічну та харчову цінність чи навпаки, а отже і однозначно рекомендувати ту чи іншу технологію його виробництва як ефективну. Досліджено технологію виробництва цільнозмеленого пшеничного борошна для борошномельних заводів, яка б одночасно поєднувала в собі переваги існуючих методів подрібнення та мінімізувала їхній негативний вплив на якість клейковинного комплексу, вміст нутрієнтів. Обґрунтувано структуру комбінованої технологічної схеми помелу та оптимальних режимів виробництва цільнозмеленого пшеничного борошна. Результати досліджень властивостей зразків цільнозмеленого пшеничного борошна промислового виробництва дозволяють зробити висновок, що якість їхня дуже різниться через відмінності у технологіях виготовлення та відсутність уніфікації самого поняття «цільнозмелене борошно», визначеного нормативною документацією поряд із вимогами до його якості. Такі показники як зольність та крупність помелу, які на пряму залежать від побудови схеми помелу, повноти потрапляння усіх анатомічних частинок у борошно, значно впливають на хлібопекарські показники. При дотриманні принципу 100-відсоткового помелу у лабораторних умовах за дослідженими трьома варіантами комбінованої технологічної схеми, найкращі хлібопекарські показники отримано при помелі на чотирьох вальцьових системах для основного подрібнення та двох жорнових системах для остаточного розмелу оболонкових продуктів, що дозволило отримати відповідно меншу крупність часток цільнозмеленого борошна: залишок на ситі № 067 склав 1.4%; прохід сита №38 – 40%. Більша кількість подрібнюючих систем хоча і дозволить отримати ще меншу крупність часток, але це приведе до збільшення енерго- та матеріаловитрат на помел, тому може бути недоцільним.

Ключові слова: цільнозмелений продукт, пшениця, цільнозмелене пшеничне борошно, помел, якість.

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