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## RATIONALE OF TECHNOLOGY FOR THE COMMON AND HULLED WHEAT PROCESSING INTO WHOLE GRAIN FLOUR

### Abstract

The article is devoted to rationale the need of expand the range of flour products and increase its nutritional and biological value by the whole wheat flour production. The article shows the main tasks and problems facing the modern grain processing industry: increasing the utilization rate of grain; reducing the energy intensity of grain processing technological process; and to expand the range of end-products with increased nutritional and biological value.

The production of whole grain flour (WGF) will allow expanding the range and increasing the nutritional value of the finished products. Ukraine's state standards for WGF are absent today. DSTU 46.004-99 named «Wheat flour. Specifications» applies only to high-grade flour and dark flour. The studying of Ukrainian WGF quality indicators showed that some manufacturers are guided by DSTU 46.004-99 in the WGF production, other manufacturers control the quality of flour with their own local specifications.

Depending on such indicators as ash and particle size, some of WGF manufacturers adhere to the principle of almost 100% entry of all anatomical grain components into end-products. Despite of this, the particle size may vary by the level of the particle size of the dark flour or significantly differ from it. It depends either on the type of grinding machines (millstones or roller mill) or also on the usage of additional bran grinding in the technological scheme. Other manufacturers, in forming WGF to improve its baking properties, adhere to the principle of eliminating a certain amount of shell particles (in bran form). Such flour has an ash content much lesser comparing to the grain, but also its size depends on different structure and modes of grinding process.

The purpose of the work is to substantiate the structure of the technological scheme and optimal modes while making WGF. During the research, a number of laboratory grindings of common wheat and spelta wheat into whole-grain flour were conducted. It is established that for the production of WGF it is most expedient to use combined technological schemes with the use of roller machines as grinding equipment on the main systems of technological process and millstones on the last stage systems for the final grinding of intermediate products. Due to the research, it is possible to recommend a scheme consisting of 3-4 roller mill systems and 1-2 millstone systems. The requirements determined for the wheat WGF particle size: top on sieve No. 067 – less than 2.0% and passage through sieve No. 38 – more than 50%.

**Key words:** whole grain wheat flour, quality indicators, particle size distribution, baking properties, manufacturing technology, grinding systems modes.

### Introduction

Currently, the grain processing industry faces a number of urgent problems, such as: increasing the grain utilization rate, reducing the power consumption of the grain processing process and expanding the range of end-products with increased nutritional and biological value. Their solution will allow to increase the competitiveness of local grain processing products.

The production of WGF will expand the range and increase the nutritional value of the end-product. However, there are still no standards for wheat WGF, so its quality indicators at local market fluctuate widely.

### Literary review

Traditional milling process of cereals is based on the gradual grinding of grain and the mechanical distribution of its three main parts – endosperm, embryo and shells. They differ significantly in their physical and mechanical properties and chemical composition. It is well known that while separated from the endosperm membranes, aleurone layer and embryo removes most of the

vitamins, proteins and minerals. While using traditional grain grinding schemes, valuable micronutrients are removed. That greatly reduces the flour and bread nutritional value compared to source grain.

While making high-quality flour according to traditional technological schemes, more than 70% of all the power consumption is accounted by the grinding grain process. The gradual grinding of the grain and the removal of its endosperm is achieved by using a large number of grinding systems. Finally, that results in significant energy cost [1].

The production of WGF allows to reduce the manufacturing cost of end-products and to preserve the whole nutritional value of the grain. Compared to high-quality wheat flour, WGF contains several times more fiber (x 12.5), calcium (x 2.1), magnesium (x 5.8), phosphorus (x 3.9), iron (x 3.4), vitamin PP (x 3.7), vitamin B1, B2 (x 2.3). In addition, WGF contains vitamin E, which is completely absent in high-grade flour. Wheat WGF can be used in the high-nutritional bread, bakery and pasta manufacturing [2-7].



### Formulation of the problem

The processing of grain into WGF is carried out by different technologies, which differ in the type of grinding equipment and the number of grinding systems. Roller mills, crushers or millstones can be used as grinding equipment. There is also the practice of using combined technological schemes, where roller mills are used as the main grinding equipment, and millstones or crushers are involved on the latest grinding stages. WGF obtained by different manufacturing technologies differs significantly by quality indicators [8-9].

Local Ukrainian state quality standards (DSTU) for wheat WGF are absent today. DSTU 46.004-99 «Wheat flour. Specifications» apply only to high-grade flour and dark flour. Research of quality indicators of Ukrainian wheat WGF showed that some manufacturers use DSTU 46.004-99 [10] in the WGF production, other manufacturers control the quality of the flour according to their own specifications.

According to the ash content and particle size, a couple of WGF manufacturers adhere to the principle of almost 100% all anatomical grain components involving into the end-product. The particle size can be equal to the dark flour or significantly differ from it. It mostly depends both on the type of grinding machines (millstones or roller mills), and on the additional bran grinding in the technological scheme. Some manufacturers prefer to exclude some part of shell particles (bran) from WGF to improve its baking properties. Thus, such flour has a much lower ash content than in grain, but its particle size also depends on the different structure of the milling process and modes of grinding machines.

Due to the lack of unified manufacturing technology, the quality indicators of Ukrainian WGF presented on the local market fluctuates greatly. Therefore, **the purpose** of the work is to substantiate the principle of the technological scheme and optimal grinding modes of production of wheat WGF.

### Materials and methods

The object of the study was the technology of wheat' and spelta's WGF production. The subject of the study is WGF from common wheat and from spelta wheat that were obtained in the laboratory due to various technological schemes.

Determination of organoleptic parameters, humidity, whiteness, particle size, quantity and quality of gluten in grain and flour was performed by standard determination procedures. The study of the baking properties of flour was carried out using the direct method (evaluation of the flour quality by test baking bread method).

The standard method for the bread baking test [11] provides a single stage method of dough preparation from flour, water, baker's yeast and salt. Bread quality assessment was performed according to physicochemical indicators according to DSTU 27669-88.

According to the quality indexes, wheat grain of 4<sup>th</sup> class (test weight 780 g/l, vitreous 53 %, protein content 10,4 %, gluten content 17,0 %), and spelta grain (test weight 670 g/l, vitreous 64 %, protein content 13,5 %, gluten content 37,0 %) were used for laboratory grain processing into WGF.

### Results of the study and their discussion

WGF was obtained from two variants of technological schemes with different modes of grinding systems. The technological scheme according to option No. 1 (grinding No. 1.1-1.4) included four break grinding systems (B1, B2, B3, B4) on roller machines and one grinding system (St1) on a millstone. The technological scheme according to option No. 2 (grinding No. 2.1-2.3) included three break grinding systems (B1, B2, B3) on roller machines (whereby I and II break grinding systems were carried out without intermediate sieving) and two grinding systems (St1, St2) on a millstone.

According to the scheme option No. 1 at each of technological system the WGF was obtained by the using of sieves No. 1,0; 090; 080; 067; 063; 056. The overtail products, after the sieving of the flour, were directed for further grinding at subsequent systems. The final grinding of the brans obtained at the last roller mill system (B4) took place on a millstone (St1). Tables 1-4 show the balances of wheat WGF laboratory grindings according to scheme option No. 1.

In laboratory grinding No. 1.1 the following operative system modes (sieve release) were maintained:  $SR_I = 34 \%$ ,  $SR_{II} = 58 \%$ ,  $SR_{III} = 57 \%$ . At the final

**Table 1 – Balance of laboratory grinding No. 1.1, %**

System	System load, %	B2	B3	B4	St1	WGF
B1	100,0	66,0				34,0
B2	66,0		28,0			38,0
B3	28,0			12,0		16,0
B4	12,0				3,0	9,1
St1	3,0					3,0
Total		66,0	28,0	12,0	3,0	100

**Table 2 – Balance of laboratory grinding No. 1.2, %**

System	System load, %	B2	B3	B4	St1	WGF
B1	100,0	67,9				32,1
B2	67,9		29,8			38,1
B3	29,8			17,5		12,4
B4	17,5				13,8	3,7
St1	13,8					13,8
Total		67,9	29,8	17,5	13,8	100

**Table 3 – Balance of laboratory grinding No. 1.3, %**

System	System load, %	B2	B3	B4	St1	WGF
B1	100,0	63,6				36,4
B2	63,6		15,5			48,2
B3	15,5			4,0		11,5
B4	4,0				0,6	3,5
St1	0,6					0,6
Total		63,6	15,5	4,0	0,6	100



grinding system the maximum amount of flour was selected. During the laboratory grinding No. 1.2 the operative modes at B3 and B4 were slightly higher than at the previous grinding:  $SR_{III} = 41\%$ ,  $SR_{IV} = 21\%$ . The load on millstone system (St1) at grinding No. 1.2 was 13.8%. During laboratory grinding No. 1.3 low operating modes of the systems were maintained:  $SR_I = 36\%$ ,  $SR_{II} = 76\%$ ,  $SR_{III} = 74\%$ ,  $SR_{IV} = 86\%$ . The load at St1 at this grinding was the lowest and equal 0.6%. Laboratory grinding No. 1.4 is characterized by the following operation modes of the grinding systems:  $SR_I = 26\%$ ,  $SR_{II} = 53\%$ ,  $SR_{III} = 36\%$ ,  $SR_{IV} = 23\%$ . In this grinding operation mode of B1 was the highest comparing to other grindings. The load on St1 at grinding No. 1.4 was the highest comparing to other similar laboratory grindings and equal 17,3%.

In the next stage, the laboratory grinding of common wheat and spelta wheat grains into WGF according to the scheme option No. 2. It consisted of three roller mill grinding systems and two millstone grinding systems, and based on gradual-parallel grain grinding. On the roller mill grinding systems, WGF was selected by passage of flour sieves No. 38, which provided separation of pure flour. Larger fraction with brans in its composition was sent for further grinding. Balances of laboratory grinding of common wheat grain are given in Table 5-6, and for spelta wheat grain – in Table 7.

For laboratory grindings the sieve release on the first two systems  $SR_{I+II}$  was gradually reduced: 54.6%, 48.8%, and 39.8% for grindings No. 2.1, 2.2, 2.3, respectively. As a result, the load on the millstone systems increased and the amount of flour obtained from the abrasion deformation also increased.

There were no significant difference in moisture content, ash content and gluten content between the obtained WGF samples (Table 8).

Analyzing the obtained data it can be noted that the best sample for quality indicators and baking properties in the grinding scheme option No. 1 was a sample of whole grain flour from laboratory grinding No. 1.3. This is connected directly to the particle size of the flour: passage through the sieve No. 38 was 55%, and the top of sieve No. 067 – 1.5%, which indicates a more balanced particle size distribution. Bread volume for samples No. 1.1-1.4 fluctuated within

330-360  $cm^3$ , the porosity of the studied bread samples varied within 76-77%. The worst quality had the sample of flour obtained as a result of laboratory grinding No 1.4, which is also related to its particle size.

**Table 4 – Balance of laboratory grinding No. 1.4, %**

System	System load, %	B2	B3	B4	St1	WGF
B1	100,0	74,1				25,9
B2	74,1		34,8			39,4
B3	34,8			22,4		12,4
B4	22,4				17,3	5,2
St1	17,3					17,3
Total		74,1	34,8	22,4	17,3	100

**Table 5 – Balance of laboratory grinding No. 2.1, %**

System	System load, %	B3	St1	St2	WGF
B1+B2	100	45,4		13,4	41,2
B3	45,4		10,1	2,7	32,6
St1	10,1			10,1	
St2	26,2				26,2
Total		45,4	10,1	26,2	100

**Table 6 – Balance of laboratory grinding No. 2.2, %**

System	System load, %	B3	St1	St2	WGF
B1+B2	100	51,2		13,4	35,4
B3	51,2		10,8	7,8	32,6
St1	10,8			10,8	
St2	32,0				32,0
Total		51,2	10,8	32,0	100

**Table 7 – Balance of laboratory grinding No. 2.3, %**

System	System load, %	B3	St1	St2	WGF
B1+B2	100	60,2		12,4	27,4
B3	60,2		16,6	10,5	33,1
St1	16,6			16,6	-
St2	39,5			-	39,5
Total		60,2	28,6	39,5	100

**Table 8 – Quality indicators of WGF**

No. grindings	Moisture, W %	Ash content, Z %	Crude gluten		Granulatory, %		Physiochemical indicators of bread		
			content, %	gluten deformation index, units	top on sieve No. 067, %	passage through sieve No. 38, %	bread volume, $cm^3$	porosity, %	specific bread volume, $cm^3/g$
1.1	12,9	1,68	17,1	71	4,3	44,3	350	75	1,5
1.2	12,5	1,68	17,0	70	4,9	40,8	350	75	1,5
1.3	12,8	1,67	17,1	71	1,5	55,0	360	77	1,6
1.4	13,0	1,68	17,2	72	11,0	36,0	330	75	1,4
2.1	12,8	1,68	17,4	70	1,3	64,3	430	79	2,0
2.2	12,6	1,68	17,2	68	3,4	60,1	400	79	1,9
2.3	11,3	1,81	39,6	106	1,6	50,3	380	67	1,8



The quality indicators of the common wheat whole grain flour obtained according to the scheme option No. 2 (grinding No. 2.1 and No. 2.2) differed with a smaller particle size of the flour: the top on sieve No. 067 was 1.3 and 3.4 %, respectively. The passage through sieve No. 38 had 64.3 % and 60.1 %, respectively. The obtained bread from these samples was characterized by good baking properties, a larger bread volume of 430 and 400 cm<sup>3</sup>, and a high porosity that corresponds with similar indicator from bread made of high-grade flours.

Particle size of spelta WGF was characterized by top on sieve No. 067 – 1.56 % and sieve No. 38 passage – 50.3 %. The content of crude gluten in the sample was 39.6 %, gluten deformation index (GDI) = 106 units. The high value of GDI resulted in worse baking properties compared to wheat flour obtained in the same scheme.

### Conclusion

Wheat and spelta WGF is popular among the population of many countries in the world. Ukrainian state standards for wheat WGF are absent for this moment. DSTU 46.004-99 «Wheat flour. Specifications» apply only to high-grade flour and dark flour. The re-

search of technological, baking quality indicators of wheat and spelta WGF and the indicators of baked bread showed completely different end-results, due to different technological approaches for its production and lack of general normative documentation.

For the production of WGF, it is most appropriate to use combined technological schemes with the usage of roller machines as grinding equipment on the main systems of the technological process and millstones at the ending systems for the final grinding of intermediate products.

Based on the conducted researches it is advisable to use the scheme, which consists of 3-4 roller mill grinding systems and 1-2 millstone grinding systems with sequentially grinding. The following operative modes of systems (passage through sieve No. 067) are recommended: SR<sub>II</sub> = 30-40 %, SR<sub>III</sub> = 60-70 %. The operation mode of other systems must be such as to ensure maximum extraction of WGF.

It was found that the particle size of wheat WGF, which is controlled by the top on sieve No. 067, must be not more than 2.0 %, while the passage through sieve No. 38 must be not less than 50 %.

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## ОБҐРУНТУВАННЯ ТЕХНОЛОГІЇ ПЕРЕРОБКИ ГОЛОЗЕРНИХ ТА ПЛІВЧАСТИХ СОРТІВ ПШЕНИЦІ У ЦІЛЬНОЗЕРНОВЕ БОРОШНО

### Анотація

Стаття присвячена обґрунтуванню необхідності розширення асортименту борошняної продукції та підвищення її харчової і біологічної цінності за рахунок виробництва цільнозернового пшеничного борошна. У статті описані основні завдання та проблеми, що стоять перед сучасною зернопереробною промисловістю. Це – підвищення коефіцієнта використання зерна, зниження енергоємності технологічного процесу переробки зерна і розширення асортименту готової продукції з підвищеною харчовою і біологічною цінністю.



Виробництво цілнозернового борошна дозволить розширити асортимент та підвищити харчову цінність готової продукції. Але стандарти України на цілнозернове пшеничне борошно на сьогоднішній день відсутні. ГСТУ 46.004-99 «Борошно пшеничне. Технічні умови» розповсюджуються тільки на борошно сортове та оббивне. Дослідження показників якості цілнозернового пшеничного борошна, яке виробляється в Україні, показало, що частина підприємств керуються ГСТУ 46.004-99 при виробництві цілнозернового борошна, інші виробники контролюють якість борошна за власними технічними умовами. Судячи з показників зольності та крупності ряд виробників при виробництві цілнозернового борошна дотримуються принципу майже 100-відсоткового потрапляння усіх анатомічних складових зерна у готову продукцію, але при цьому крупність борошна може бути на рівні крупності оббивного борошна або істотно від нього відрізнятися. Це залежить від виду подрібнюючих машин (жорнові посади чи вальцові верстати), а також від застосування у технологічній схемі додаткового подрібнення висівок або ні. Інші виробники при формуванні цілнозернового борошна для покращення його хлібопекарських властивостей дотримуються принципу виключення певної частки оболонкових частинок у вигляді висівок, тому таке борошно має зольність значно меншу ніж у зерні, але також його крупність залежить від різної побудови та режимів процесу його розмелу.

Метою роботи було обґрунтування структури технологічної схеми та оптимальних режимів виробництва цілнозернового пшеничного борошна. У ході досліджень проведено ряд лабораторних помелів пшениці та спелти у цілнозернове борошно. Встановлено, що для виробництва цілнозернового борошна найбільш доцільним є застосування комбінованих технологічних схем з використанням вальцових верстатів в якості подрібнюючого обладнання на основних системах технологічного процесу та жорнового посаду на останніх системах для остаточного зріблення проміжних продуктів. На основі проведених досліджень можливо рекомендувати схему, яка складається з 3-4 драних систем та 1-2 жорнових систем. Встановлено вимоги до крупності цілнозернового пшеничного борошна: залишок на ситі № 067 не більше 2,0 % та прохід крізь сито № 38 – не менше 50 %.

**Ключові слова:** цілнозернове пшеничне борошно, показники якості, гранулометричний склад, хлібопекарські властивості, технологія виробництва, режими подрібнюючих систем.

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