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THE PROBLEM OF ASSESSING THE BAKING QUALITY OF WHEAT WITH GENETICALLY DIFFERENT ALLELES OF STORAGE PROTEINS

Abstract

The article is devoted to the study of the wheat samples of the 3rd classwith the same quality indicators according to DSTU 3768, but had different baking properties. In particular, the "strength" of flour (W) significantly differed. The quantitative and qualitative state of the gluten-protein complex is significant factor for obtaining grain and flour of high baking quality. But only the quality indicators of red winter wheat according to DSTU 3768 - protein content, amount and quality of gluten cannot objectively characterize the baking quality of a specific batch of grain. For the main indications of the Ukrainian standard for wheat, all batches of wheat are practically identical. Foreign buyers do not use our Ukrainian standards, they give precedence to international methods and one of the most integral of them is the "strength" (W). The method demonstrates the main characteristics of the physical properties of wheat dough, which maybe especially important during bread making: elasticity (P), extensibility (L) and alveogram configuration coefficient (P/L). It has been established that the reason is the difference in the genetically determined alleles of the storage proteins of the studied samples. In the last years "filler" and "weak" varieties of wheat of domestic and foreign selection have appeared in Ukraine. In the conditions of replacing traditionally grown varieties of "strong" wheat in Ukraine with new high-yielding varieties of domestic and foreign breeding, it is not enough to determine the parameters recorded in DSTU 3768 to determine the baking quality, it is necessary to introduce new, more objective research methods. It is concluded that for an objective assessment of the baking properties of wheat, international standards ISO 27971, ISO 21415, ISO 5529 should be used.

Keywords: wheat, bread-making properties, "strength" of wheat, indicators of baking quality, storage proteins, standards for wheat

Introduction

The reason for the writing of this article was the cases when wheat with excellent basic quality indicators belonged to 1, 2 and 3 classes according DSTU 3768, but according to the "strength" of wheat, "W" - is one of the main indicators of baking quality - these batches was not correspond to the requirements for milling wheat.

For a long time, breeding and genetic institutions in Ukraine created wheat varieties of the HRW class (Winter Hard Red Wheat), with high bread-making properties, the so-called "strong" wheat. However, taking into account the current trends of the domestic and world grain markets, domestic breeders have launched breeding programs involving new original genetic material. Breeding was carried out to increase the productivity of new varieties. The most radical improvement of wheat is possible mainly on the basis of separate hybridization - the crossing of cultivated wheat with its wild and cultivated relatives (for example, with rye), which, as a rule, have a negative effect on the baking quality of wheat, but a positive effect on abiotic factors - drought resistance, frost resistance , resistance to diseases.

In addition, in recent years, Ukraine increased in the use of varieties of foreign origin [1]. By 2014, the number of varieties of foreign origin in the State Register was 18%, and as of 2018, the percentage of such varieties is as much as 27% (Fig. 1). Of these, only 17% are nominated as strong category, and the remaining 83 are valuable, filler and fodder wheat.

According to "APK-Inform", farmers used more than 223 varieties of winter wheat in 2017, 15 of which occupied for almost 52% of all sown areas. Of them, more than 12% of all areas were sown with wheat varieties of foreign origin [2].

So, at the moment, in Ukraine, in addition to the traditional "strong" wheat of high quality, new varieties

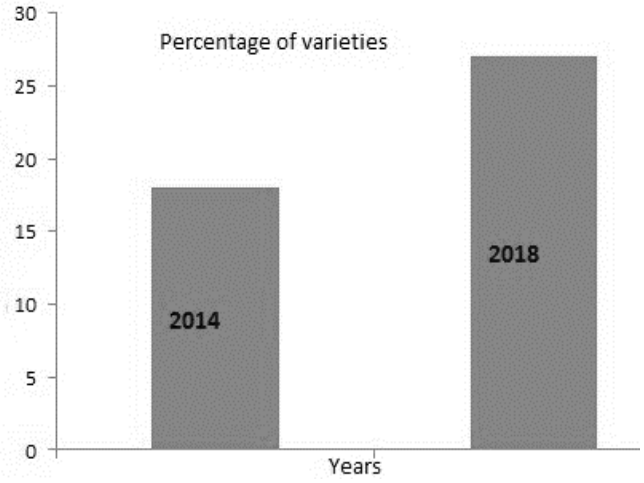

Fig. 1. The share of foreign wheat varieties in the Register of varieties of Ukraine by year

of Ukrainian selection and varieties of foreign origin are grown, which are classified as “weak" and "fillers". Classificationaccordingtothe "strength" ofwheatisprimarilydeterminedbythepropertiesoftheprotein-glutencomplex.

The quantitative and qualitative state of the gluten-protein complex is significant factor for obtaining grain and flour of high baking quality, the ref ore the works of many researchers are devoted to the study of the composition and properties of proteins [4-11]. Of all the tested methods of protein research, the electrophoresis method turned out to be the most effective in studying the properties, both theoretically and practically. Electrophoresis is a method of fractionation of protein mixtures in porous material (gel) under the action of direct electric power. It is also known that electrophoregrams based on the number, intensity, and mobility of individual components are a distinct varietal characteristic and their character does not depend on the year and place of harvest, protein content, and grain quality level of the same wheat variety [8-10]. Electrophoresis makes it possible to identify individual molecules and their aggregates, the synthesis of which is controlled by certain genes. The difference between varieties in the component composition of proteins is controlled by genes, each of which is represented by a certain number of alleles and each of which controls the number of components (subunits) characteristic for it and the nature of their placement in the gel.

To date, catalogs of identified alleles of gliadin- and gluten-encoding loci have been created [9, 10].

The purpose and tasks of the research

The purpose of the work is to establish methods for determining the quality of wheat, which must be used for the objective assessment of baker's wheat.

The object of research: three batches of wheat grain, which according to the quality indicators determined according to DSTU 3768, belong to the 3rd class.

Research materials and methods

An analysis of the physic-chemical properties of commercial batches of wheat grain was carried out in accordance with the DSTU 3768 standard. Moisture content of wheat grain performed by GOST 29143-91 Gluten content and Gluten Quality (Gluten index) in grain and flour was determined out according to procedure described in GOST 13586.1-68 and ISO 21415-2.

Rheological quality indicators (which are contractual in the case of international trade) were determined according to international standards ISO 27971, ISO 21415-2, ISO 5529. on the Alveograph PC. The following parameters have been defined: resistance to extension (P), dough extensibility (L), curve configuration ratio (P/L ratio), deformation energy (W), swelling index (G) and elasticity (P200/P ratio).

To determine the genetic components, the method of electrophoresis of wheat storage proteins in a polyacrylamide gel was used according to the PBI (Plant Breeding Institute, Odesa) method.

Research results and their discussion

For the main indications of the Ukrainian standard for wheat, all batches of wheat are practically identical. All the main quality parameters of wheat – the protein quantity, the quantity and the quality of gluten are in the third class, which is acceptable for bread making due to the baking properties (table 1).

Foreign buyers do not use our Ukrainian standards, they give precedence to international methods and one of the most integral of them is the “strength” (W).

The method demonstrates the main characteristics of the physical properties of wheat dough, which maybe especially important during bread making: elasticity (P), extensibility (L) and alveogram configuration coefficient (P/L), alveographs welling index (G), dough elasticity Index (Ie). So, according to international standards and requirements to milling wheat, the "strength" can be more than 160-180 a.u.

The results of the determination according to the international methods are shown in Table 2.

Despite the identity of the quality indicators according to DSTU 3768, the indicator of "strength" of flour and other parameters of the alveogram, the quality of gluten in grain according to ISO 21415-2 (Gluten index) and the Zeleny test are significantly different in them (Fig. 2).

The first two samples differed significantly in terms of flour strength from sample No. 3, which has a high bread-making ability. It should be noted that the first two wheat samples were significantly differ to sample No. 3 in terms of gluten quality (gluten index) when using whole grain 65 and 64 vs. 95, respectively, but this difference became insignificant when washing gluten in flour 89 and 85 vs. 98, respectively. According to most international contracts, the "strength" of wheat should be 160-180 alveograph units, i.e. the first two samples do not meet the criteria of baker's wheat according to inter-

Table 1– Main quality parameters of red winter wheat samples according to DSTU 3768

Parameters	Method	Results		
		Sample № 1	Sample № 2	Sample № 3
Moisture, %	GOST 29143-91	11,55	12,40	12,00
Protein content on dry basis, %	GOST 10846-91	12,10	12,15	11,95
Gluten content, % *	GOST 13586.1-68	21,4	21,2	21,6
Gluten quality, IDK unit*	GOST 13586.1-68	80	85	78
Falling number, s	GOST 27676-88	320	351	300
Bug damaged grains, %		0,4	0,7	0,5

* - grading was carried out on whole-milled grain

Table 2 – The results of the determination quality parameters according to the international methods

Parameters	Method	Results		
		Sample № 1	Sample № 2	Sample № 3
«Strength» (W), u.a.	ISO 27971	152	170	250
Elasticity (P), mm	ISO 27971	44	75	69
Extensibility (L), mm	ISO 27971	111	65	100
Configuration coefficient(P/L)	ISO 27971	0,40	1,15	0,69
Dough Elasticity Index (Ie), %	ISO 27971	55	50	62,
Gluten content*, %	ISO 21415-2	26,4	23,9	23,2
Gluten Quality (Gluten index)*	ISO 21415-2	65	61	95
Gluten content**, %	ISO 21415-2	25,6	24,7	25,4
Gluten Quality (Gluten index)**	ISO 21415-2	89	85	98
Test Zeleny, ml	ISO 5529	31	28	45

* - determination was made on whole grain

** - the determination was carried out on flour

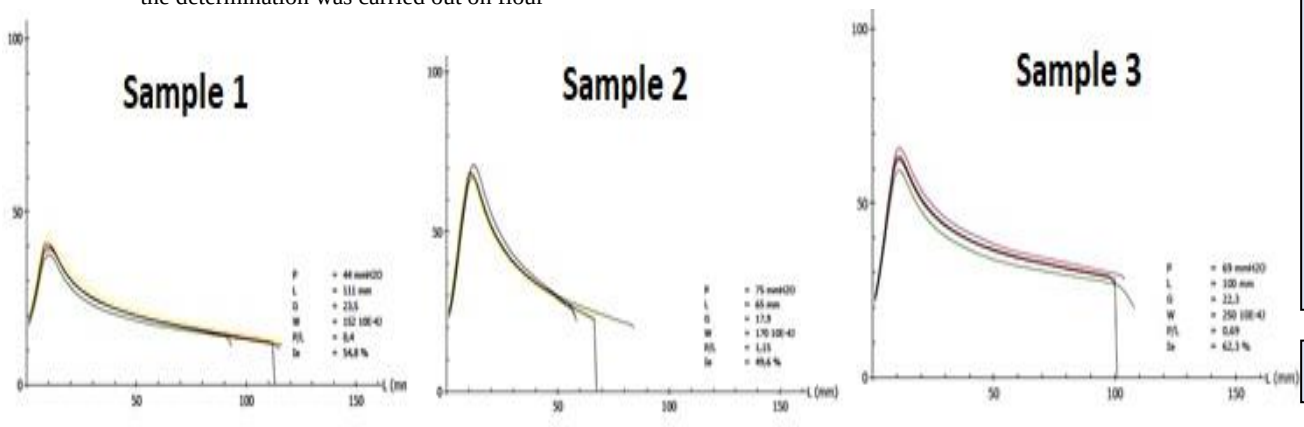

Fig. 2. Alveograms of 3 samples hard red winter wheat

national requirements, despite the fact that they were assigned to the third class according to DSTU 3768.

The sedimentation determination according to Test Zeleny was also significantly different - 31 ml and 28 ml in the first two samples against 45 ml in the third sample.

It follows from the above that only the quality indicators of red winter wheat according to DSTU 3768 - protein content, amount and quality of gluten cannot objectively characterize the baking quality of a specific batch of grain.

The samples were also examined by electrophoretic analysis of the spectra of storage (gluten) proteins gliadins and glutenins, as key components of the formation of the baking quality of wheat grain. To date, catalogs of identified alleles of gliadin- and gluten-encoding loci have been created, which allow recording the features of gluten proteins in the form of formulas of any variety known in the world [12]. Modern genetic research combined with technological tests indicate that

Table 3 – Results of electrophoretic analysis of gluten proteins gliadins and glutenins of wheat samples

Sample	Biotype	% biotypes	Gliadins							Glutenins		
			1A	1B	1D	6A	6B	6D	2-1A	1A	1B	1D
Alleles of gliadin- and gluten-encoding loci of common winter wheat varieties in Ukraine, which determine high baking quality			3	1	4	1	1	1	1	1	1	1
			4	4	5	3	2	2	3	2	2	
			10	15	7	4	3	3			5	
					10		4	4				
№ 1	1	80	n	n	1	1	2	1	1	2	n	**1**
	2	20	n	n	1	1	2	1	1	2	4	2
№ 2	1	78	3	3	1	3	2	1	1	2	2	**1**
	2	22	2	1	1	3	2	1	1	2	2	**1**
№ 3	1	67	4	1	4	3	2	2	1	1	1	1
	2	33	10	15	4	4	2	3	1	2	5	1

the technological specialization of varieties, or the suitability of their flour for the manufacture of certain types of products, including bakery products, can be predicted based on the allelic composition of loci encoding the biosynthesis of wheat grain proteins and starch [13].

It can be seen (Table 3) that the provided samples are not homogeneous according to the electrophoretic spectra of reserve proteins. The main biotypes of the first sample of wheat are represented by new alleles at the main loci of both gliadins and glutenins, which are not typical for winter wheats of Ukraine Gld1A, Gld1B, Glt1B, and in their composition have an allele at the key locus Glt 1D, which causes a sharp negative impact on bakery quality. This is evidenced by the results of quality indicators that reflect the genetically determined quality of wheat grain - the "Strength" of flour and the Zeleny sedimentation indicator. Therefore, it is most likely that sample No. 1 is a variety of foreign origin, which is also evidenced by the uncharacteristic (new) alleles of gliadin- and gluten-encoding loci for our conditions. It was the lack of adaptability to our climatic conditions that led to a sharp deterioration of the organoleptic and physical properties of wheat batch No. 1, the wrinkling of the grain surface, and the abnormal (whitish) color of the grain, which negatively manifests itself in the commercial form of wheat. Sample No. 2 contains alleles common in our agricultural zone, but all of them have a negative effect on the quality of wheat grain (gliadin-encoding loci Gld 1A3, Gld 1B3, Gld 1D1), but produce an increase in yield and improve the physical properties of the grain. All genotypes with the above-hidden alleles have high resistance to diseases and abiotic factors of cultivation and cause a sharp decrease in the baking quality of wheat. Sample No. 3 is an example of a typical "strong" wheat of Ukrainian selection with excellent baking properties, which is confirmed by the "strength" index of wheat, the quality of gluten according to ISO 21415-2 (Gluten index) and the indicator of the Zeleny test. The alleles that have a positive effect on the baking properties of wheat include the gliadin-encoding loci Gld 1A4 and Gld 1A10, Gld 1B1 Gld 1B15 and especially the gluten-encoding locus Glt 1B5.

During 2015 - 2017, the main quality indicators of a large number of batches of red winter wheat destined for export and processing were determined. Most of the indicators, such as Protein Content, Quantity and Quality of gluten, the Falling Number, the Test Weight of the grain from year to year were in the same interval, but the "strength" of flour was characterized by a clear tendency to decrease. Thus, if as early as 2015, the number of wheat samples with a "strength" indicator of more than 180 a.u. was only 10%, then in the following years their number rapidly increased to 15 and 17% in 2016 and 2017, respectively.

What explains the tendency to decrease the baking quality of commercial batches of wheat grain in recent years? The results of electrophoretic analysis of gluten proteins gliadins and glutenins of three different batches of red winter wheat showed their genetically determined difference in allelic composition (Table 3). Until recently, wheat varieties with alleles causing low baking quality were absent from the Register of Varieties of Ukraine, and especially its south, has always been a zone of cultivation of high-quality commercial grain of winter wheat, and the varietal composition stood out with high genetic potential. Such varieties were created by the Breeding and Genetics Institute, special attention was paid to baking quality, and each breeding line was annually passed through a hard "sieve" according to the following parameters: grain hardness, flour yield, flour "strength" (W), alveogram configuration index (P/ L), dough elasticity index (Ie), dough stability during kneading, water absorption capacity of flour, Hagberg's number, volume of bread and its evaluation, tolerance to grain damage by the shell bug [14, 15].

Currently, there is a tendency to enter the Register of “filler”and “weak”wheat varieties. These include varieties of foreign origin and some domestic varieties, the baking properties of which have not been sufficiently studied, because it is known that recently the main criterion for entering a variety into the register is to surpass the standard variety exclusively in terms of yield. That is why recently flour mill technologists and bakers are sounding the alarm - it is not possible to bake normal bread, even if the raw materials meet class 2 and 3 according to DSTU 3768. The imperfection of the existing system of methods for assessing bakery quality leads to numerous problems in the production of bakery products and execution of international contracts.

Conclusions

1. In the conditions of replacing traditionally grown varieties of "strong" wheat in Ukraine with new high-yielding varieties of domestic and foreign breeding, it is not enough to determine the parameters recorded in DSTU 3768 to determine the baking quality, it is necessary to introduce new, more objective research methods.

2. Ukraine exports a significant part of wheat grain, therefore, when determining the baking quality, it is necessary to apply internationally recognized methods and standards: ISO 27971, ISO 21415, ISO 5529 in order to avoid misunderstandings during the execution of contracts.

3. The analysis of commercial batches of wheat by the method of electrophoresis of storage proteins showed the presence of new alleles of gliadin-gluten-encoding loci in the genotype, which were not characteristic of Ukrainian wheat, and their presence is observed mainly in varieties of leading European seed companies. Every year, the share of such varieties with a low genetically determined level of baking quality is increasing.

4. An effective method for assessing the baking quality of samples is the method of electrophoretic analysis of wheat gluten proteins. The results of electrophoretic analysis are used to identify specific Glt/Gld alleles that are associated with the baking properties of wheat, analysis of genetic homo/heterogeneity of wheat samples, genetic purity of seed material, genetic purity of wheat varieties.

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ПРОБЛЕМА ОЦІНКИ ХЛІБОПЕКАРСЬКОЇ ЯКОСТІ ПШЕНИЦІ З ГЕНЕТИЧНО РІЗНИМИ АЛЕЛЯМИ ЗАПАСНИХ БІЛКІВ

Анотація

Стаття присвячена дослідженню зразків пшениці 3-го класу з однаковими показниками якості за ДСТУ 3768, але з різними хлібопекарськими властивостями. Зокрема, суттєво відрізнялася «сила» борошна (W). Кількісний та якісний стан клейковино-білкового комплексу є вагомим фактором для отримання зерна пшениці та борошна високої хлібопекарської якості. Але лише показники якості, які регламентує ДСТУ 3768 (вміст білка, кількість і якість клейковини) для зерна червоної озимої пшениці не можуть об'єктивно характеризувати хлібопекарські якості конкретної партії зерна. За основними показниками українського стандарту всі партії пшениці практично ідентичні. Іноземні покупці не користуються нашими українськими стандартами, вони віддають перевагу міжнародним методам, серед яких одним із найвагоміших є оцінка показника «сила» (W). Цей метод демонструє основні характеристики фізичних властивостей пшеничного тіста, які можуть бути особливо важливими при випіканні хліба: еластичність (P), розтяжність (L) та коефіцієнт конфігурації альвеограми (P/L). Встановлено, що причиною різної «сили» досліджуваних зразків зерна пшениці є різниця в генетично обумовлених алелях запасних білків. Останніми роками в Україні з'явилися «філери» та «слабкі» сорти пшениці вітчизняної та зарубіжної селекції. В умовах заміни традиційно вирощуваних сортів «сильної» пшениці в Україні новими високоврожайними сортами вітчизняної та зарубіжної селекції для визначення хлібопекарської якості недостатньо визначити параметри, які зафіксовані в ДСТУ 3768. Для коректної оцінки хлібопекарських властивостей необхідно запровадити нові, більш об'єктивні методи дослідження. Зроблено висновок, що для об'єктивної оцінки хлібопекарських властивостей зерна пшениці необхідно використовувати міжнародні стандарти ISO 27971, ISO 21415, ISO 5529.

Ключові слова: пшениця, хлібопекарські властивості, «сила» пшениці, показники хлібопекарської якості, запасні білки, стандарти на пшеницю.

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