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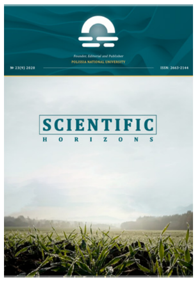

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Molecular and genetic basis for improving the quality of soft wheat grain

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Abstract. The increase in agricultural territories in Azerbaijan can no longer cover the problem of shortage of high-quality baking flour in the domestic market. Thus, there is a need to improve the quality of grain harvested from existing areas to obtain more grain products. The purpose of this study is to review and investigate the physico-chemical and genetic parameters of local and introduced soft wheat varieties to further identify promising areas of breeding. For this purpose, a PCR study of individual loci of the Wx genes responsible for amylose synthesis and electrophoresis of Glu genes encoding gluten quantity and quality were performed. In addition, for the varieties Shafaq 2 and Gonen, which were selected during the research for the test baking of bread, a PCR analysis was performed to compile the gliadin formula of the varieties using a sample of the Bezostaya 1 variety as a marker. The physico-chemical characteristics

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were determined according to quality standards, as well as baking bread sample. During the pilot sowing, one of the varieties – Girmizi Gul1, was sown on plots with various tillage methods – traditional, minimal, and zero. Thus, it was determined that the varieties Gonen and Ekinci 84 contain a zero allele of the Wx-B1 – Wx-B1b gene, which means that their endosperm contains higher-quality starch, and the varieties Askeran, Azemetli 95, Gonen, Kirmizigul, Nurlu 99, Tale 38, and Ugur, in turn, contain a zero allele of the gene GluA1 – GluA1d, which on the contrary worsens the gluten quality of these varieties. As for tillage, the traditional system showed itself to be the best, the minimal tillage was slightly worse, and the zero tillage system turned out to be the least suitable in these conditions. Thus, the obtained data outline further areas for conducting research and open up prospects for targeted selection for alleles of the considered genes

Keywords: flour; starch; gluten; gliadin; baking qualities

INTRODUCTION

The decline in the quality of soft wheat caused by a number of unfavourable yield factors leads to an increase in the agricultural area in Azerbaijan. During 2020-2021, the quality of the crop was most influenced by temperature conditions, in particular abnormally high temperatures, and poor resistance of a number of varieties to infectious diseases – both to brown rust, which spread during the years of observation, and to yellow rust, outbreaks of which were observed for seven years, on the moment when the authors conducted the study.

These trends, which go beyond the years presented, and issues of irrigation and soil erosion, recorded in a number of studies, lead to the fact that as of 2021, about 50% of the republic's wheat needs had to be covered by imports. However, the area of crops has increased by 60% since 2011 (Huseun Oglu, 2021; Mustafayeva *et al.*, 2021). Increasing the amount of grain produced does not fully solve the problem of shortage, because as a result, significantly fewer bread products are obtained from low-quality wheat than from high-quality grain (Tadesse *et al.*, 2019). The suitability of grain for the manufacture of food products, including bread, is mainly determined by its composition. The greatest focus of research in this context is the influence of the physicochemical properties of the constituents of glutens and gliadins (Mirzayeva *et al.*, 2022). These are proteins responsible for the rheological parameters of the dough, since they have the ability to trap air bubbles and form a porous structure of finished products, and also affect the elasticity of the dough (Ospanov *et al.*, 2020). Another significant factor is the influence of the starch content and structure, as well as the ratio of polar and nonpolar lipids, which also affects the volume of bread (Cesevičienė *et al.*, 2022).

The quality of soft wheat, according to E. Hajiyev *et al.* (2021), depends on two groups of factors: environmental and genetic. Environmental factors include weather conditions, soil quality, methods of tillage, method of fertilisation, etc. Genetic factors are currently less investigated, however, the study of genetic control and polymorphism of various enzyme and non-enzyme proteins opens up new opportunities for breeding and selecting varieties with optimal nutritional indicators (Afanasyeva *et al.*, 2023). According to the research by S. Kalenska *et al.* (2023), Glu-type genes are responsible for the synthesis of gluten, which are localised on the long arms of chromosomes of group 1: 1A, 1B, and 1D. At the same time, Glu-D1 genes have the greatest contribution to wheat quality, and Glu-A1 are the least variable. Y. Zi *et al.* (2022), in turn, summarised information on the effect of various genes responsible for starch synthesis on the yield and quality of flour. The Wx genes affect the synthesis of amylose, which reduces the quality of flour and its products. The main effect is provided by the Wx-B1 allele, the smaller one – by Wx-A1. The absence of the first allele significantly improves the quality of flour.

For genes of the Gld group that encode the synthesis of gliadins, as indicated by G. Özer *et al.* (2020), at the moment, no alleles have been identified that have an unambiguous qualitative effect. Alleles Glu-B1d (6+8), Glu-B1h (14+15), and Glu-B1b (7+8) are associated with higher gluten strength and pasta quality. The 1Dx5+1Dy10 alleles determine the level of increase in dough consistency, elasticity, viscosity, and extensibility, baking quality and the corresponding volume of a loaf of bread. Bx7, Bx7 OE, 1Bx17+1By18, 1Bx13+1By16, Bx7+By9 and 1Bx7+By8 in the Glu-B1 and 1Ax2 alleles found on Glu-A1 increase the strength of the dough and positively affect the consistency, extensibility, viscosity, and elasticity of bread dough.

Thus, given the confirmed directional effect of certain groups of genes on the quality of wheat flour, this study is designed to determine whether breeding for these genes really has prospects of becoming one of the ways to overcome the shortage of high-quality baking flour in Azerbaijan.

MATERIALS AND METHODS

Studies on the productivity of 37 local and breeding varieties of soft wheat were conducted in 2020 at the Terter zonal experimental station located in the northwestern part of the Karabakh lowland at an altitude of 175 m above sea level. Observations and measurements were carried out three times on the selected plots with an area of 1 m². Irrigation was applied at the stage of onset of tube emergence, earing and onset of milk maturity of grain. The agrotechnical practices recommended for the region were also carried out within the framework of the traditional tillage system. The sowing of the Girmizi Gul 1 variety was carried out in the third ten days of November using traditional, minimal, and zero tillage methods.

Thus, the study consisted of three blocks designed to determine the main measures to improve the quality of wheat grain: determining the optimal type of tillage, analysing the grain quality of the main wheat varieties suitable for cultivation in Azerbaijan, and determining the molecular genetic basis of the determining indicators.

As part of the grain quality assessment, weight of 1,000 grains, percentage composition and fibre deformation measurement (FDM), falling number, level of sedimentation, and nitrogen content were determined. The grains were randomly selected, counted and weighed. To determine the gluten content, a sample of medium grain weighing about 50 g was taken. The sample was crushed in a laboratory mill and cleaned of impurities: debris, husks, spoiled and underdeveloped grains by sieving through a series of sieves with holes of different diameters. About 25 g of pure ground grain was taken, 14 cm^3 of distilled water was poured, and a lump of dough was kneaded, which was allowed to settle for 20 minutes. The settled dough was washed under running water until the turbidity of the water stopped and the lump mass decreased. The resulting gluten was squeezed out and wiped with a dry towel during the entire process. They were weighed, recording the results with an accuracy of 0.1. The gluten content was calculated using the equation (1):

$$x = \frac{m_1}{m_2} \times 100. \quad (1)$$

The gluten quality was determined using the IDK-1M and IDK-2 devices. The falling number was determined using a viscometric tube. All stages of grain quality research were carried out using methodological recommendations and Interstate Standard 13586.1-68 (1987). In the study, the Bezostaya 1 variety was used as a marker for electrophoretic analysis. Electrophoresis of spare proteins was performed on gel electrophoresis plates with glycine acetate buffer (pH 3.1). The identification of wheat samples based on the results of electrophoregrams of gliadin coding loci Gld 1A, Gld 1B, Gld 1D, Gld 6A, Gld 6B and Gld 6D was carried out according to the catalogue of allele component blocks of gliadin of the Bezostaya 1 variety (marker), taken as the standard.

The collections were evaluated for the allelic state of the Wx genes using PCR analysis using primers AFC/AR2, Wx-A1b-F-MH/Wx-A1b-R-MH, Sun-1F/Sun1R, BDFL/BRD, 4F/4R, BDFL/BRC1/BRC2/BFC, WxB1L/Wx-B1R, Wx-D1-2F/Wx-D1-2R, Wx-D1-1F/Wx-D1-1R, BDFL/DRSL. In determining the glutenin-coding genes, the UMN19 codominant marker was used to identify allelic variants of the glutenin IUD genes encoded by the Glu-A1 locus. A fragment of 362 pn in size was amplified on samples having subunit 2 (Glu-A1b allele). In samples with a null allele and having subunit 1 (Glu-A1a allele), a fragment of 344 pn was observed.

It was also decided to conduct a test baking of bread to compare varieties with different indicators of the qualitative and quantitative composition of starch. The bread was baked using a straight dough method, dough fermentation, and further baking were carried out on Domino and Arianna devices. The duration of resting was determined organoleptically, baking was carried out at a temperature of 220-230°C. For comparison, the paper presented a comparison of loaves made from flour of varieties Shafaq 2 and Gonen. Statistical processing of the research results was carried out using Microsoft Excel 2010 software suite.

RESULTS

The first stage of the study was the test sowing of one of the varieties – Girmizi Gul 1 – on experimental areas with different types of tillage: traditional, minimal, and zero. The data obtained were highlighted separately (Table 1).

Table 1. *Quality indicators of the Girmizi Gul1 variety under various cultivation methods 2021*

Tillage methods	Weight of 1,000 grains, g.	Vitreousness, %	Gluten, %	FDM, p.p.	Sedimentation, ml	Total nitrogen content, %
Traditional	32.1	50.5	26	76.8	31.5	12.7
Null	32.1	9.5	18.6	95.5	21	11.7
Minimal	32.8	14	28	88	27	10.4

Source: *compiled by the authors*

From the presented results, it can be seen that none of the listed tillage methods revealed statistically significant advantages in terms of the weight of a thousand grains and sedimentation rates. At the same time, the difference in vitreousness indices is noticeable – the highest proportion, more than 50%, is found in grains obtained from plants grown using the traditional method of tillage. This indicator shows a high protein content in the endosperm, compared with the starch content. With zero and minimal treatment, which included less interference with the soil structure, the percentage of vitreousness was in the range of 9-14.

In a separate way, it is worth highlighting the difference in the composition of gluten and the quality of starch. Despite the higher percentage of gluten in grain with traditional and minimal tillage methods – 26-28% versus 18.6% with the zero method. At the same time, the gluten quality expressed through FDM coefficient correlated similarly – the indicator of zero tillage was more than 95 p.p., at minimal tillage – 88, and at traditional tillage method FDM was the lowest – about 77 p.p. Total nitrogen content correlated weakly with tillage method in this case.

The subsequent stages of the study were devoted to determining the molecular soil quality characteristics of the studied wheat varieties. When conducting PCR analysis of 37 local varieties to investigate the allelic diversity of Wx genes, attention was paid to the alleles Wx-B1 – Wx-B1e, Wx-B1 – Wx-B1a, and Wx-B1 – Wx-B1b, where the presence of one of the first or second alleles – "e" or "a" – indicated the presence of active amylose synthesis in the endosperm, in turn, the "b" allele – the so-called null allele, indicates the absence of amylose synthesis. Thus, three samples were found where amplification for the "e" allele according to Wx-B1 – Wx-B1e presumably occurred, these are the varieties Ag Bugda, Berektli 95, and Pervin. Three more samples, according to this analysis, turned out to be presumably heterogeneous and contained both the "a" allele and the "e" allele for this gene. These are wheat varieties Shiraslan 23, Karabakh, and Shafaq 2. The target allele, Wx-B1 – Wx-B1b, is presumably found in the endosperm of two varieties: Gonen and Ekinci 84. All other wheat samples contained the "a" allele of the Wx-B1 gene (Fig. 1).

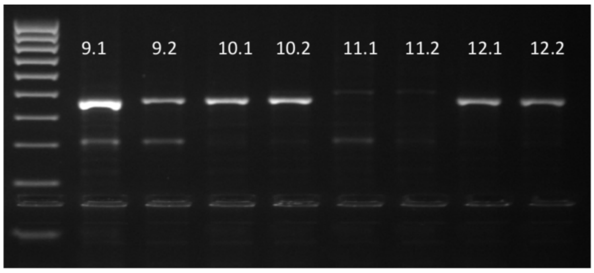

Figure 1. *Example of PCR analysis of the Wx-B1 locus, where sample 11 is the putative "b" allele according to Wx-B1 – Wx-B1b (null allele), and the remaining "a" is the wild type*
Source: *compiled by the authors*

The next group of genes analysed were the Glu group genes responsible for the synthesis of high molecular weight glutenins (HMW-GS) encoded by the Glu-A1, Glu-B1, and Glu-D1 loci localised on the long arms of chromosomes 1A, 1B, and 1D, respectively. Allelic variants Glu-A1a and Glu-A1b encoding subunits 1 and 2, respectively, have a positive effect on baking qualities, whereas the null allele Glu-A1d worsens them. Among all the samples, Glu gene null alleles were detected in seven samples numbered 8, 9, 11, 16, 23, 30, and 34 (Fig. 2). These are the varieties Askeran, Azemetli 95, Gonen, Kirmizigul, Nurlu 99, Tale 38, and Ugur. For the remaining varieties, the presence of the second, Glu-A1b, allele variant was determined to be the most likely, whereas the Glu-A1a allele was not found in any of the samples.

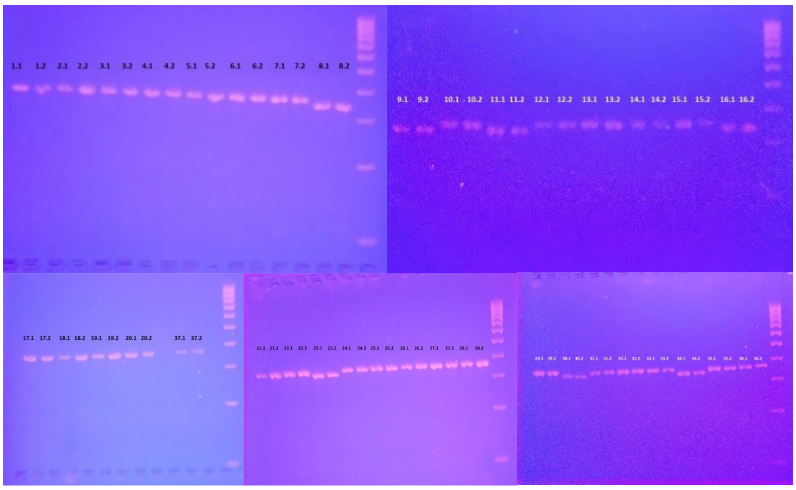

Figure 2. *Determination of the Glu-A1 locus, using the UMN19 codominant marker, where the samples 8, 9, 11, 16, 23, 30, 34 – carry a null allele, and the samples 1-7, 10, 12-15, 17-22, 24-29, 31-33 – carry subunit 2*
Source: *compiled by the authors*

When comparing the physico-chemical parameters determined in the framework of grain quality assessment, varieties with different alleles of Glu group genes, first of all, the indicators involved in the quality of gluten were analysed. Thus, the percentage of gluten for all varieties with a zero allele turned out to be, with minor deviations, about 28 and 30%, only the Azemetli variety showed a result of 24.4%, which is slightly less than the average result of other samples with the same allele. It should be noted that the gluten content of the other varieties containing the coding subunit also ranged from 26-32%. The lowest result in the Ruzi 84 variety is 22.1% gluten, and the highest in the Mirvari variety is 35%. The gluten quality turned out to be average in absolutely all samples, and the FDM was in the range of 90-111 p.a. The best indicators were in the varieties for which the presence of the coding allele of glutenin genes was determined: varieties Azeri – 90; Yagut – 93; Gobustan – 94, and Karakylchyk 2 – 95 p.a. The indices of varieties with a zero allele ranged from 100-109 p.a. There were no clear traceable patterns with the considered genetic factors for the indicators of total nitrogen content, sedimentation, and falling number (Table 2).

Table 2. *Results of the analysis of grain quality of local and introduced varieties (2020)*

No.	Varieties	Weight of 1,000 grains, g	Gluten, %	FDM, p.a.	Sedimentation, ml	Total nitrogen, %	Falling number, seconds	Baking quality, in points
1	Agali	46.1	32.1	110	34.7	13.8	190	4.5
2	Ag bugda	41.9	28	109	21	14	145	4.5
3	Aran	50.2	31.4	100	34.8	14	232	4.7
4	Azeri	49	32.8	90	30	14	177	4.6
5	Berektli 95	37.7	24.5	110.6	-	12.4	123	4.4
6	Ekinci 84	38.2	28.2	100.6	24.4	12	120	4.4
7	Elinge84	56	32.6	100	-	13.4	200	4.5
8	Askeran	45.7	28	105.4	30.5	14.2	180	4.6
9	Azemetli 95	46.2	24.4	100.3	25.7	14	200	4.5
10	Fatima	50	28	95.6	30	13.9	264	4.5
11	Gonen	47.7	30.6	100	33.1	14.4	218	4.8
12	Guneshli	51.2	26.8	112	29.7	14.4	205	4.7
13	Kehraba	49.6	28.4	103.8	-	14.3	189	4.6
14	Karabakh	51.8	28.6	111	-	14.6	244	4.7
15	Karakylchyk 2	47.5	30	95	-	13.6	174	4.5
16	Kirmizigul	52.2	30	97.8	40	14.8	222	4.9
17	Gobustan	50	30.8	94	40	14.9	220	5
18	Ləyaqətli	42.6	30	106.6	33	14.5	190	4.7
19	Mirbeshir50	49.0	32	96.6	-	14.4	138	4.6
20	Mirvari	39.8	35	109.9	-	13.6	144	4.5
21	Mugan	48.8	30	111	-	12.7	200	4.5
22	Murov 2	51.4	33	101.5	33.4	14.3	197	4.6
23	Nurlu 99	37.5	28	109.3	27.7	13	156	4.4
24	Pervin	40	26.4	106	33	13.4	177	4.6
25	Ruzi 84	33.9	22.1	109.9	29	12.4	159	4.4
26	Shafaq 2	50.4	28.4	109	30.3	14	232	4.8
27	Sheki 1	42	30.2	100.4	33.3	13.9	179	4.7
28	Shark	40	28.8	110.5	32.8	14.6	188	4.7
29	Shiraslan 23	50.1	28.6	108.8	32.4	13.9	177	4.6
30	Tale 38	52	30.4	104.1	33.3	13.9	163	4.6
31	Tereggi	48.8	32.6	109.5	30	14.4	190	4.6
32	Terter	49.5	32.1	105	-	13.9	166	4.5
33	Terter 2	50.8	32.6	106.6	-	14	169	4.4
34	Ugur	43.6	30	108.3	33.1	13.4	154	4.5
35	Vugar	52.7	28.8	102	-	14.5	200	4.7
36	Yagut	50.9	28.8	93	-	14.5	196	4.7
37	Peringe (tetraploid)	54.2	26.4	109.4	-	13.0	134	4.3

Source: *compiled by the authors*

For a more detailed comparison of the baking properties and quality of the finished bread product, two varieties were selected: Gonen and Shafaq 2. The Gonen variety was the only one of the studied ones containing two target null alleles: Wx-B1 – Wx-B1b, which led to the absence of amylose synthesis in the endosperm of the grain of this variety, and the Glu-A1d allele of glutenin-synthesising genes, which leads to lower gluten quality. For comparison, the Shafaq 2 variety is heterogeneous in the Wx-B1 gene, and contained both the Wx-B1 – Wx-B1a and Wx-B1 – Wx-B1e alleles, but, on the contrary, the Glu-A1b allele of glutenin-synthesising genes turned out to be characteristic of it. Thus, potentially, the starch composition in the Gonen variety should have been more suitable for baking, and in the Shafaq 2 variety, on the contrary, the gluten quality was more optimal. An important factor in choosing varieties was that both samples received a final score for baking properties at the same level – 4.8.

The physico-chemical properties of flour of these varieties turned out to be quite comparable, such as the weight of 1,000 grains, level of nitrogen, FDM, and percentage of gluten (Table 3). The Shafaq variety is slightly superior in terms of the falling number and is inferior in terms of gluten content and sedimentation rate, however, the difference between these indicators is not statistically significant.

***Table 3**. Results of the analysis of the grain quality of the Gonen and Shafaq 2 varieties*

No.	Varieties	Weight of 1,000 grains, g.	Gluten, %	FDM p.a.	Sedimentation, ml	Total nitrogen, %	Falling number, seconds	Baking quality, in points
1	2	3	4	5	6	7	8	9
11	Gonen	47.7	30.6	100	33.1	14.4	218	4.8
26	Shafaq 2	50.4	28.4	109	30.3	14	232	4.8

***Source:** compiled by the authors*

The obtained bread samples, despite the fact that the varieties received an equal score in baking properties, differed visually and organoleptically (Fig. 3 and 4).

***Figure 3.** Laboratory baking of bread from the variety Gonen*
***Source:** compiled by the authors*

***Figure 4.** Laboratory baking of bread from the variety Shafaq 2*
***Source:** compiled by the authors*

The photo shows that the colour and porosity of the bread are different: the pulp of bread made from flour of the Gonen variety is lighter, has a whiter shade and is less porous, the rise of the bread on the side section is smooth, high, arched. The flesh of bread made from Shafaq 2 flour is, accordingly, more porous, has an even texture, a dark colour, and a more yellowish shade. The rise of this sample is low and smooth, the volume is somewhat smaller. The taste properties of both samples are satisfactory, the texture of the second one is softer, moist and elastic, whereas the first sample is denser.

Gluten-coding genes were additionally analysed for the selected varieties. The compilation of the genetic formula of the electrophoregrams of the glutein-coding loci Gld 1A, Gld 1B, Gld 1D, Gld 6A, Gld 6B, and Gld 6D was carried out according to the catalogue of allele-component blocks of gluten of the Bezostaya 1 variety, as a result of which it turned out that the gluten components of the Gonen variety differ from the Bezostaya 1 marker variety in the following blocks: Gld 1D2, Gld 6B2, Gld 6A12; the block components: Gld 1D4, Gld 1A7 of Shafaq 2 variety differ in five blocks: Gld 1B, Gld 6A3, Gld 6D9 (Fig. 5).

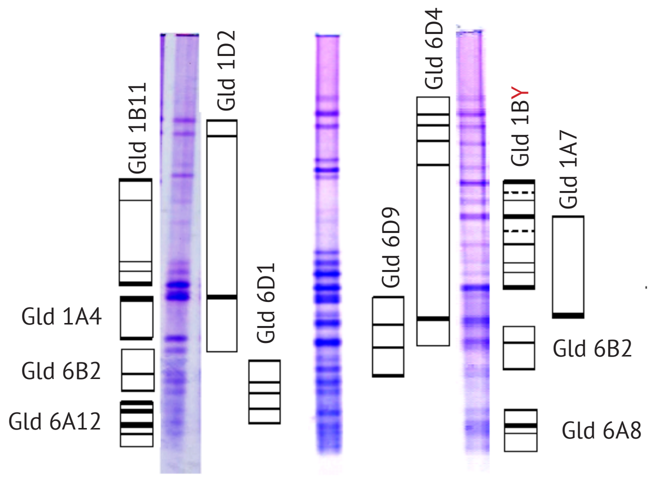

Figure 5. *Gliadin formula of varieties 1 – Gonen (a variety of Turkish origin); 2 – Bezostaya 1 (marker); 3 – Shafaq 2*
Source: *compiled by the authors*

Since gliadin-coding genes are responsible for the porosity of bread products, this information can be used in further studies aimed at investigating the desired texture of bread. Targeted selection of target alleles of genes encoding the synthesis of starch, gluten, and gliadin may be a promising area in improving the quality of wheat.

DISCUSSION

Improving the quality of wheat and the yield of flour from it for the production of high-quality bakery products in quantities capable of meeting demand is a goal that can potentially be achieved by a set of measures. First of all, it is reasonable to consider the factors affecting soil preparation for sowing, namely the tillage system. Despite evidence of the effectiveness of zero tillage for some crops, such as cotton, legumes, or vineyards, the impact of this system is currently only beginning to be actively studied (Fan *et al.*, 2020). B. Barna *et al.* (2023) in their studies note an improvement in the quality and yield of grain with zero tillage. In the study by Z. Peng *et al.* (2020), this tillage system has been identified as one of the most promising in the context of arid or semi-arid climate conditions. In turn, Z.R. Kan *et al.* (2020) are somewhat more skeptical about the prospects of using zero tillage, and note the difficulty of absorbing moisture and developing roots in the absence of loosening the soil, but they still define this system as more promising than the traditional one. Moreover, the conclusions of these researchers are close to the results obtained in this study, regarding the fact that the best indicators were obtained during minimal or rotational tillage.

Very simillar results were obtained by M. Yousefian *et al.* (2021). The researchers noted that the zero tillage system reduces the average physical and chemical properties of grain, increases the amount of fibre and water, while reducing the protein and ash content, while rotary tillage was close in its results to the traditional one and is defined by the researchers as an equivalent replacement. It is noteworthy that the climatic conditions of the region in which the study took place are quite comparable to those in Azerbaijan. The next group of factors that could improve the situation with wheat quality, and which at the same time would be weakly dependent on unfavourable external factors, were genetic (Litvinov & Olefirenko, 2023). E. Filip *et al.* (2023) note three key factors for the selection of varieties containing high-quality starch: the baking potential of flour depends on the amylose content in starch, a decrease in the amylose content improves the quality of flour and the fact that the amylose content is most influenced by the Waxy-B1 locus.

Z. Maryami *et al.* (2020), during the analysis of 160 Iranian wheat varieties, found a pattern to the situation with Azerbaijani varieties reflected in this paper.

Most varieties contained the Wx-B1 – Wx-B1a allele, which corresponds to the so-called "wild type" – that is, it occurs mainly in free-growing, non-selective wheat varieties. Only 2 samples, as well as among Azerbaijani varieties, contained the allele Wx-B1 – Wx-B1b – which has the greatest effect on reducing the synthesis of amylose in the wheat endosperm. For Iranian realities, this is only 1.25% of all the varieties studied, whereas among the varieties considered in this study, there are more than four times as many – 5.4%. The researchers, despite the fact that they did not bake bread and were not involved in the production and study of physical and chemical properties of flour of the identified varieties, see prospects for breeding wheat varieties based on minimisation of amylose content.

Target study by Y. Li *et al*. (2022), in turn, confirms that the expression of the null allele of the Wx-B1 locus affects the content of amylose, reducing it, and its blocking, respectively, increases the proportion of this polysaccharide residue in the composition of starch granules. Accordingly, the type of starch granules, their microstructure, size, thermal properties, etc., and how they affect the baking qualities of flour obtained from this wheat, change. Thus, with the expression of the Wx-B1 – Wx-B1b gene and a decrease in the amylose content, the researchers noted such an effect on the quality of bread as a more homogeneous porous structure, an increase in the volume of bread and its storage time. Y. Sung *et al*. (2023) recorded an increase in the protein content and a greater ability to swell in flour products of the so-called "glass" varieties, which were characterised by a reduced content of amylose in the starch composition. The bread sample obtained by baking from Gonen flour generally corresponds to the characteristics given in other works, especially with regard to volume increase. Indeed, it turned out to be larger in volume than bread made from a similar sample of flour obtained from Shafaq 2 grain, which contained alleles responsible for encoding amylose in significant quantities (Figs. 3, 4).

However, when evaluating the baking qualities and other physico-chemical properties of flour from different wheat varieties, there was no fundamental distinguishable difference between varieties with zero allele and "a" or "e" alleles. This is probably due to differences in the quality of the varieties themselves, which are conditioned by a combination of other genes not considered in this study, and their interaction with climatic and other external factors, which also significantly and differently affect the properties and characteristics of the grain (Panfilova *et al.*, 2019). Another equally important factor affecting the baking potential of wheat is the content and quality of gluten, which is part of it. M.E. Bayram and K.Z. Korkut (2020) identify three main groups of genes important for the optimal state of gluten: Glu-A1, Glu-B1, and Glu-D. They associate the absence of these genes, or rather their zero alleles, with a deterioration in the quality of bread products made from such flour.

C. Guzmán *et al*. (2022) clarify that high-molecular-weight glutenins encoded, in particular, by the Glu–A1 locus, mainly affect the increase in gluten strength, dough extensibility, and also, like the considered allele of the Wx-B1 – Wx-B1b gene, contribute to an increase in the volume of finished baking. The researchers associate zero alleles of the Glu-A gene with a decrease in the quality of finished products. Similar conclusions were obtained by M.H. Lee *et al*. (2022), and they additionally investigated the effect of these loci on some physico-chemical factors of flour quality and found that the Glu-A1 allele positively affects the sedimentation coefficient and an increase in protein content. They also noted the prospects for the selection and use of varieties obtained as a result of targeted breeding for these genes to increase yields in an unfavourable or unstable climate. The Gonen variety, which contains a zero allele for the Glu-A1d gene, is slightly inferior to bread made from Shafaq 2 grain in elasticity and porosity when baked, which may probably be due to differences in the alleles of Glu genes.

Currently, there are not enough studies on the effect of specific gluten-coding genes on certain baking qualities of wheat, since, as noted by K. Pourmohammadi *et al*. (2023), the variability of these genes is very large. However, this opens up space for further work with genotyping and the study of the correlation of the ratio of certain loci and physico-chemical and organoleptic parameters of wheat and its product. In general, this study outlines the way to further work on both a more detailed study of the genome of existing varieties, and breeding work to create new ones that are more stable, productive, and of high quality. Currently, the qualitative analysis was hampered by the fact that the assessment was carried out between different characteristics of different varieties, which led to a more overview character of the article. However, the data obtained can become the basis for a number of studies focused on more narrow aspects.

CONCLUSIONS

Currently, there is a problem in Azerbaijan related to the shortage of grain capable of meeting the needs of the domestic market. Climate change, which has been accompanied by abnormally high temperatures in recent years, has significantly reduced wheat yields. In the part of the study related to determining the optimal tillage for the Girmizi Gul1 variety, it was determined that the most optimal option is minimal tillage, and zero intervention gives results noticeably worse than traditional and minimal tillage methods.

In the main part of the study, 37 local and introduced wheat varieties were analysed, and their quality was determined: weight of 1,000 grains, level of nitrogen and sedimentation, gluten percentage, FDM, and baking quality. Further, samples of each variety were analysed for Waxy-B1 and Glu-A1 gene loci to determine which varieties have a prospect for selective selection based on these genes. As a result, the target null allele of starch-synthesising genes was probably found only in two varieties: Gonen and Ekinci 84. Starch of these varieties has a reduced amylose content, which increases the baking potential of flour from grains of these varieties. The null allele of the Glu-A1 – Glu-A1d gene, on the contrary, worsens the quality of gluten and the baking potential of the variety. Such an allele is probably found in the varieties Askeran, Azemetli 95, Gonen, Kirmizigul, Nurlu 99, Tale 38, and Ugur.

The test baking of bread from grain varieties Gonen and Shafaq 2, as carriers of opposite alleles at both target loci, showed that, in general, the quality of gluten is more important for the texture and porosity of bread than the quality of starch, whereas the reduced amylose content, in turn, contributes more to the volume of baking. However, the clarity and validity of comparisons in this study was not helped by the fact that different varieties were compared that had different traits not only for the target genes. Thus, it seems logical further steps to identify separate lines of research that will be conducted in parallel: determining the effect of the genes in question on specific baking parameters; determining several varieties for experimental work and further breeding; also separately, research related to the influence of specific loci of glutenin-coding genes can be continued.

At the moment, the varieties Kirmizigul and Gobustan, which received the highest scores for baking properties, are promising. It is also rational to involve Gonen and Ekinci 84 varieties in breeding, which are carriers of the zero allele of the Waxy-B1 locus and require modification of glucan-coding genes. The Shafaq 2 variety also demonstrated good baking qualities. Thus, further research will be able to provide a more constructive and measurable answer to the question to what extent the study of the considered genes and the selection work aimed at them can contribute to an increase in the production of bakery products and cover the domestic demand of the Azerbaijani market.

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CONFLICT OF INTEREST

None.

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Молекулярно-генетичні основи підвищення якості зерна м'якої пшениці

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Анотація. Збільшення сільськогосподарських територій в Азербайджані вже не може покрити проблему нестачі високоякісного хлібопекарського борошна на внутрішньому ринку. Таким чином, існує потреба в поліпшенні якості зерна, зібраного з існуючих площ, для отримання більшої кількості зернових продуктів. Метою даного дослідження є огляд та вивчення фізико-хімічних та генетичних параметрів місцевих та інтродукованих сортів м›якої пшениці для подальшого визначення перспективних напрямків селекції. Для цього було проведено ПЛР-дослідження окремих локусів генів Wx, що відповідають за синтез амілози, та електрофорез генів Glu, що кодують кількість і якість клейковини. Крім того, для сортів Shafaq 2 і Gonen, які були відібрані в ході досліджень для тестового випікання хліба, був проведений ПЛР-аналіз для складання гліадинової формули сортів з використанням зразка сорту Безоста 1 в якості маркера. Фізико-хімічні показники визначали за стандартами якості, а також за результатами випікання зразків хліба. Під час дослідного посіву один із сортів – Girmizi Gul1 – висівали на ділянках з різними способами обробітку ґрунту – традиційним, мінімальним та нульовим. Так, було визначено, що сорти Gonen і Ekinci 84 містять нульовий алель гена Wx-B1 – Wx-B1b, що означає, що їх ендосперм містить крохмаль більш високої якості, а сорти Askeran, Azemetli 95, Gonen, Kirmizigul, Nurlu 99, Tale 38 і Ugur, в свою чергу, містять нульовий алель гена GluA1 – GluA1d, що навпаки погіршує якість клейковини цих сортів. Щодо обробітку ґрунту, то найкраще себе показала традиційна система, дещо гірше – мінімальний обробіток, а найменш придатною в даних умовах виявилася система нульового обробітку. Таким чином, отримані дані окреслюють подальші напрями проведення досліджень і відкривають перспективи для цілеспрямованої селекції на алелі розглянутих генів

Ключові слова: борошно; крохмаль; клейковина; гліадин; хлібопекарські властивості