Variability and Evaluation of Technological Grain Quality Traits in Wheat (Triticum Aestivum L.) Varieties

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Abstract

The present study aimed to evaluate the technological grain quality traits of winter wheat (Triticum aestivum L.) varieties grown under selection nursery conditions. Grain quality plays a crucial role in determining wheat suitability for processing and baking. In this study, 30 winter wheat varieties developed by local breeders were analyzed for key quality parameters, including grain bulk density (test weight), protein content, gluten content, and grain vitreousness.

The results showed significant variation among the studied genotypes. Grain bulk density ranged from 800.9 to 885.0 g/L, with the highest values observed in Muzbuloq, Temiryazevka 150, OʻITI-1, and Obod. Protein content varied between 11.6% and 16.5%, with higher values in Nurafshon, OʻITI-1, and Yangi hayot. Gluten content ranged from 25.8% to 30.9%, with superior показатели in Barqaror, OʻITI-1, Obod, and Nurafshon. Grain vitreousness varied from 71.0% to 83.2%, indicating differences in grain structure and technological properties.

Statistical analysis revealed low variability for grain bulk density and vitreousness, while protein and gluten content showed moderate variability. The study confirmed that grain quality traits are interrelated and should be evaluated комплекс tarzda. Among the studied varieties, Obod, Barqaror, and OʻITI-1 were identified as promising genotypes with high technological and nutritional potential. These varieties can be recommended for breeding programs and for improving wheat grain quality in agricultural production.

1. Introduction

Wheat (Triticum aestivum L.) is one of the most important cereal crops worldwide, serving as a staple food for a large portion of the global population [1,2]. Its importance is determined not only by grain yield but also by grain quality, which directly affects its suitability for processing, baking, and industrial applications [3,4]. In recent years, increasing demand for high-quality wheat products has emphasized the importance of evaluating technological grain traits alongside productivity in breeding programs.

Grain quality in wheat is a complex trait controlled by

both genetic and environmental factors [5,6]. Key technological indicators such as grain bulk density (test weight), protein content, gluten content, and grain vitreousness are widely used in wheat quality evaluation [7,8]. These traits significantly influence flour yield, dough properties, and end-use quality, particularly in bread-making. Protein and gluten content determine dough strength and elasticity, while grain bulk density and vitreousness reflect grain structure, maturity, and milling performance [9,10].

Recent studies have highlighted the importance of selecting wheat varieties with superior technological quality traits for breeding programs [11,12]. In Uzbekistan and other regions with similar agro-climatic conditions, the development and selection of wheat varieties with high grain quality remain a priority. Local breeding programs have produced numerous promising genotypes; however, their comprehensive evaluation under selection nursery conditions is essential to identify stable and high-performing varieties. Understanding the variability and relationships among grain quality traits enables breeders to select superior genotypes and improve wheat quality through targeted breeding strategies [13].

Therefore, the aim of this study was to evaluate the variability of key technological grain quality traits in winter wheat varieties and to identify promising genotypes with high technological and nutritional potential for breeding and practical cultivation.

2. Methods

Plant Material and Experimental Conditions

The study was conducted under selection nursery conditions using 30 winter wheat (Triticum aestivum L.) varieties developed by local breeders and widely cultivated in the main grain-growing regions. The experiment was carried out in three replications to ensure the reliability and accuracy of the obtained results. Standard agronomic practices were applied uniformly to all genotypes during the growing season.

Assessment of Grain Quality Traits

After harvesting, grain samples from each variety were collected and analyzed for key technological quality traits. Grain bulk density (test weight) was determined as the mass of grain per unit volume (g/L) using standard measurement procedures. This parameter was used to evaluate grain density, maturity, and milling quality.

Protein and gluten contents were measured using a ZEUTEC SpectraAlyzer GRAIN NEO near-infrared (NIR) analyzer. Protein content was expressed as a percentage of grain weight, while gluten content was determined as wet gluten percentage, reflecting dough-forming ability and baking quality. Grain vitreousness was assessed visually as the percentage of vitreous kernels in each sample.

Statistical Analysis

All experimental data were processed using standard statistical methods. The mean value ($\bar{X}$), standard error (Sx), standard deviation (σ), and coefficient of variation (CV, %) were calculated for each trait. Analysis of variance was used to assess the variability among varieties.

The experimental error was evaluated using mean square error (MSE), and the reliability of differences among genotypes was determined using the least significant difference ($LSD_{0.05}$). The use of three replications ensured the accuracy and repeatability of the results.

3. Results

The evaluation of technological grain quality traits in winter wheat varieties revealed significant variation among the studied genotypes. Key indicators such as grain bulk density (test weight) and grain vitreousness are essential parameters that determine grain structure, maturity, and processing suitability. The comparative analysis of these traits allows the identification of high-quality and stable genotypes suitable for breeding and practical cultivation. The variation in grain bulk density and vitreousness among the studied wheat varieties is presented in Figure 1.
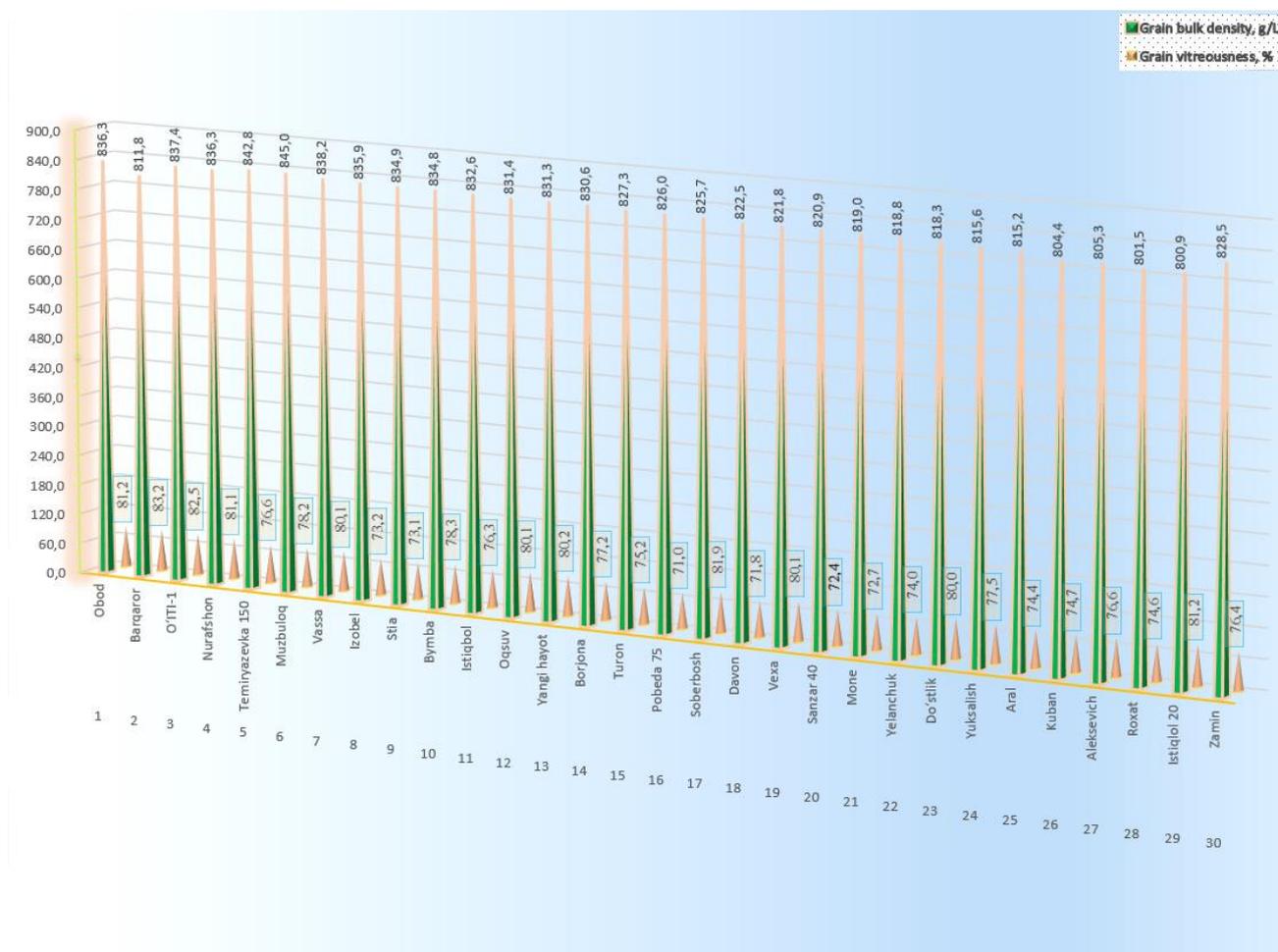
Figure 1. Grain bulk density (g/L) and vitreousness (%) of winter wheat varieties

Figure 1 illustrates the variation in grain bulk density and vitreousness across 30 winter wheat varieties. The results indicate that grain bulk density ranged from approximately 800 g/L to 845 g/L, demonstrating noticeable differences among genotypes. The highest values were recorded in Obod, Barqaror, and O'ITI-1, confirming their superior grain density and well-developed endosperm structure. In contrast, relatively lower values were observed in Istiqbol 20, Roxat, and Kuban, indicating comparatively lower grain fullness.

Grain vitreousness also showed variation among the studied varieties, ranging from approximately 71% to 83%. The highest vitreousness values were observed in Barqaror, O'ITI-1, and Obod, suggesting a harder endosperm and better technological properties. Lower values were recorded in Pobeda 75, Kuban, and Roxat,

which may be associated with softer grain structure and relatively lower processing quality.

A comparative assessment of these two traits indicates a tendency for varieties with higher grain bulk density to also exhibit higher vitreousness. This relationship reflects the importance of endosperm development in determining overall grain quality. However, some genotypes showed deviations from this trend, confirming that grain quality traits should be evaluated комплекс tarzda rather than individually.

Overall, the results demonstrate that varieties such as Obod, Barqaror, and O'ITI-1 combine high grain density and vitreousness, making them promising candidates for breeding programs and industrial use.
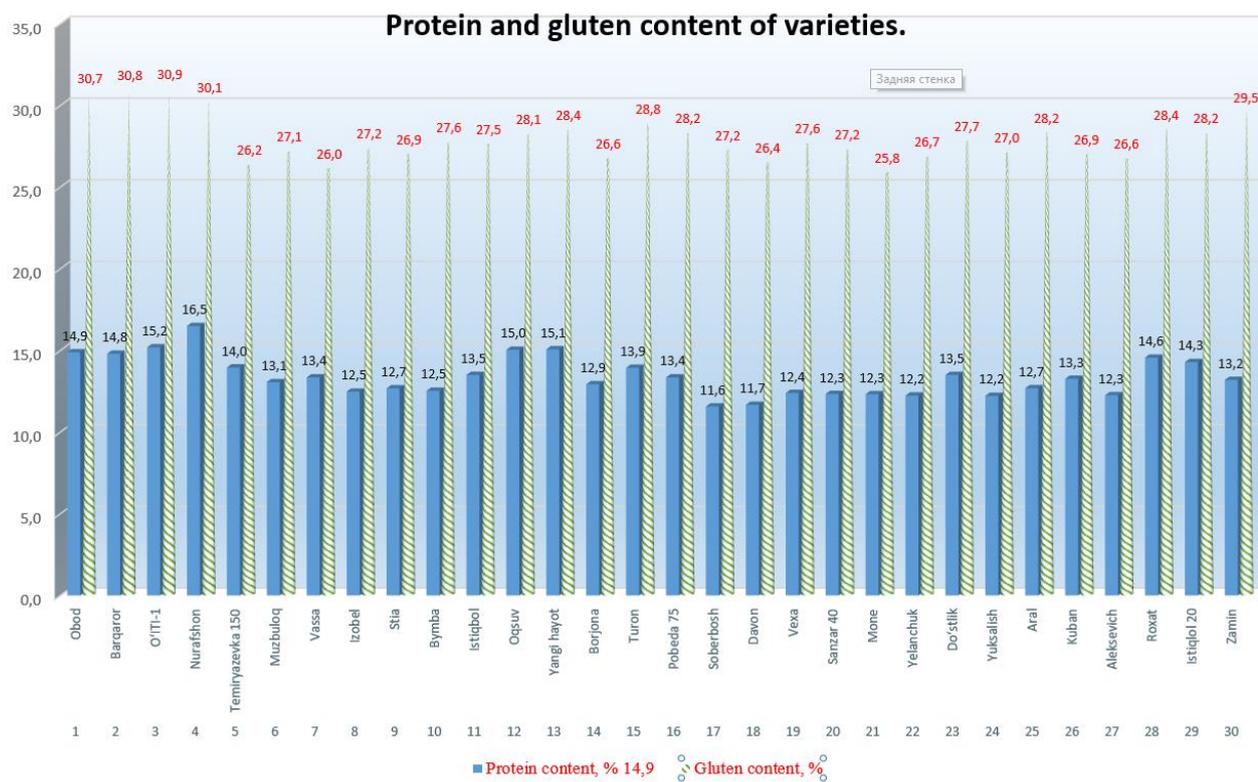
Figure 2. Protein (%) and gluten (%) content of winter wheat varieties

Figure 2 presents the variation in protein and gluten content among 30 winter wheat varieties, highlighting significant differences in grain nutritional and technological quality. Protein content ranged from 11.6% to 16.5%, while gluten content varied from 25.8% to 30.9%, indicating substantial genotypic variability. The variation in protein and gluten content among the studied winter wheat varieties is presented in Figure 2.

The highest protein content was recorded in Nurafshon (16.5%), followed by O'ITI-1 (15.2%), Yangi hayot (15.1%), and Oqsuv (15.0%). These varieties can be classified as high-protein genotypes and are of particular importance for both food production and breeding programs aimed at improving grain nutritional value. In contrast, relatively lower protein content was observed in Soberbosh (11.6%), Davon (11.7%), and Yelanchuk (12.2%), indicating comparatively lower nutritional quality.

Gluten content, which directly influences dough elasticity and bread-making properties, showed a range from 25.8% to 30.9%. The highest gluten values were identified in O'ITI-1 (30.9%), Barqaror (30.8%), Obod (30.7%), and Nurafshon (30.1%). These varieties demonstrated strong gluten-forming ability and can be

considered highly suitable for baking purposes. On the other hand, lower gluten values were recorded in Mone (25.8%), Izobel (26.0%), and Aleksevich (26.6%), although these values still fall within acceptable технологик limits.

A comparative analysis of protein and gluten content revealed a generally positive relationship between these two traits. Varieties with higher protein content tended to exhibit higher gluten levels, confirming that protein composition plays a key role in determining gluten strength and dough quality. However, some deviations from this trend were observed, suggesting that gluten quality is not solely dependent on protein quantity but also on protein composition (gliadin and glutenin fractions).

The variability of protein content was moderate, reflecting the influence of both genetic factors and environmental conditions, whereas gluten content showed relatively lower variability, indicating more stable expression across genotypes. This suggests that gluten content may serve as a reliable selection criterion in wheat breeding programs.

Overall, the results indicate that varieties such as O'ITI-1, Barqaror, Obod, and Nurafshon combine high protein

and gluten content, making them promising candidates for improving wheat quality. These genotypes can be effectively utilized as donor material in breeding programs aimed at enhancing both technological and nutritional properties of wheat grain.

Table 1. Statistical characteristics of grain bulk density and protein content of winter wheat varieties under selection nursery conditions (three replications)

No	Variety	Grain bulk density (X̄ ± Sx), g/L	σ	CV, %	Protein content (X̄ ± Sx), %	σ	CV, %
1	Obod	836.32 ± 0.81	1.40	0.17	14.89 ± 0.38	0.66	4.43
2	Kuban	804.35 ± 0.84	1.46	0.18	13.27 ± 0.32	0.55	4.12
3	Barqaror	811.77 ± 1.48	2.57	0.32	14.80 ± 0.23	0.40	2.70
4	Yangi hayot	831.34 ± 9.38	16.25	1.95	15.07 ± 0.38	0.66	4.35
5	Nurafshon	836.28 ± 0.23	0.40	0.05	16.50 ± 0.43	0.75	4.53
6	Izobel	835.86 ± 0.53	0.91	0.11	12.48 ± 0.29	0.50	3.98
7	O'ITI-1	837.39 ± 0.44	0.76	0.09	15.19 ± 0.58	1.00	6.57
8	Zamin	828.49 ± 3.65	6.32	0.76	13.20 ± 0.39	0.67	5.08
9	Yelanchuk	818.84 ± 6.72	11.64	1.42	12.24 ± 0.26	0.44	3.61
10	Vexa	821.76 ± 1.05	1.82	0.22	12.40 ± 0.33	0.57	4.56
11	Temiryazevka 150	842.84 ± 0.33	0.57	0.07	13.96 ± 0.14	0.25	1.76
12	Mone	818.95 ± 0.84	1.45	0.18	12.32 ± 0.20	0.35	2.80
13	Do'stlik	818.30 ± 0.86	1.49	0.18	13.50 ± 0.25	0.43	3.15
14	Oqsuv	831.39 ± 0.37	0.64	0.08	15.04 ± 0.56	0.97	6.43
15	Pobeda 75	826.03 ± 0.97	1.69	0.20	13.35 ± 0.24	0.41	3.07
16	Istiqbol	832.62 ± 1.03	1.79	0.21	13.50 ± 0.21	0.36	2.63
17	Yuksalish	815.57 ± 0.41	0.71	0.09	12.22 ± 0.36	0.62	5.04
18	Roxat	801.51 ± 1.48	2.57	0.32	14.56 ± 0.42	0.73	4.99
19	Turon	827.27 ± 2.13	3.69	0.45	13.94 ± 0.43	0.74	5.31
20	Davon	822.51 ± 2.06	3.57	0.43	11.67 ± 0.23	0.40	3.44
21	Vassa	838.15 ± 0.40	0.69	0.08	13.35 ± 0.28	0.49	3.64
22	Borjona	830.56 ± 0.52	0.90	0.11	12.93 ± 0.48	0.83	6.43
23	Aleksevich	805.26 ± 0.58	1.00	0.12	12.26 ± 0.35	0.61	4.97
24	Istiqlol 20	800.94 ± 1.23	2.13	0.27	14.29 ± 0.36	0.63	4.41
25	Soberbosh	825.74 ± 0.77	1.34	0.16	11.57 ± 0.32	0.56	4.84
26	Aral	815.18 ± 1.12	1.94	0.24	12.69 ± 0.33	0.57	4.52
27	Sanzar 40	820.90 ± 2.30	3.98	0.48	12.34 ± 0.27	0.47	3.81
28	Bymba	834.81 ± 1.52	2.63	0.31	12.53 ± 0.10	0.17	1.36
29	Stia	834.88 ± 0.28	0.49	0.06	12.68 ± 0.61	1.06	8.37
30	Muzbuloq	844.96 ± 0.57	0.98	0.12	13.06 ± 0.45	0.78	5.94

The statistical analysis of grain bulk density and protein content revealed significant variation among the studied winter wheat varieties (Table 1). Grain bulk density ranged from 800.94 g/L to 844.96 g/L, indicating differences in grain maturity, density, and endosperm development. The highest value was observed in Muzbuloq (844.96±0.57 g/L), followed by Temiryazevka 150 (842.84±0.33 g/L), Vassa (838.15±0.40 g/L), and O'ITI-1 (837.39±0.44 g/L). In contrast, the lowest values were recorded in Istiqlol 20 (800.94±1.23 g/L), Roxat (801.51±1.48 g/L), and Kuban (804.35±0.84 g/L). The statistical characteristics of grain bulk density and protein content of winter wheat varieties are presented in Table 1.

The coefficient of variation (CV) for grain bulk density was very low across all varieties (0.05–0.76%), indicating high stability of this trait and minimal influence of environmental factors. This suggests that grain bulk density is largely genetically controlled and can be effectively used as a reliable selection criterion in breeding programs.

Protein content showed a wider range, varying from 11.57% to 16.50%, reflecting moderate variability among genotypes. The highest protein content was observed in Nurafshon (16.50±0.43%), followed by O'ITI-1 (15.19±0.58%), Yangi hayot (15.07±0.38%), and Oqsuv (15.04±0.56%). These varieties can be classified as high-protein genotypes with significant value for improving grain nutritional quality. Lower protein content was recorded in Soberbosh

(11.57±0.32%), Davon (11.67±0.23%), and Yelanchuk (12.24±0.26%).

The coefficient of variation for protein content ranged from 1.76% to 8.37%, indicating moderate variability and suggesting that this trait is influenced by both genetic factors and environmental conditions. Compared to grain bulk density, protein content exhibited greater sensitivity to external factors.

Overall, the results demonstrate that while grain bulk density is a stable and genetically determined trait, protein content shows greater variability and plays a crucial role in determining grain quality. Varieties such as O'ITI-1, Nurafshon, and Yangi hayot combine relatively high grain density with elevated protein content, making them particularly valuable for breeding programs aimed at improving both technological and nutritional characteristics of wheat.

Table 2. Statistical characteristics of gluten content and grain vitreousness of winter wheat varieties under selection nursery conditions (three replications)

No	Variety	Gluten content ($\bar{X} \pm S_x$), %	σ	CV, %	Grain vitreousness ($\bar{X} \pm S_x$), %	σ	CV, %
1	Obod	30.67 ± 0.32	0.55	1.80	81.23 ± 0.38	0.65	0.80
2	Kuban	26.90 ± 0.42	0.73	2.70	74.73 ± 0.45	0.78	1.04
3	Barqaror	30.84 ± 0.34	0.58	1.89	83.23 ± 0.32	0.55	0.66
4	Yangi hayot	28.37 ± 0.39	0.68	2.39	80.20 ± 0.42	0.72	0.90
5	Nurafshon	30.09 ± 0.07	0.13	0.42	81.10 ± 0.23	0.40	0.49
6	Izobel	27.24 ± 0.42	0.73	2.69	73.23 ± 0.32	0.55	0.75
7	O'ITI-1	30.90 ± 0.36	0.62	2.02	82.47 ± 0.38	0.67	0.81
8	Zamin	29.48 ± 1.62	2.80	9.50	76.37 ± 0.30	0.51	0.67
9	Yelanchuk	26.73 ± 0.52	0.90	3.35	73.97 ± 0.29	0.50	0.68
10	Vexa	27.56 ± 0.23	0.40	1.44	80.13 ± 0.20	0.35	0.44
11	Temiryazevka 150	26.23 ± 0.31	0.54	2.06	76.63 ± 0.32	0.55	0.72
12	Mone	25.78 ± 0.43	0.74	2.87	72.67 ± 0.12	0.21	0.29
13	Do'stlik	27.70 ± 0.55	0.96	3.45	79.97 ± 0.39	0.68	0.85
14	Oqsuv	28.11 ± 0.44	0.77	2.74	80.10 ± 0.35	0.60	0.75
15	Pobeda 75	28.20 ± 0.46	0.80	2.84	70.97 ± 0.29	0.50	0.71
16	Istiqbol	27.53 ± 0.29	0.50	1.82	76.30 ± 0.26	0.46	0.60
17	Yuksalish	27.01 ± 0.13	0.23	0.83	77.50 ± 0.21	0.36	0.47
18	Roxat	28.40 ± 0.25	0.44	1.54	74.60 ± 0.32	0.56	0.75
19	Turon	28.76 ± 0.40	0.70	2.44	75.23 ± 0.19	0.32	0.43
20	Davon	26.40 ± 0.33	0.57	2.14	71.80 ± 0.17	0.30	0.42
21	Vassa	26.04 ± 0.04	0.08	0.29	80.07 ± 0.26	0.45	0.56
22	Borjona	26.64 ± 0.37	0.64	2.42	77.23 ± 0.30	0.51	0.66
23	Aleksevich	26.62 ± 0.68	1.17	4.40	76.60 ± 0.32	0.56	0.73
24	Istiqlol 20	28.17 ± 0.18	0.31	1.09	81.17 ± 0.23	0.40	0.50
25	Soberbosh	27.15 ± 0.48	0.83	3.05	81.93 ± 0.38	0.67	0.81
26	Aral	28.23 ± 0.46	0.80	2.83	74.40 ± 0.32	0.56	0.75
27	Sanzar 40	27.17 ± 0.37	0.64	2.37	72.40 ± 0.32	0.56	0.77
28	Bymba	27.61 ± 0.20	0.35	1.27	78.33 ± 0.30	0.51	0.66
29	Stia	26.90 ± 0.54	0.93	3.46	73.10 ± 0.26	0.46	0.63
30	Muzbuloq	27.06 ± 0.34	0.59	2.16	78.23 ± 0.20	0.35	0.45

The analysis of gluten content and grain vitreousness revealed significant differences among the studied winter wheat varieties (Table 2). Gluten content ranged from 25.78% to 30.90%, indicating moderate variability among genotypes. The highest gluten content was observed in O'ITI-1 (30.90±0.36%), followed by Barqaror (30.84±0.34%), Obod (30.67±0.32%), and Nurafshon (30.09±0.07%). These varieties demonstrated

strong gluten-forming ability and can be classified as high-quality genotypes suitable for bread-making.

In contrast, lower gluten content was recorded in Mone (25.78±0.43%), Temiryazevka 150 (26.23±0.31%), Davon (26.40±0.33%), and Aleksevich (26.62±0.68%). However, even these values fall within acceptable technological standards. The coefficient of variation

(CV) for gluten content ranged from 0.29% to 9.50%, indicating that this trait shows moderate variability and is influenced by both genetic and environmental factors. Notably, Zamin exhibited the highest variability (CV = 9.50%), suggesting instability of this trait under the given conditions.

Grain vitreousness varied from 70.97% to 83.23%, reflecting differences in endosperm hardness and grain structure. The highest values were observed in Barqaror (83.23%), O'ITI-1 (82.47%), Soberbosh (81.93%), Obod (81.23%), and Istiqlol 20 (81.17%), indicating superior grain hardness and better технологик properties. Lower vitreousness values were recorded in Pobeda 75 (70.97%), Davon (71.80%), Mone (72.67%), and Sanzar 40 (72.40%), which may be associated with softer grain texture.

The coefficient of variation for vitreousness was very low across most varieties (generally below 1%), indicating high stability of this trait and minimal environmental influence. This confirms that grain vitreousness is largely genetically controlled and can be reliably used in selection programs.

Overall, the results indicate that varieties such as O'ITI-1, Barqaror, Obod, and Nurafshon combine high gluten content and high vitreousness, making them particularly valuable for improving wheat технологик quality. These genotypes can serve as promising donor material in breeding programs aimed at enhancing baking quality and grain structure.

Table 3. Experimental error and variability of technological grain quality traits under selection nursery conditions (three replications)

Trait	MSE	±√MSE	CV, %
Grain bulk density, g/L	17.87	4.23	0.51
Protein content, %	0.387	0.62	4.65
Gluten content, %	0.687	0.83	2.98
Grain vitreousness, %	0.275	0.52	0.68

The evaluation of experimental error parameters demonstrated that all studied grain quality traits were measured with high accuracy and reliability (Table 3). The mean square error (MSE) values were relatively low for all traits, indicating good precision of the experimental data obtained under three replications.

Grain bulk density showed an MSE value of 17.87, with a standard error (±√MSE) of 4.23 g/L and a very low coefficient of variation (CV = 0.51%). This confirms the high stability and repeatability of this trait, suggesting that grain bulk density is minimally affected by environmental variation and can be considered a reliable indicator in wheat quality assessment.

Protein content exhibited a slightly higher variability, with an MSE of 0.387, ±√MSE of 0.62, and CV = 4.65%. This indicates moderate variability of the trait, reflecting its sensitivity to both genetic and environmental factors. However, the observed variability remains within acceptable limits and does not compromise the reliability of the results.

Gluten content showed moderate stability, with an MSE value of 0.687, ±√MSE of 0.83, and a coefficient of variation of 2.98%. These results indicate that gluten content is relatively stable across replications and can be effectively used as a selection criterion in breeding programs.

Grain vitreousness demonstrated the highest stability among all studied traits, with an MSE of 0.275, ±√MSE of 0.52, and a very low coefficient of variation (CV = 0.68%). This suggests that vitreousness is a highly stable trait with minimal experimental error, making it a reliable parameter for evaluating grain технологик quality.

Overall, the low levels of experimental error and coefficients of variation confirm the reliability and consistency of the experimental results. Particularly, grain bulk density and vitreousness were identified as highly stable traits, while protein and gluten content showed moderate variability but remained within acceptable limits. These findings support the validity of the obtained data and their suitability for further selection and breeding applications.

Table 4. Least significant difference (LSD$_{0.05}$) for technological grain quality traits under selection nursery conditions

Trait	LSD$_{0.05}$
Grain bulk density, g/L	7.06
Protein content, %	1.04
Gluten content, %	1.38
Grain vitreousness, %	0.88

The calculated least significant difference (LSD$_{0.05}$) values allowed the assessment of statistically significant differences among the studied winter wheat varieties for key grain quality traits (Table 4). These values provide a threshold for determining whether the observed differences between genotypes are significant at the 5% probability level.

For grain bulk density, the LSD$_{0.05}$ value was 7.06 g/L, indicating that differences between varieties exceeding this value can be considered statistically significant. Compared to other traits, this relatively higher threshold suggests that larger differences are required to confirm significant variation in grain bulk density.

Protein content showed an LSD$_{0.05}$ value of 1.04%, indicating that even moderate differences among genotypes can be statistically meaningful. This reflects the relatively higher variability of protein content and its sensitivity to genetic and environmental factors.

For gluten content, the LSD$_{0.05}$ value was 1.38%, suggesting that differences above this level are statistically reliable. This moderate threshold confirms that gluten content can be effectively used to distinguish genotypes with different technological qualities.

Grain vitreousness exhibited the lowest LSD$_{0.05}$ value (0.88%), indicating that even small differences between varieties are statistically significant. This highlights the high sensitivity and stability of this trait, making it a reliable parameter for comparative evaluation.

Overall, the obtained LSD$_{0.05}$ values demonstrate that all studied traits show statistically significant variation among the wheat varieties. In particular, protein content and grain vitreousness allow the detection of smaller differences, while grain bulk density requires relatively larger differences for statistical confirmation. These results enhance the reliability of genotype comparisons and support the identification of superior varieties based on technological grain quality traits.

4. Discussion

The results of this study demonstrated that winter wheat varieties exhibit significant variability in key technological grain quality traits, including grain bulk density, protein content, gluten content, and grain vitreousness. Such variability is primarily determined by genetic differences among genotypes as well as the influence of environmental conditions during grain formation. These findings are consistent with previous studies reporting that wheat grain quality is a complex trait controlled by the interaction of genetic and environmental factors [14,15].

Grain bulk density showed very low variability and high stability across the studied varieties (CV < 1%), confirming that this trait is largely genetically controlled and less influenced by environmental variation [16]. High grain density is associated with better endosperm development and higher flour yield, making it an important criterion in wheat quality evaluation. The superior performance of varieties such as Muzbuloq, Temiryazevka 150, O'ITI-1, and Obod suggests their suitability for industrial processing and their potential use as donor material in breeding programs aimed at improving milling quality.

In contrast, protein content exhibited moderate variability, indicating its sensitivity to both genotype and environmental conditions. The observed range (11.6–16.5%) corresponds with previously reported values for bread wheat and highlights the importance of selecting high-protein genotypes for improving nutritional quality [17,18]. Varieties such as Nurafshon, O'ITI-1, and Yangi hayot demonstrated superior protein content, confirming their potential value in breeding programs targeting improved grain quality.

Gluten content, which is closely related to protein composition, also showed moderate variability but remained within optimal technological limits for most varieties. The strong performance of Barqaror, O'ITI-1,

Obod, and Nurafshon indicates their suitability for bread-making due to enhanced dough elasticity and strength. The positive relationship observed between protein and gluten content is consistent with previous studies showing that gluten-forming proteins (gliadin and glutenin) constitute the major fraction of total grain protein [19,20].

Grain vitreousness exhibited high stability and low variability, indicating that this trait is less affected by environmental fluctuations and can serve as a reliable indicator of grain hardness and processing quality [21]. Varieties with high vitreousness, such as Barqaror, O'ITI-1, and Obod, are characterized by a well-developed and dense endosperm, which positively influences milling efficiency and flour quality.

The combined analysis of all studied traits revealed that grain quality should not be evaluated based on a single parameter. Although some varieties exhibited high values for individual traits, only a few genotypes demonstrated consistently high performance across multiple indicators. In particular, Obod, Barqaror, and O'ITI-1 showed superior results in terms of grain bulk density, protein and gluten content, and vitreousness, indicating their overall technological advantage. These findings are in agreement with studies emphasizing the importance of комплекс evaluation of grain quality traits in wheat breeding programs [22–24].

Furthermore, the low experimental error and statistically significant differences ($LSD_{0.05}$) confirmed the reliability of the obtained results and allowed for accurate differentiation among genotypes. Traits such as protein content and vitreousness enabled the detection of even small differences, while grain bulk density required relatively larger differences for statistical significance.

Overall, the findings of this study emphasize the importance of integrated evaluation of grain quality traits in wheat breeding programs. The identified superior genotypes can be effectively utilized as donor material for improving technological and nutritional characteristics of wheat, thereby contributing to the development of high-quality wheat varieties suitable for both production and industrial processing.

5. Conclusion

The results of this study demonstrated significant variability among winter wheat (Triticum aestivum L.) varieties in terms of technological grain quality traits, including grain bulk density, protein content, gluten content, and grain vitreousness. Grain bulk density and vitreousness showed high stability and low variability, indicating strong genetic control, whereas protein and gluten content exhibited moderate variability, reflecting the influence of both genetic and environmental factors.

The комплекс evaluation of these traits revealed that several varieties combine high technological and nutritional quality. In particular, Obod, Barqaror, and O'ITI-1 were identified as the most promising genotypes due to their consistently high performance across multiple quality parameters. These varieties are characterized by high grain density, elevated protein and gluten content, and superior vitreousness, making them suitable for both breeding and industrial applications.

The obtained results confirm that grain quality should be assessed using an integrated approach rather than relying on a single indicator. The identified superior genotypes can serve as valuable donor material in wheat breeding programs aimed at improving grain quality and технологик properties. Furthermore, these findings provide a scientific basis for the selection and cultivation of high-quality wheat varieties under local agro-climatic conditions.

References

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