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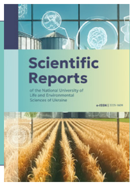

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Evaluation of winter bread wheat (*Triticum aestivum* L.) varieties based on grain quality indicators

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Abstract. Increasing the gross yield of high-quality grain requires the improvement of breeding programmes through their continuous enrichment with new genetic plasma. Therefore, the aim of the study was to identify sources of improvement in grain quality indicators for use in the breeding process by differentiating between different varieties of winter bread wheat in the central part of the Forest-Steppe zone of Ukraine. Thirty-one varieties of winter bread wheat were evaluated for protein content, wet gluten content, and sedimentation index in the 2023 and 2024 harvests. The distribution of the obtained grain quality indicators was analysed. It was found that the degree of asymmetry and excess distribution did not exceed the critical value ($|As/\sigma As| \leqslant 3$ and $|Ex/\sigma Ex| \leqslant 3$). Thus, the experimental data on sedimentation, protein and wet gluten content during the years of testing were close to normal distribution. The variability of the quality indicators of winter bread wheat grain depending on the hydrothermal conditions of cultivation was established. A higher average protein content (13.3%) and wet gluten content (28.7%) were obtained in 2023, and a higher sedimentation index (74 ml) in 2024. The coefficient of variation revealed significant variability (CV = 10.2-13.5%) in the sedimentation index between winter bread wheat varieties during the years of testing, as well as weak and moderate

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variation in protein content (CV = 5.3-8.6%) and wet gluten content (CV = 3.9-5.8%). A decisive (40.7-63.8%) influence of the variety on the studied grain quality indicators was revealed. The conditions of the year had an insignificant effect on the sedimentation index (2.5%), but a significant effect on the protein (23.2%) and wet gluten (24.0%) content. The proportion of the interaction between the variety × year factors was significant (26.9-32.5%) for all three grain quality indicators. The following winter bread wheat varieties were identified as having the highest protein content: 'MIP Kniazhna' and 'Avrora Myronivska'; wet gluten content: 'MIP Kniazhna', 'Avrora Myronivska', 'Pokrovska', 'Hlad', 'Zolotokolosa', 'Kolumbiia', 'Optyma odeska', 'Doskonalist odeska', 'Perevaga', 'Nyva odeska', 'Kuialnyk', 'Kubok', 'Vahoma'; for sedimentation value – 'Pokrovska', 'Osnova odeska', 'Kuialnyk', 'Kubok'

Keywords: *Triticum aestivum* L.; protein content; wet gluten content; sedimentation index; hydrothermal conditions; coefficient of variation; ANOVA

Introduction

Wheat – one of the principal food crops in both Ukraine and worldwide. The grain of *Triticum aestivum* L. is a staple food for a large proportion of the global population due to its high nutritional value. Owing to its production potential and technological value, wheat plays a crucial role in the global economy. According to the State Register of Plant Varieties Suitable for Dissemination in Ukraine, as of 2025, there are 776 registered varieties of winter bread wheat. However, not all of them are of high quality. The majority (38%) belong to the category of valuable wheats, while only 27% meet the criteria for strong wheats. A considerable proportion (23%) are fillers, and 12% belong to an undefined quality group (State Register..., 2025). To improve grain quality, both in Ukraine and globally, targeted breeding programmes are being carried out to combine in a single genotype a high yield potential with enhanced technological properties of grain and flour, as well as resistance to a complex of adverse abiotic and biotic environmental factors.

K. Wysocka *et al.* (2024) studied the effect of different cultivation systems for winter bread wheat (organic, integrated, and conventional) on flour quality. The authors found that the cultivation technology significantly affects baking quality parameters, particularly protein content, wet gluten content, and sedimentation value. Grain from organic systems had lower protein and wet gluten contents, whereas integrated and conventional systems ensured higher values of the protein and wet gluten complex and better baking quality. T.P. Khumalo-Mthembu *et al.* (2025) analysed the current state and prospects of breeding bread wheat (*Triticum aestivum* L.) for pre-harvest sprouting resistance in South Africa, emphasising that this trait is crucial for maintaining baking quality, and that effective breeding requires combining traditional methods with modern molecular and genomic approaches. A.A. Melash & E.B. Ábrahám (2022) conducted a detailed analysis of innovative agronomic and breeding strategies to improve wheat productivity and grain quality under changing climatic conditions. The authors demonstrated that optimal nitrogen fertilisation and the selection of cultivars capable of efficiently utilising nutrients make it possible to obtain high yields with improved technological properties of the grain. T. Hao *et al.* (2023) examined the effect of different nitrogen application frequencies under drip irrigation on the quality indicators of winter wheat grain. They found that increasing the frequency of nitrogen application significantly increased protein content (by 2-8.6%) and wet gluten (by 4.5-22.1%) and had little effect on the sedimentation value, although it could lead to a reduction in flour quality.

H.A. Dutova *et al.* (2024), when evaluating new cultivars of winter bread wheat under various soil and climatic conditions with respect to grain quality indicators, observed a trend of increasing protein and crude wet gluten content from the north to the south of Ukraine, specifically from the Polissya zone to the Steppe. A.M. Zvonar (2020) investigated the influence of cultivar and annual weather conditions on the quality of winter wheat grain and established that nitrogen accumulation in wheat grain depends more on the genetic characteristics of the cultivar than on hydrothermal conditions. Higher protein and wet gluten content were obtained under dry growing conditions. A. Szuba-Trznadel *et al*. (2024) compared winter bread wheat cultivars based on their chemical composition, biological value of proteins, and content of macro- and microelements, and found that the chemical composition of the grain was dependent on the genetic properties of the cultivars. They established that a higher protein content in the grain, even with a greater sum of essential amino acids, does not always correlate with a higher nutritional value of the protein, which depends on the specific amino acid composition. Knowledge and understanding of the various physical and chemical properties, protein quality, and information on the amino acid composition will be useful for a wide range of specialists, and conducting a targeted breeding process to create cultivars with the necessary nutrients will satisfy diverse dietary needs. H. Wieser *et al*. (2020) analysed the chemical composition of wheat grain in detail and concluded that the content and composition of proteins in the grain largely determine its baking qualities. The authors note that the variation in protein content in wheat grain ranges from 7% to 22%, but most commonly lies between 10% and 15%. Protein content, wet gluten content, and its quality play an important role in the food industry, as these indicators determine the quality of the final product. The quantity and quality of the protein-gluten complex primarily influence the formation of the commercial value of wheat samples. M.V. Radchenko *et al*. (2024) evaluated the potential of winter wheat cultivars created in various breeding centres for the rational utilisation of agro-meteorological resources and identified cultivars with high adaptive potential and superior baking qualities. The authors noted that the successful choice of cultivar is one of the most important elements of winter wheat cultivation technology for realising the genetic potential.

Breeding programmes necessarily require constant replenishment with new genetic material – a condition without which progress in breeding is impossible. Evaluating new winter bread wheat cultivars based on grain quality indicators and selecting samples with higher content and better quality of the protein-gluten complex will provide breeders with high-quality starting material for further use in breeding programmes of various directions.

The aim of this study was to evaluate winter bread wheat cultivars under the conditions of the central part of the Forest-Steppe of Ukraine for protein content, wet gluten content, and sedimentation index, and to identify genotypes with higher grain quality indicators. To achieve this aim, the following tasks needed to be addressed:

- to determine the level of expression of grain quality indicators of winter bread wheat depending on the hydrothermal conditions of the year;
- to establish the pattern of distribution of grain quality indicators of winter bread wheat;
- to differentiate winter bread wheat cultivars according to protein content, wet gluten content, and sedimentation index.

Materials and Methods

The study was conducted under the conditions of the V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (NAAS), located in the village of Tsentralne, Obukhiv District, Kyiv Region, Ukraine (49°38′41.5″ N, 31°05′33.2″ E). Thirty-one varieties of winter bread wheat (*Triticum aestivum* L.) harvested in 2023 and 2024 were evaluated, including four varieties of winter bread wheat bred by the V.M. Remeslo Myronivka Institute of Wheat NAAS (MIW) and the Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine – 'Podolianka', 'Expromt', 'Kolumbiia', and 'Zolotokolosa'; three varieties bred by MIW – 'MIP Kniazhna', 'MIP Yuvileina', and 'Avrora Myronivska'; 24 varieties selected by the Plant Breeding and Genetics Institute – National Centre of Seed and Cultivar Investigation – 'Pokrovska', 'Heizer', 'Hlad', 'Optyma odeska', 'Doskonalist odeska', 'Spadshchyna odeska', 'Versiia odeska', 'Manera odeska', 'Perevaha', 'Pontiika', 'Vidpovid odeska', 'Virnist', 'Osnova odeska', 'Peremoha odeska', 'Zhuravka odeska', 'Zysk', 'Zorepad', 'Nyva odeska', 'Kantata odeska', 'Kuialnyk', 'Mudrist odeska', 'Kubok', 'Lira odeska', and 'Vahoma'. The research was carried out in accordance with the Convention on Biological Diversity (1992).

The soil cover of the MIW experimental fields is represented by deep low-humus slightly leached chernozem (38-42 cm). The humus content in the 20 cm soil layer is 3.6-4.0%, with readily available nitrogen – 0.006%, phosphorus – 0.025%, and exchangeable potassium – 0.011-0.018%. Soil pH ranges from 5.3 to 6.4, the sum of absorbed bases is 0.23-0.29 g-eq kg^{-1} soil, and the base saturation degree is 86.2-94.4%. Winter bread wheat was cultivated according to the standard agronomic practices recommended for the Forest-Steppe zone of Ukraine (Siroshtan & Kavunets, 2023). The preceding crop was soybean. Sowing was performed on 10 October using a cassette drill SN-10Ts at a sowing depth of 4-5 cm and a seeding rate of 4.5 million viable seeds per hectare, with an experimental plot area of 3 m^2. Grain was harvested manually.

To obtain flour, winter bread wheat grains were ground in a Quadrumat Junior Brabender laboratory mill (Germany). The protein and wet gluten content was measured using a near-infrared reflectance spectrometer (spectral range 1,400-2,400 nm) on a SPECTRAN 119M Lomo Photonics (Russia) device. The sedimentation index was determined in a 2% acetic acid solution with the addition of bromophenol blue dye using the micro method of A.Ya. Pumpianskyi. Statistical processing of experimental data was performed using descriptive statistics and analysis of variance (ANOVA) (Rudakov & Tishkov, 2016; Koval, 2021).

Results and Discussion

The years of research were characterised by variability in air temperature and precipitation by month. In 2022/23, the average annual air temperature exceeded the long-term average (LTA) by 1.4°C, and in 2023/24 by 3.3°C. Each year, there was a significant increase in the average monthly air temperature of 1.0-6.5°C above the LTA in August, November, December, January, February, March and June. September, October, April and July 2023/24 were also abnormally warm, exceeding the LTA by 3.6-4.2°C. A decrease in air temperature from the LTA was observed only in September and October 2022/23, by 1.6 and 0.2°C, respectively (Fig. 1).

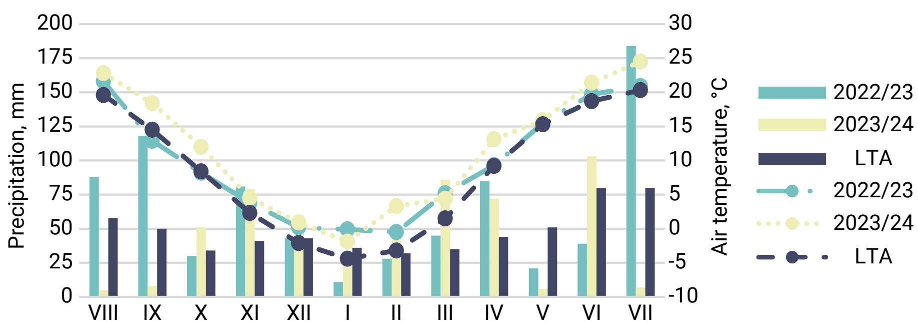

Figure 1. *Hydrothermal regime during the study period*

Note: LTA – long-term average value for 1960/61-2021/22

Source: developed by the authors of this study based on data from the Department of Biotechnology, Genetics and Physiology of the Myronivka Institute of Wheat

During the 2022/23 growing season, precipitation amounted to 773 mm (132% of the LTA), and in 2023/24 – 544 mm (93% of the LTA). Critically low precipitation (<50% of the LTA) was observed in January, May and June 2022/23, and in August, September, May and July 2023/24. An abnormally high amount (⩾150% of the LTA) was recorded in August, September, November, April and July 2022/23, and in October, November, March and April 2023/24. It should be noted that torrential rainfall (230% of the LTA) in July 2023 fell after the harvest from the experimental plots, so its excessive amount during that month did not have a negative impact on the accumulation of nitrogen-containing compounds in winter bread wheat grain.

The results of the studies showed significantly higher minimum, maximum and average values of protein (12.2, 15.5 and 13.3%, respectively) and wet gluten (26.7, 32.3 and 28.7%, respectively) content in 2023 than in 2024 (Table 1).

Table 1. *Variation in grain quality indicators during the study period*

Value	Protein content, %			Wet gluten content, %			Sedimentation rate, ml		
	2023	2024	X	2023	2024	X	2023	2024	X
Min	12.2	10.4	11.5	26.7	24.0	25.7	47	49	57
Max	15.5	14.3	14.4	32.3	29.2	29.9	89	89	87
X	13.3	12.3	12.8	28.7	27.0	27.9	71	74	73
CV, %	5.3	8.6	5.5	4.3	5.8	3.9	11.5	13.5	10.2
LSD_{05}	0.4			0.6			3		

Note: Min, Max, X – minimum, maximum and average values, respectively, CV – coefficient of variation, LSD_{05} – smallest significant difference at $p \leq 0.05$
Source: developed by the authors of this study

The conditions of the trial years did not significantly affect the formation of the sedimentation index limits, but the above-average value of this characteristic (74 ml) was obtained in 2024. A slight variation (CV ⩽ 5.0%) in protein and wet gluten content was observed in 2023 and a moderate variation (6.0 ⩽ CV ⩽ 10.0%) in 2024. The variation in the sedimentation index was significant (11.0 ⩽ CV ⩽ 20.0%) for both years. A.Z. Ghafoor *et al.* (2024) also noted a slight variation between winter bread wheat genotypes in protein content (CV = 5.23%) and a significant variation in sedimentation index (CV = 12.95%). The authors showed that genotype is the leading factor in the formation of the protein-gluten complex, while growing conditions and fertilisation system can significantly affect the variability of quality indicators, in particular the wet gluten level, the variability of which was significant in their studies (CV = 12.95%). These results are consistent with current data and confirm that the combination of genotypic characteristics and hydrothermal conditions is a key factor in the differentiation of varieties in terms of grain quality. Depending on the nature of the distribution of experimental data, appropriate statistical calculation methods should be applied. Analysis of distribution patterns involves assessing the degree of sample homogeneity, asymmetry, and excess distribution (Danilov, 2019). The obtained grain quality values are homogeneous, since the condition CV ⩽ 33% is met (Table 1).

The asymmetry coefficient (As) characterises the symmetry of the distribution law of a random variable relative to its centre, i.e. the symmetry of the tails of the distribution (Koval, 2021). The statistical distribution of the sedimentation index sample, both annually and on average over the years of testing, had a negative (left-sided) asymmetry with the asymmetry coefficient (As) varying from -0.30 to -0.71 (Table 2). In 2023, positive (right-sided) asymmetry was obtained for the values of protein content (As = 0.95) and wet gluten (As = 0.75), however, in 2024, the distribution of samples of these grain quality indicators was characterised by negative values (As = -0.10 and -0.36, respectively) (left-sided asymmetry). The sample of protein and wet gluten content values averaged over the years had a slight right-sided asymmetry (As = 0.16 and 0.05, respectively). Positive asymmetry indicates that the sample contains several values that greatly exceed the average value of a particular trait. Negative asymmetry indicates the presence of values in the sample that are significantly lower than the mean value (Rudakov & Tishkov, 2016).

Table 2. *Characteristics of the distribution of quality indicators for winter bread wheat during the trial years*

Numerical characteristics	Protein content			Wet gluten content			Sedimentation index		
	2023	2024	X*	2023	2024	X*	2023	2024	X*
As	0.95	-0.10	0.16	0.75	-0.36	0.05	-0.44	-0.71	-0.30
Ex	1.64	-1.01	-0.12	1.22	-1.03	-0.26	1.78	-0.25	-0.49
σAs	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
σEx	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
|As/σAs|	2.33	0.25	0.40	1.85	0.89	0.13	1.09	1.75	0.74
|Ex/σEx|	2.22	1.36	0.16	1.65	1.40	0.35	2.40	0.34	0.66

Note: As – asymmetry coefficient, Ex – excess, σAs – standard deviation of asymmetry coefficient, σEx – standard deviation of excess, X* – calculated based on the average values of experimental data for two years
Source: developed by the authors of current study

Excess (Ex) characterises the degree of concentration of variants around the mean value, i.e. it is an indicator of the steepness (sharpness) of the statistical distribution graph compared to the normal distribution. For a normal distribution, Ex = 0. If the excess is positive, the curve has a higher and "sharper" peak than the normal distribution; if the excess is negative, the curve under study has a lower and "flatter" peak than the normal curve. In 2023, a sharp peak (Ex = 1.22-1.78) was observed in the distribution of samples of the studied flour quality indicators; in 2024 and on average over two years, a flat peak was observed with a variation in excess from 0.12 to 1.03. Thus, the experimental data obtained for grain quality indicators differed somewhat from the normal distribution in terms of both the asymmetry coefficient and the excess. However, the degree of significance of asymmetry is assessed by the ratio of the asymmetry coefficient to the mean square error of this coefficient (|As/σAs|), and the significance of the excess of distribution is assessed by the ratio of the excess to its mean square error (|Ex/σEx|). The degree of significance of asymmetry and excess of grain quality indicators corresponded to the condition |As/σAs| ⩽ 3 and |Ex/σEx| ⩽ 3 (Table 2), under which deviations in the asymmetry coefficient and excess are considered insignificant, and the distributions of the obtained data are recognised as close to normal distribution. Thus, the experimental data obtained for the sedimentation index, protein and wet gluten content during the years of testing were close to normal distribution. This made it possible to apply statistical methods designed for normal distribution.

N.V. Vasylenko *et al*. (2019), when establishing the nature of the distribution of wheat grain quality indicators, obtained a negative excess of protein content (Ex = 0.84) and wet gluten content (Ex = 0.41), however, according to the asymmetry coefficient, the protein content was characterised by left-sided asymmetry (As = 0.13), and the wet gluten content by right-sided asymmetry (As = 0.26). The degrees of significance of asymmetry and excess of both grain quality indicators were below the critical value (As/σAs| ⩽ 3; |Ex/σEx| ⩽ 3). Thus, the authors also found a normal distribution of protein and wet gluten content.

Comparing the results of this study with current data, differences in the asymmetry coefficient of protein content were noted, but the flat-topped distribution of experimental data for both protein and wet gluten content, as well as their proximity to normal distribution, was confirmed. X. Yang *et al.* (2014), evaluating 330 Chinese wheat varieties for flour quality indicators, also observed a normal distribution of protein content, wet gluten content, and sedimentation index. To determine the normality of the distribution of experimental data, the authors used Z-statistics with the Kolmogorov-Smirnov (K-S) normality criterion. The statistical values of the sedimentation rate ($Z0.05 = 0.502$), protein content ($Z0.05 = 0.340$) and wet gluten content ($Z0.05 = 0.891$) were lower than the critical value ($Z0.05 = 1.63$), and their asymptotic significance was greater than 0.05, indicating their normal distribution. These results are consistent with current data and confirm the normality of the distribution of protein content, wet gluten content and sedimentation index.

According to the results of the variance analysis, the maximum influence (40.7-63.8%) of the variety on the studied grain quality indicators was established (Table 3). The conditions of the year had the least influence on the sedimentation rate (2.5%). The formation of protein and wet gluten content significantly depended on both the year of cultivation (23.2 and 24.0%, respectively) and the interaction of the variety × year factors (26.9 and 27.9%, respectively). A significant influence (32.5%) of the interaction between the variety × year factors on the sedimentation index was also found.

Table 3. *Results of variance analysis of winter bread wheat grain quality indicators, 2023 and 2024*

Source of variation	df	SS	MS	F act.	Share of influence,%
	Protein content				
Total	247	288.4722	-	-	-
Variety (A)	30	129.041	4.30	54.030*	44.7
Year (B)	1	66.99681	67.00	841.561*	23.2
A×B	30	77.62694	2.59	32.503*	26.9
Unaccounted factors	186	14.8075	0.08	-	5.1
	Wet gluten content				
Total	247	767	-	-	-
Variety (A)	30	312.0387	10.40	33.975*	40.7
Year (B)	1	183.7994	183.80	600.372*	24.0
A×B	30	214.2194	7.14	23.325*	27.9
Unaccounted factors	186	56.9425	0.31	-	7.4
	Sedimentation index				
Total	247	20,973.35	-	-	-
Variety (A)	30	13,389.35	446.31	329.421*	63.8
Year (B)	1	522.5806	522.58	385.714*	2.5
A×B	30	6,809.419	226.98	167.533*	32.5
Unaccounted factors	186	252	1.35	-	1.2

Note: df – number of degrees of freedom, SS – sum of squares, MS – mean square, F act. – Fisher's criterion actual value, * – $p \leq 0.001$

Source: developed by the authors of current study

The highest proportion of influence of the variety, compared to other factors, on the studied grain quality indicators indicates the decisive role of genetic potential in the formation of protein content, wet gluten content and sedimentation index. This confirms that breeding work and the right choice of variety are of paramount importance for obtaining high-quality grain. The low level of influence of annual conditions indicates relative stability to external conditions, i.e. the sedimentation index was least affected by growing conditions. The formation of protein and wet gluten content was influenced by a combination of both genetic and weather factors. In general, the results of the variance analysis prove that the quality of winter wheat grain is determined mainly by the genetic characteristics of the variety, but external factors also have a significant influence, especially in interaction with the genotype.

Researchers A.Z. Ghafoor *et al.* (2024) identified the influence of genotype, environment and farming methods (moderate and high) on the baking properties of wheat grain. The authors established a decisive influence of the genotype on the formation of the sedimentation index and a significant influence on the content of protein and wet gluten. They also noted that growing conditions have a significant impact on quality indicators. They emphasised the need for a comprehensive assessment of the influence of genetic and environmental factors, as well as their interactions on the formation of economically valuable traits. According to the results of studies by O. Demydov *et al.* (2023), the constitutive influence of the variety, compared to other factors (agrotechnical and environmental), was established only on the sedimentation index (30.2%). The wet gluten content was determined by the interaction of the variety × year factors (40.3%), and the formation of the protein content depended both on the growing conditions (23.4%) and on the interaction of the variety × year factors (21.8%). The authors note that genotype and genotype-environment interaction are the main factors influencing wheat grain quality. L.M. Prysiazhniuk *et al.* (2022), when determining the influence of genotype, year conditions and growing area on the quality indicators of winter bread wheat grain, established the maximum influence of the growing area on protein (49.0%) and wet gluten (65.0%) content, while the impact of annual conditions was 42% for protein content and 28% for wet gluten content, and that of genotype was only 5% and 4%, respectively. The authors emphasised that the synthesis and accumulation of nutrients in wheat grain depends on moisture supply and air temperature, so even minor changes in weather conditions and soil properties affect protein and wet gluten content. Some discrepancies were observed between the results obtained in this study and those reported by other researchers, as well as similar patterns in the influence of various factors on grain quality indicators, particularly the sedimentation index. However, all authors emphasise the reliable effect of genotype on the formation of wheat grain quality traits.

On average over the years of testing (Fig. 2), most winter bread wheat varieties significantly exceeded the Podolyanka standard variety: 60% of varieties in terms of protein content, 70% in terms of wet gluten content, and 93% in terms of sedimentation index. Winter bread wheat varieties were selected that, on average over two years, significantly exceeded the standard in terms of the studied flour quality indicators, namely: 'MIP Kniazhna', 'MIP Yuvileina', 'Avrora Myronivska', 'Pokrovska', 'Hlad', 'Zolotokolosa', 'Expromt', 'Kolumbiia', 'Optyma odeska', 'Doskonalist odeska', 'Perevaga', 'Kantata odeska', 'Kuialnyk', 'Mudrist odeska', 'Kubok', 'Lira odeska', 'Vahoma'. Of these, the varieties 'MIP Kniazhna', 'MIP Yuvileina', and 'Avrora Myronivska' significantly exceeded the 'Podolianka' variety in terms of protein and wet gluten content, while the varieties Pokrovska, Hlad, and Kolumbiia exceeded it in terms of three indicators. According to classification standards (Tkachyk, 2016), the following varieties of strong wheat were identified on average for 2023 and 2024 by protein content (⩾14.0%) – MIP Kniazhna and Avrora Myronivska; based on wet gluten content (⩾28.0%) – 'MIP Kniazhna', 'Avrora Myronivska', 'Pokrovska', 'Hlad, Zolotokolosa', 'Kolumbiia', 'Optyma odeska', 'Doskonalist odeska', 'Perevaha', 'Nyva odeska', 'Kuialnyk', 'Kubok', and 'Vahoma'; by sedimentation index (⩾60 ml) – all varieties except 'Vidpovid odeska'. 'Varieties Pokrovska', 'Osnova odeska', 'Kuialnik', and 'Kubok' had a higher sedimentation index (⩾80 ml). The varieties 'MIP Kniazhna' and 'Avrora Myronivska' were characterised by a complex of high grain quality indicators. Thus, the above-mentioned varieties of winter bread wheat should be used in the breeding process as sources of appropriate grain quality indicators for the creation of high-quality material.

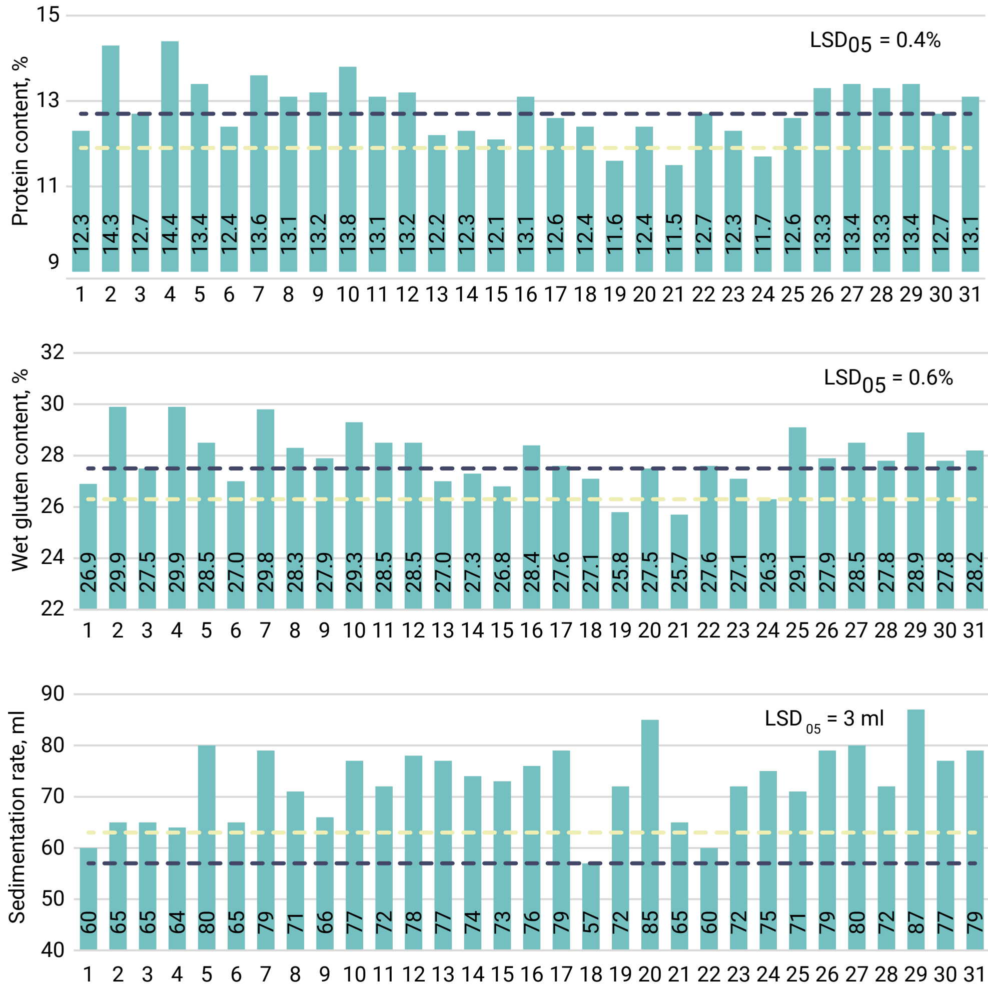

Figure 2. *Grain quality indicators for winter bread wheat varieties, average for 2023 and 2024*

Note: 1 – 'Podolianka', 2 – 'MIP Kniazhna', 3 – 'MIP Yuvileina', 4 – 'Avrora Myronivska', 5 – 'Pokrovska', 6 – 'Heizer', 7 – 'Hlad', 8 – 'Zolotokolosa', 9 – 'Expromt', 10 – 'Kolumbiia', 11 – 'Optyma odeska', 12 – 'Doskonalist odeska', 13 – 'Spadshchyna odeska', 14 – 'Versiia odeska', 15 – 'Manera odeska', 16 – 'Perevaha', 17 – 'Pontiika', 18 – 'Vidpovid odeska', 19 – 'Virnist', 20 – 'Osnova odeska', 21 – 'Peremoha odeska', 22 – 'Zhuravka odeska', 23 – 'Zysk', 24 – 'Zorepad', 25 – 'Nyva odeska', 26 – 'Kantata odeska', 27 – 'Kuialnyk', 28 – 'Mudrist odeska', 29 – 'Kubok', 30 – 'Lira odeska', 31 – 'Vahoma'; dashed lines indicate the confidence interval of differences from the standard ($p \leq 0.05$)
Source: developed by the authors of current study

Over a period of 16 years, O.Yu. Leonov *et al.* (2025) evaluated 1,200 genotypes of winter bread wheat for a wide range of grain quality indicators. As a result of summarising many years of data, sources of high protein and wet gluten content and quality, high rheological properties and other grain quality indicators were identified. Lines with a combination of high values of various quality indicators for different areas of use were selected. It should be noted that the variation in protein (10.99-14.89%) and wet gluten (20.4-33.1%) content in this study was close to the current data. In studies by I. Havryliuk & H. Kovalyshyna (2024), when evaluating 53 varieties of winter bread wheat selected by four research institutes in Ukraine, significantly lower values of protein content (8.70-11.60%) and wet gluten content (15.57-20.73%) were noted compared to the results of the current study. However, the authors still identified varieties with higher grain quality indicators and recommended them for further use in breeding programmes. K.V. Kostetska *et al*. (2024), evaluating Ukrainian winter bread wheat varieties for their milling properties, obtained higher maximum values for protein (12.2-15.0%) and wet gluten (24.9-31.7%) content compared to results from the current study. however, a significantly lower sedimentation rate (27-58 ml) was noted. The authors emphasised that evaluating varieties for their milling properties makes it possible to justify their further use. Thus, the differences between the results obtained by different scientists and the current data depend on genotypes, specific cultivation factors and the environment.

The results of the studies confirmed the important role of both the genotypic characteristics of winter bread wheat varieties and hydrothermal conditions in determining grain quality indicators. It was established that the most stable factor is genetic potential, while external conditions significantly modify the manifestation of protein and wet gluten content. The differences identified between varieties made it possible to identify valuable sources for breeding work and the creation of high-quality starting material.

Conclusions

The study revealed variability in the quality indicators of winter bread wheat depending on the hydrothermal conditions of cultivation. Higher average protein (13.3%) and wet gluten (28.7%) contents were observed in 2023, and higher sedimentation (74 ml) in 2024. It was established that the experimental data on grain quality indicators obtained during the years of testing were close to normal distribution, since the degree of asymmetry and excess distribution did not exceed the critical value ($|As/\sigma As| \leq 3$ and $|Ex/\sigma Ex| \leq 3$). Weak and moderate variation in protein content (CV = 5.3-8.6%) and wet gluten content (CV = 3.9-5.8%) between winter bread wheat varieties during the years of testing and significant variability (CV = 10.2-13.5%) in the sedimentation index.

A decisive (40.7-63.8%) influence of the variety on the studied grain quality indicators was revealed. The conditions of the year had an insignificant effect on the sedimentation index (2.5%), but a significant effect on the protein (23.2%) and wet gluten (24.0%) content. The interaction between variety and year had a significant effect (26.9-32.5%) on three grain quality indicators. The results of the analysis of variance confirmed that the quality of winter wheat grain is mainly determined by the genetic characteristics of the variety, but external factors also have a significant influence, especially in interaction with the genotype. Winter bread wheat varieties that can be used in the breeding process as sources of increased protein content were identified: 'MIP Kniazhna' and 'Avrora Myronivska'; wet gluten content – 'MIP Kniazhna', 'Avrora Myronivska', 'Pokrovska', 'Hlad', 'Zolotokolosa', 'Kolumbiia', 'Optyma odeska', 'Doskonalist odeska', 'Perevaha', 'Nyva odeska', 'Kuialnyk', 'Kubok', and 'Vahoma'; sedimentation index – all varieties except the variety Vidpovid odeska. Winter bread wheat varieties that combine high values of the complex of studied grain quality indicators in one genotype have been identified – 'MIP Kniazhna' and 'Avrora Myronivska'.

The evaluation of winter bread wheat genotypes according to grain quality indicators and the selection of the best ones will help accelerate the breeding process in the creation of strong and valuable varieties. The further introduction of high-quality varieties into production will ensure: improvement in the quality of grain, flour and bakery products; improvement in the economic performance of agricultural enterprises, which will contribute to the development of the grain processing industry in Ukraine.

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Conflict of Interest

None.

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Оцінювання сортів пшениці м'якої озимої (*Triticum aestivum* L.) за показниками якості зерна

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Анотація. Підвищення валового збору високоякісного зерна потребує удосконалення селекційних програм шляхом їх постійного збагачення новою генетичною плазмою. Тому мета дослідження полягала у виявленні джерел поліпшення показників якості зерна для використання у селекційному процесі за рахунок диференціації різних сортів пшениці м'якої озимої в умовах центральної частини Лісостепу України. Оцінювали 31 сорт пшениці м'якої озимої за вмістом білка, вмістом клейковини та показником седиментації урожаю 2023 та 2024 рр. Проаналізовано характер розподілу отриманих значень показників якості зерна. Виявлено, що ступінь істотності асиметрії та ексцесу розподілення не перевищував критичного значення ($|As/\sigma As| \leqslant 3$ і $|Ex/\sigma Ex| \leqslant 3$). Таким чином, експериментальні дані за показником седиментації, вмістом білка та клейковини у роки випробувань були наближеними до нормального розподілу. Встановлено мінливість показників якості зерна пшениці м'якої озимої залежно від гідротермічних умов вирощування. Отримано вищий середній вміст білка (13,3 %) та клейковини (28,7 %) у 2023 р., а показника седиментації (74 мл) у 2024 р. За коефіцієнтом варіації виявлено значну варіабельність (CV = 10,2-13,5 %) показника седиментації між сортами пшениці м'якої озимої у роки випробування, а також слабку та помірну варіацію вмісту білка (CV = 5,3-8,6 %) та клейковини (CV = 3,9-5,8 %). Виявлено визначальний (40,7-63,8 %) вплив сорту на досліджувані показники якості зерна. Умови року неістотно впливали на показник седиментації (2,5 %), однак суттєво на вміст білка (23,2 %) та клейковини (24,0 %). Частка впливу взаємодії чинників сорт × рік була значною (26,9-32,5 %) для всіх трьох показників якості зерна. Виділено сорти пшениці м'якої озимої з вищими значеннями вмісту білка – 'МІП Княжна' та 'Аврора Миронівська'; вмісту клейковини – 'МІП Княжна', 'Аврора Миронівська', 'Покровська', 'Гладь', 'Золотоколоса', 'Колумбія', 'Оптима одеська', 'Досконалість одеська', 'Перевага', 'Нива одеська', 'Куяльник', 'Кубок','Вагома'; показника седиментації – 'Покровська', 'Основа одеська', 'Куяльник', 'Кубок'

Ключові слова: *Triticum aestivum* L.; вміст білка; вміст клейковини; показник седиментації; гідротермічні умови; коефіцієнт варіації; ANOVA