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# The Genetic Potential of Spring Durum Wheat Grain Quality in the North of Kazakhstan

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**Abstract:** The paper presents information about the cultivation of spring durum wheat in the conditions of Northern Kazakhstan. Methods for assessing the quality of grain and semolina in the breeding process are shown: SDS sedimentation, protein content according to Kjeldahl, content, and index of gluten using the Glutomatic 2200 system, vitreousness, hardness SKCS 4100, content of carotenoid pigments, measurements of the color of grain and semolina using a CR-colorimeter. 410, Konica Minolta, commodity and technical properties of pasta; the characteristics of durum wheat genotypes are given as well. Relationships between quality indicators based on correlation analysis are established; indicators of hardness and vitreousness are in close connection with the most significant features: Protein content, gluten, pasta color, and evaluation of pasta properties. The quality of the studied durum wheat genotypes was found to meet the requirements of importers of Kazakh grain: Protein content averaged 14.9%, bulk density averaged 80.5 kg/hL, and the b* value in the Lab color evaluation system was at the level of 26.78 on average for semolina genotypes, with the maximum values found in Damsinskaya 2017 (32.17). Among the Kazakh varieties with the highest quality characteristics, the varieties Lavina, Damsinskaya Yubileinaya, and Korona stand out: Protein content (14.86-15.22%), gluten content 33.2-36.2%, gluten index 50-65, b* value (yellowness index) 23.82-26.74, vitreousness 80-84%. All studied genotypes belonged to hard-grained forms (hard-grain index 67-75).

**Keywords:** Vitreousness, Gluten, Gluten Index, Carotenoid Pigments, Correlation

## Introduction

Durum wheat grain serves as a raw material for the production of semolina and flour from durum wheat and is used for the manufacture of pasta, couscous, yeast, unleavened bread, bulgur, and freekeh (Branković *et al*., 2018).

The protein content in the grain, the quality of the protein, and the color of the semolina are the main qualitative characteristics of durum wheat. The challenge for breeders and chemists is to apply screening methods. Pigment and other color factors are inherited and are easy enough to measure (Clarke *et al*., 2000; Pinheiro *et al*., 2013). The color is classified according to three parameters of the colorimeter: L*, which measures brightness (0 = black and 100 = bright, white), and a*, where a positive value of a* indicates red and a negative a* indicates green and b*, where a positive b* indicates yellowness and a negative b* indicates blue (Hidalgo *et al*., 2014).

Italian and Turkish importers have the following requirements for the quality of Kazakh grain: Bulk density of 78-79 kg/hL, vitreousness of about 80%, protein content from 10.5 to 16.0%, admixture of soft wheat equaling 3-4%, cracked or broken grains: 5-6% Maximum. Particular importance is attached to the quality of protein, determined through the gluten index. In Kazakhstan, the gluten index for durum wheat is normalized by the national standard of the Republic of Kazakhstan (ST RK) 1046-2008 and equals 20-100 units. According to AbuHammad *et al*. (2012), the gradation of gluten depending on the gluten index can be described as follows: 91-100: Very strong, 71-90: Strong, 31-70: Moderately strong.

A large Italian company Barilla has published several requirements for the quality of pasta, namely, a uniform amber-yellow color without shades of gray or red; (and) a clean appearance of the surface without brown, black, or white spots or other signs; cooked pasta should not be sticky on the surface, i.e., stick together, but should have good ribbing, pleasant aroma and taste inherent in pasta. Long-term studies have shown that the resistance of pasta to cooking is mainly conditioned by three factors: High protein content, high gluten concentration, and elasticity and the drying cycle of pasta at high temperatures. The requirements of the European and North American durum wheat grain markets provide for a much wider range of features for assessing grain quality Sodium Dodecyl Sulfate (SDS) sedimentation, gluten index, mixograph, farinograph, and alveograph parameters) (Malchikov et al., 2019).

Durum wheat production in Kazakhstan is concentrated mainly in three regions: North Kazakhstan, Kostanay, and Akmola. The areas occupied by spring durum wheat vary between 400-500 thousand hectares.

The grain was classified according to the national standard 1046-2008, Wheat. Technical specifications for five classes, taking into account 16 indicators characterizing its condition, color, smell, amount of impurities, presence of diseased grains, and pest infestation. According to the Ministry of Agriculture of the Republic of Kazakhstan, in 2018-19, 70% of Class 4 grain was produced with a bulk grain density of 71.7-73.7 kg/hL, the protein content of 9.5-11.0%, gluten content of 18-22.0% and a gluten index of 20-100 (Fursov, 2021).

According to the SGS Kazakhstan Limited laboratory, the quality of durum wheat grain for 2020-2021 changed as follows: Protein content was 15.5-15.9%, grain unit or bulk density equaled 75.3-76.4 kg/hL, gluten content was 28-29.7%, with a gluten index of 10-12, vitreousness 80-82% and a yellowness index of 22-24 (Fursov, 2021).

In North Kazakhstan, one of the main criteria for the creation of durum wheat varieties is the high quality of the grain, which depends on weather conditions and the spread of diseases of this crop (Babkenova et al., 2017). There are 36 varieties in the list of spring durum wheat varieties approved for use in the Republic of Kazakhstan, 7 of them were created in Barayev Scientific and Production Center of Grain Farming LLP (Adilet, 2020). The aridity of the climate of North Kazakhstan, sufficient solar insolation, and provision of the soil with easily accessible forms of nitrogen in good weather conditions allows obtaining large, vitreous, transparent, high-protein grain, which can produce durable pasta during processing.

The purpose of the study is to evaluate the genetic potential of the quality of varieties and promising breeding lines, assess its compliance with the requirements of importers, and establish the dependency between the main quality characteristics of grain, semolina, and pasta.

## Materials and Methods

The object of the study was 12 varieties and breeding lines (hereinafter genotypes) of spring durum wheat from 2018 to 2020.

Determination of grain hardness was carried out using the SKCS 4100 analyzer of individual grains (Perten, Sweden), which characterizes wheat samples by such classes as soft, hard, or a mixture of classes. The 4100 device automatically separates 300 individual grains that are part of one sample, determining the weight, diameter, humidity, and hardness of an individual grain type. The grain hardness classification is carried out according to the average grain hardness coefficient of one sample and the measurement values of this indicator belong to one of the four-grain hardness classes established by the US Grain Marketing Research Laboratory. Classification of soft wheat according to the grain Hardness Index (HI) in units of the SKCS-4100 device: Hard-grain: 66-120, medium-hard-grain: 53-65, Mixture: 52-48, Semi-soft-grain: 47-36, Soft-grain: 35-0.

To determine the vitreousness, two methods were used. In the first, the incompletely vitreous durum wheat grains were determined according to ISO 5532-87 (IOS, 1987), where all grains that were visually incompletely vitreous, outwardly powdery, with a matte surface, were separated. With the help of a scalpel, all the remaining grains were cut across in the middle and both parts of each grain which turned out to be incompletely vitreous were separated. Grains that were visually incompletely vitreous were collected and weighed and the halves of those grains that turned out to be incompletely vitreous after cutting were separated from the halves of vitreous grains. The number of incompletely vitreous grains was calculated.

The second method according to the State Standard is based on the translucency of the grain under study by the light flux. From the average grain sample, a 50 g weight was isolated, poured onto the cassette of the diaphanoscopic device, filled all 100 cells, and viewed. The vitreous grain was completely translucent, the floury grain was not translucent. Grains with partially translucent or partially non-translucent endosperm were classified as partially vitreous or incompletely vitreous. The total vitreousness of the grain as a percentage was calculated by the formula $Tv = Cv + Pv/2$, where Cv is the number of completely vitreous grains in pcs and Pv is the number of partially vitreous grains, pcs.

The protein content was determined by the Kjeldahl method with the conversion of nitrogen by a factor of 5.7 for wheat.

The SDS sedimentation index was determined as follows: 0.5 g of whole-ground grain (protein meal) was placed in a graduated cylinder with a capacity of 10, 4 mL of distilled water was added, shaken, then stirred for 2 min, then 6 mL of working solution was added (17 g of sodium dodecyl sulfate dissolved in distilled water and 3 mL of iced acetic acid was added acid and the volume was brought to 1 liter), after which the suspension was stirred for 5 min. After settling the mixture (15 min), the sedimentation value (sediment volume in mL × 10) was measured.

The content of carotenoid pigments in wheat grain was carried out by extraction of carotenoids from a sample with water-saturated n-butanol, followed by a determination of the optical density of the extract at a wavelength of 440 nm (ISO 11052).

The studies used the method of gluten washing using the Glutomatic 2200 system (Sweden), which allows obtaining gluten from the wheatmeal. Then the gluten was centrifuged through a special sieve. Part of it remained on the sieve, part passed through the holes. The total weight of gluten represents its content. The proportion of gluten remaining on the sieve is considered the Gluten Index.

Grain and semolina color measurements were carried out in the L, a, b color coordinate system using the CR-410 colorimeter, Konica Minolta, (Japan). For each sample, the average values for 5 particular measurements were calculated.

The grinding of grain to semolina was carried out at the MLU 202 mill (Bueller, Switzerland). Obtaining the pasta: 600 g of semolina were placed in a dough mixer of a pasta press and water was gradually added, while the mixture was heated to 60-65°C. The total kneading time was 20 min. Then the dough was pressed for 5-6 min through a bronze matrix with a hole diameter of 5.5 mm and an internal diameter of 3.5 mm. The resulting pasta was loaded into cassettes and dried in a thermostat at a temperature of 36°C and air humidity of 85-90%. On the second day, the pasta was actively dried with an electric fan for 40 h and on the third day, the temperature was reduced to 25-28°C. After the end drying, the pasta was folded for a month's rest, after which the analysis of the commercial and technical properties of the pasta was carried out. Pasta should be smooth and uniform, without visible cracks, whitish stripes, and inclusions. The color of dry and boiled pasta was determined organoleptically and expressed in points, yellow (maximum 5), dark or white with a gray shade (1). The coefficient of digestibility by weight was calculated based on the ratio of the weight of boiled pasta to the weight of dry pasta. The overall score of pasta properties in points was the result of averaging all the scores.

Mathematical data processing was carried out according to the formulas of correlation analysis in the Excel software. The correlation coefficient was calculated at the 0.05% level, T r = r/sr if the actual t criterion was greater than the theoretical t (4.30) with a degree of freedom of n -2 (Dospekhov, 1985).

## Results

According to our data, after 3 years of studying the presented genotypes, the following variation of properties was noted: The protein content varied from 14.06 to 15.58% with an average of 14.90%, sedimentation level was 28-39 ms with an average of 36 mL, the weight of 1,000 grains was 38.7-46.3 g, with an average of 42.1 g, the gluten content was 30.4-36.9%, with an average of 35.2%, the gluten index was 6-75, with the average by genotypes equaling 46 and the content of carotenoid pigments was 0.402-0.731 mg/100 g, with an average of 0.531 mg/100 g.

In terms of protein content, 6 genotypes showed an excess compared to the Damsinskaya 90 standard variety (14.93%): Lavina and Damsinskaya yubileynaya varieties (15.20-15.22%), lines 272-08-9, 47-11-14 and 228-11-17 (15.00-15.58%) (Table 1). The gluten content in comparison with the standard (36.4%) was higher in the Damsinskaya yantarnaya variety (37.2%), lines 228-11-17 and 300-09-8 (36.9-39.4%), and was at the same level as in the Lavina variety. The gluten index was highest in lines 69-08-2 (75) and 272-08-9 (68).

Large grain in comparison with the standard (43.7 g) was observed in the Damsinskaya yantarnaya variety (45.2 g) and lines 300-09-8 (44.6 g) and 47-11-1 (46.3 g).

The maximum content of carotenoid pigments in the grain was observed in the Damsinskaya 2017 variety (0.731 mg/100 g) and line 47-11-1 (0.635 mg/100 g). According to the classification, all the presented samples are classified as solid-grain forms with HI from 67 to 75 units measured by the device, where the highest value of HI was recorded in the Lavina variety (79 units) and line 228-11-17 (IT-75).

The Lavina variety and line 47-11-1 were characterized by the most vitreous grain (80-84%), with the least amount of incomplete vitreous grains (44-45%).

The highest indicator of bulk density was recorded in the Korona variety with 81.2 kg/hL and the line 69-08-2 with 81.7 kg/hL (Fig. 1).

The brightest pasta color was noted in lines 47-11-1, 228-11-17, and the Damsinskaya variety 2017 (4.6-4.7 points) with a large stock of carotenoid pigments.

The overall score of pasta properties was highest in genotypes 47-11-1 and 228-11-17 with 4.8 points (Fig. 2).

According to our measurements, the b* level for grain varied by genotypes from 13.85 to 14.97 and for semolina from 22.84 to 32.17. The maximum b* indicators of grains were noted in the varieties Korona (14.97), Damsinskaya yubileynaya (14.67), lines 219-09-8 (14.63), 272-08-9 (14.52). A high value of b* for semolina was shown by the Damsinskaya variety 2017 (32.17) and line 219-09-8 (30.31) (Table 2). The large range of variability in the colorimeter data (b * 22.84-32.17) is explained by varietal characteristics, the color of the endosperm of the grain, the size of the endosperm particles, the content of inclusions that worsen the appearance of the grain and, accordingly, pasta (Steinberg *et al*., 2014). There are no close links between the color characteristics of grain and semolina.

In the process of correlation analysis, it has been found that great attention should be paid to vitreousness, which is in various degrees of relationship (from r = -0.60 to r = 0.75) with many significant quality characteristics (grain hardness, protein content, gluten, color of pasta, general score of pasta properties). Similar to the vitreousness, in the conditions of North Kazakhstan the determining factor of the high quality of durum wheat is the grain hardness and its correlations (r = -0.61-0.72) with the protein content and indicators of the physical properties of grain and commercial and technical properties of pasta (Table 3).

A close correlation r = 0.77 was established between the number of incompletely vitreous grains and the value L characterizing the brightness in the Lab system, as well as an average negative relationship r = -0.61 with the value a* (Table 4).

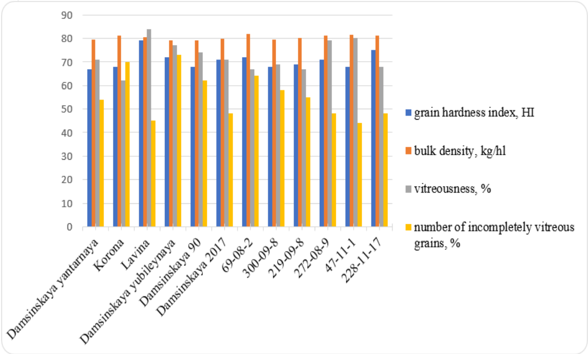


**Fig. 1:** Structural, mechanical, and physical properties of grain genotypes of spring durum wheat, on average for 2018-2020

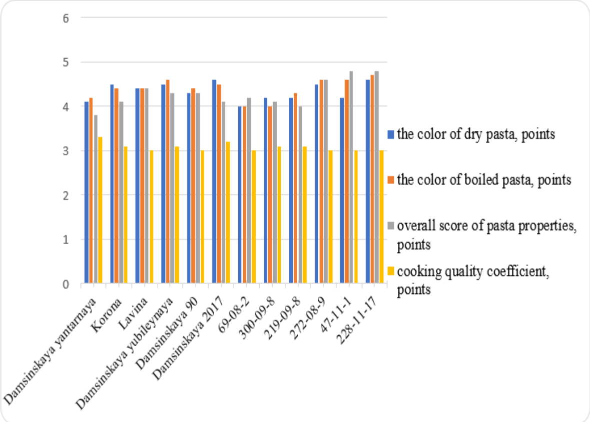


**Fig. 2:** Commercial and technical properties of pasta made from grain of spring durum wheat genotypes, on average for 2018-2020

**Table 1:** Biochemical and technological indicators of grain quality of spring durum wheat genotypes, on average for 2018-2020

| Genotype | Protein content, % | Sedimentation, ml | Weight of 1000 grains, g | Gluten content, % | Gluten index | Carotenoid pigment content, mg//100 g |
|---|---|---|---|---|---|---|
| Damsinskaya 90, standard | 14.93 | 37 | 43.7 | 36.4 | 46 | 0.475 |
| Damsinskaya yantarnaya | 14.49 | 36 | 45.2 | 37.2 | 26 | 0.473 |
| Korona | 14.86 | 39 | 42.9 | 33.2 | 65 | 0.492 |
| Lavina | 15.22 | 37 | 38.7 | 36.2 | 60 | 0.422 |
| Damsinskaya yubileynaya | 15.20 | 36 | 39.5 | 34.4 | 50 | 0.525 |
| Damsinskaya 90 | 14.93 | 37 | 43.7 | 36.4 | 46 | 0.475 |
| Damsinskaya 2017 | 14.06 | 28 | 39.4 | 31.9 | 60 | 0.731 |
| 69-08-2 | 14.95 | 37 | 42.1 | 30.4 | 75 | 0.424 |
| 300-09-8 | 15.20 | 32 | 44.6 | 39.4 | 20 | 0.529 |
| 219-09-8 | 14.08 | 37 | 42.2 | 33.8 | 40 | 0.589 |
| 272-08-9 | 15.00 | 37 | 39.0 | 36.4 | 68 | 0.500 |
| 47-11-1 | 15.32 | 39 | 46.3 | 36.4 | 58 | 0.635 |
| 228-11-17 | 15.58 | 38 | 42.1 | 36.9 | 41 | 0.575 |
| Min-max | 14.06-15.58 | 28-39 | 38.7-46.31 | 30.4-36.9 | 6-75 | 0.422-0.731 |
| Average | 14.9 | 36 | 42.1 | 35.2 | 46 | 0.531 |

**Table 2:** Color characteristics of grain and semolina of spring durum wheat genotypes determined on Minolta CR - 410, on average for 2018-2020

| | Grain | | | Semolina | | |
|---|---|---|---|---|---|---|
| Genotype | L* | a* | b* | L* | a* | b* |
| Damsinskaya yantarnaya | 47.35 | 4.80 | 13.98 | 93.70 | 0.68 | 22.84 |
| Korona | 47.20 | 5.27 | 14.97 | 94.40 | -1.97 | 26.00 |
| Lavina | 46.80 | 5.28 | 14.17 | 94.41 | -1.13 | 23.82 |
| Damsinskaya yubileynaya | 47.66 | 5.31 | 14.67 | 93.32 | 1.19 | 26.74 |
| Damsinskaya 90 | 47.68 | 4.81 | 14.02 | 93.11 | -0.79 | 23.00 |
| Damsinskaya 2017 | 46.76 | 5.06 | 14.46 | 92.12 | -2.13 | 32.17 |
| 300-09-8 | 46.82 | 5.17 | 13.85 | 93.46 | -1.37 | 27.60 |
| 188-09-2 | 46.09 | 5.12 | 14.03 | 93.59 | -1.30 | 26.17 |
| 219-09-8 | 47.57 | 4.73 | 14.63 | 93.64 | 2.24 | 30.31 |
| 272-08-9 | 46.93 | 5.34 | 14.52 | 94.11 | -1.47 | 25.25 |
| 47-11-1 | 45.14 | 5.26 | 13.93 | 93.29 | -1.77 | 29.46 |
| 228-11-17 | 46.19 | 5.42 | 14.50 | 93.26 | -2.08 | 28.03 |
| Min-max | 45.14-47.68 | 4.73-5.42 | 13.85-14.97 | 92.12-94.40 | 0.68-2.24 | 22.84-32.17 |
| Average | 46.82 | 5.13 | 14.31 | 93.53 | -0.82 | 26.78 |

**Table 3:** Correlation between the quality characteristics of spring durum wheat genotypes

| Indicators | The correlation coefficient, r | The standard error of the coefficient, criterion Sr | Materiality of the correlation coefficient tr |
|---|---|---|---|
| Vitreousness-protein content | 0.75 | 0.12 | 6.25 |
| Vitreousness-the number of incompletely vitreous grains | -0.60 | 0.14 | 4.28 |
| The number of incompletely vitreous grains | -0.69 | 0.13 | 5.30 |
| The bulk (weight) density of a hectoliter | | | |
| Gluten content-protein content | 0.85 | 0.09 | 9.44 |
| Gluten content-vitreousness | 0.68 | 0.13 | 5.23 |
| The color of dry pasta-vitreousness | 0.64 | 0.14 | 4.57 |
| The color of dry pasta-the content of carotenoid pigments | 0.60 | 0.14 | 4.28 |
| The color of boiled pasta-vitreousness | 0.65 | 0.13 | 5.00 |
| Cooking quality-protein content | 0.75 | 0.12 | 6.25 |
| Cooking quality-the weight of 1000 grains | 0.63 | 0.14 | 4.50 |
| Cooking quality-gluten content | -0.65 | 0.13 | 5.00 |
| The general score of pasta properties-protein content | 0.90 | 0.08 | 1.25 |
| The general score of pasta properties-vitreousness | 0.75 | 0.12 | 6.25 |
| The general score of pasta properties-gluten content | 0.75 | 0.12 | 6.25 |
| The general score of pasta properties-the color of dry pasta | 0.64 | 0.14 | 4.57 |
| The general score of pasta properties-the color of boiled pasta | 0.66 | 0.18 | 3.66 |
| The general score of pasta properties-cooking quality | -0.79 | 0.11 | 7.18 |
| Grain hardness-protein content | 0.69 | 0.13 | 5.30 |
| Grain hardness-the weight of 1000 grains | -0.72 | 0.12 | 6.00 |
| Grain hardness-vitreousness | 0.67 | 0.13 | 5.15 |
| Grain hardness-cooking quality | -0.61 | 0.14 | 4.36 |
| Grain hardness-general score of pasta properties | 0.69 | 0.13 | 5.31 |

**Table 4:** Correlation between grain quality characteristics of spring durum wheat genotypes and color characteristics in the lab system

| Indicators | The correlation coefficient, r | The standard error of the correlation coefficient, Sr | Materiality criterion of the correlation coefficient tr |
|---|---|---|---|
| L* -the bulk (weight) density of a hectoliter | -0.68 | 0.13 | 5.23 |
| L* -vitreousness | -0.68 | 0.13 | 5.23 |
| L* -The number of incompletely vitreous grains | 0.77 | 0.11 | 7.00 |
| A* -the bulk (weight) density of a hectoliter | 0.71 | 0.12 | 5.92 |
| A* -the number of incompletely vitreous grains | -0.61 | 0.14 | 4.36 |

## Discussion

New technologies for the production of pasta, introduced by such modern manufacturers as Barilla Group and De Cecco (the largest European operators of the pasta market), are making increasingly high demands on the raw materials, purchasing large, highly dense grain with resilient and elastic gluten, high content of carotenoids and protein (Goncharov and Kurashov, 2018). The protein content is the main factor related to the quality of pasta preparation (Autran *et al*., 1986; Fedin 1988; D'egidio *et al*., 1990; Lyapunova, 2019). The formation of high protein content is characteristic of North Kazakhstan. This indicator is closely related to the gluten content, vitreousness, grain hardness, and commercial and technical properties of pasta. Durum wheat grains from Italy and Spain contain an average of 14.2-14.7% protein, whereas, for the industrial production of pasta, the requirements are set at a level of at least 12.5% (Peña *et al*., 2002). The increase in gluten strength largely compensates for the decrease in protein content. The protein quality of Italian and Spanish varieties has been improved mainly by breeding. Moreover, breeding programs have been successful in increasing gluten stability. The level of the protein content of Kazakhstani varieties presented in this study varied from 14.06 to 15.58%, which makes it possible for them to meet the requirements of Italian importers.

The gluten index is very popular all over the world as an indicator of the gluten strength of durum wheat varieties (Cubadda *et al*., 1992; Ames *et al*., 2003). According to scientists, the gluten index and the volume of SDS sedimentation strongly correlate and indicate a measurement of similar aspects of gluten strength, or gluten quality (Clarke *et al*., 2010). Taneva *et al*. (2019) believe that SDS sedimentation characterizes the strength of gluten. Connections between the volume of SDS sedimentation and the rheological properties of the test have also been established (Leshchenko, 2015). Pasta manufacturers in Europe are seeking to use the gluten index and alveograph to measure the gluten complex of semolina, whereas the mixograph is widely used in North America.

Our studies have established an average positive correlation between r = 0.54 gluten index and SDS sedimentation. It is believed that the gluten index would be more desirable than the volume of SDS deposition for use in selection (Wang and Kovacs, 2002; Clarke *et al*., 2010), since the efficiency of the SDS deposition volume for selection purposes is problematic due to the association with protein concentration, whereas the gluten index is relatively independent of this concentration.

A feature of Kazakhstan durum wheat grain over the past two years, according to SGS Kazakhstan Limited, is weak gluten (index 10-12). The gluten index (6-26), characteristic of the varieties and lines in our studies (Damsinskaya yantarnaya, Damsinskaya 2017 and 300-09-8) requires improvement by breeding.

Differences in grain hardness are the single most important feature determining the quality of wheat for final use. The grain hardness distinguishes durum wheat from soft wheat and makes it possible to obtain granular flour (semolina) used for the manufacture of high-quality macaroni (pasta) during grinding (Malchikov *et al*., 2014; Murray *et al*., 2016). The grain texture classification is based primarily on the resistance of kernels to crushing (Morris, 2002). Grain crushing was carried out on the SKCS 4100 device, which is used for selections in the program of improvement of durum varieties and for determining adulteration of durum wheat (the presence of soft impurities in it) (Dexter and Marchylo, 2001; Sissons *et al*., 2000). According to the classification of this device, all the studied genotypes belonged to hard-grained forms (HI 67-75).

The vitreousness usually differs between varieties (Subira *et al*., 2014). In Kazakhstan, the method of determining the incompletely of vitreous grains is used only in export/import operations and therefore it was interesting to compare the two methods. Determining the amount of incompletely vitreous grains from 100 g of grain is more time-consuming in comparison with the method based on the translucency of grain on a diaphanoscope. However, an average reliable negative relationship, r = -0.60, was established between them, which probably indicates the influence of the visual factor during the analysis. According to Evdokimov *et al*. (2019), vitreousness has a positive relationship with the bulk density and the color of pasta. In the research of Golik and Golik (2008), the correlation between the bulk density and vitreousness has a negative value. In our studies, the number of incompletely vitreous grains is in a significant negative relationship with the bulk density (r = -0.69). The inconsistency of the data on the correlation of vitreousness with quality indicators is explained by different conditions and a different set of varieties studied.

Requirements for the quality of raw materials for pasta in Canada: Protein content: 13-15%, yellowness index: More than 23.5. The quality of wheat is focused on increasing the level of yellow pigment and the brightness of pasta. The variation in the most common Canadian commercial varieties AC Avonlea, AC Navigator, Strong field, and Commander, ranged from 13.7 to 14.6% in protein content, with a gluten index of 34-94 (Dexter, 2008; Dexter *et al*., 2004).

Among Kazakhstan varieties, Lavina, Damsinskaya yubileynaya, and Korona varieties stand out in terms of protein content (14.86-15.22%), gluten content 33.2-36.2% with an index of 50-65, and the b* value with b* = 23.82-26.74.

The combination of high vitreousness, protein content, and strong gluten made it possible to obtain pasta with an average and high overall score (4.1-4.8 points) (Appendix 1).

For several breeding lines in two Turkish regions, the ranges of color characteristics were: 45.55-49.29 for grain L values, 87.50-90.28 for semolina L values, 7.47-8.67 for grain a* values, 1.27-1.94 for semolina a* values, 16.34-17.50 for grain b values and 16.27-20.62 for grain a values b semolina (Şahin *et al.*, 2006). These data differ from ours in the higher values of a and b for grain and semolina.

The maximum b* values for durum wheat semolina in the conditions of North Kazakhstan were noted in the Damsinskaya variety 2017-32.17. The grain of durum varieties with a high content of yellow pigments is characterized by a better qualitative composition of gluten proteins and has a lighter and thinner husk (Banach *et al*., 2021).

The ability of the b* index to express natural coloration depended on the characteristics of the sample, as evidenced by the relationships found between this index and pigments (Fratianni *et al*., 2005). In our conditions, the relationship between the grain b* index and the content of carotenoid pigments was weak (r = 0.35) and not reliable. Similarly, according to the data of Şahin *et al*. (2006), there was no significant correlation between the b value and important indicators of the quality of grain and semolina.

## Conclusion

Thus, the data presented in the paper on the quality of the studied durum wheat genotypes meet the requirements of importers of Kazakh grain: The protein content is on average 14.9%, the bulk density is 80.5 kg/hL, the b* value characterizes the intensity of yellow in the Lab color evaluation system and on average equaled 26.78 for semolina genotypes, with the maximum values observed in the Damsinskaya 2017 variety (32.17). It has been established that grain hardness and vitreousness are closely related to the most significant signs of quality, such as protein content, gluten content, color, and the score of pasta properties.

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## Author’s Contributions

All authors equally contributed to this study.

## Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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**Appendix 1:** Grain quality of spring durum wheat for 2018-2020

| Variety, line | Year | Protein content, % | Sedimentation, ml | Weight of 1000 grains, g | Bulk density, kg/hl | Vitreousness, % | The number of incompletely vitreous grains | Gluten content, % | Gluten index | Carotenoid pigment content, mg/100 g | Color of dry pasta, points | Color of boiled pasta, points | The coefficient of cooking quality by weight, points | Overall score of pasta properties, points |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Damsinskaya | 2018 | 13.14 | 34 | 47.0 | 79.9 | 61 | 31 | 32.6 | 62 | 0.417 | 3.9 | 3.8 | 3.4 | 3.3 |
| 90 standard | 2019 | 16.13 | 36 | 35.6 | 75.6 | 76 | 23 | 37.2 | 36 | 0.488 | 4.7 | 4.8 | 2.7 | 4.9 |
| | 2020 | 15.53 | 41 | 48.6 | 82.1 | 86 | 60 | 39.3 | 40 | 0.520 | 4.3 | 4.5 | 3.0 | 4.6 |
| Average | | 14.93 | 37 | 43.7 | 79.2 | 74 | 38 | 36.4 | 46 | 0.475 | 4.3 | 4.4 | 3.0 | 4.3 |
| Damsinskaya yantarnaya | 2018 | 12.28 | 34 | 46.2 | 78.9 | 57 | 28 | 31.2 | 40 | 0.473 | 3.3 | 3.3 | 3.4 | 2.9 |
| | 2019 | 16.15 | 36 | 38.7 | 76.9 | 70 | 16 | 41.4 | 7 | 0.447 | 4.2 | 4.3 | 3.1 | 4.5 |
| | 2020 | 15.04 | 39 | 50.6 | 82.4 | 87 | 94 | 39.1 | 31 | 0.500 | 4.8 | 4.8 | 3.4 | 3.9 |
| Average | | 14.49 | 36 | 45.2 | 79.4 | 71 | 46 | 37.2 | 26 | 0.473 | 4.1 | 4.2 | 3.3 | 3.8 |
| Korona | 2018 | 12.45 | 36 | 44.2 | 80.5 | 42 | 9 | 28.2 | 69 | 0.444 | 3.9 | 3.9 | 3.4 | 3.2 |
| | 2019 | 16.60 | 36 | 39.7 | 78.2 | 61 | 8 | 39.2 | 45 | 0.467 | 4.9 | 4.7 | 2.8 | 4.9 |
| | 2020 | 15.53 | 46 | 44.9 | 84.8 | 83 | 74 | 32.1 | 81 | 0.567 | 4.7 | 4.6 | 3.2 | 4.3 |
| Average | | 14.86 | 39 | 42.9 | 81.2 | 62 | 30 | 33.2 | 65 | 0.492 | 4.5 | 4.4 | 3.1 | 4.1 |
| Lavina | 2018 | 13.62 | 35 | 40.1 | 80.1 | 72 | 46 | 31.4 | 73 | 0.376 | 3.8 | 4.0 | 3.1 | 4.0 |
| | 2019 | 16.81 | 36 | 36.5 | 78.2 | 94 | 42 | 42.1 | 47 | 0.376 | 4.7 | 4.6 | 2.8 | 4.9 |
| | 2020 | 15.23 | 41 | 39.6 | 83.4 | 87 | 77 | 35.1 | 60 | 0.515 | 4.8 | 4.7 | 3.2 | 4.3 |
| Average | | 15.22 | 37 | 38.7 | 80.5 | 84 | 55 | 36.2 | 60 | 0.422 | 4.4 | 4.4 | 3.0 | 4.4 |
| Damsinskaya | 2018 | 14.00 | 33 | 43.8 | 79.9 | 71 | 24 | 32.6 | 38 | 0.462 | 4.0 | 4.2 | 3.4 | 3.4 |
| yubileynaya | 2019 | 16.13 | 34 | 35.6 | 75.6 | 76 | 14 | 37.2 | 36 | 0.488 | 4.7 | 4.8 | 2.7 | 4.9 |
| | 2020 | 15.48 | 42 | 39.2 | 81.6 | 85 | 44 | 33.3 | 77 | 0.626 | 4.8 | 4.9 | 3.2 | 4.7 |
| | | 15.20 | 36 | 39.5 | 79.0 | 77 | 27 | 34.4 | 50 | 0.525 | 4.5 | 4.6 | 3.1 | 4.3 |
| Damsinskaya 2017 | 2018 | 11.71 | 20 | 43.0 | 79.2 | 41 | 23 | 21.4 | 6 | 0.599 | 3.9 | 3.7 | 3.6 | 2.7 |
| | 2019 | 16.39 | 32 | 34.0 | 78.2 | 89 | 57 | 42.4 | 8 | 0.682 | 4.8 | 4.8 | 3.0 | 4.9 |
| | 2020 | 14.08 | 31 | 41.1 | 82.4 | 83 | 75 | 32.0 | 4 | 0.914 | 5.0 | 5.0 | 3.3 | 4.6 |
| | | 14.06 | 28 | 39.4 | 79.9 | 71 | 52 | 31.9 | 6 | 0.731 | 4.6 | 4.5 | 3.2 | 4.1 |
| 69-08-2 | 2018 | 14.93 | 31 | 43.4 | 80.3 | 56 | 30 | 29.8 | 77 | 0.370 | 3.6 | 3.5 | 3.0 | 3.8 |
| | 2019 | 14.95 | 36 | 42.1 | 83.2 | 67 | 36 | 30.4 | 75 | 0.424 | 4.0 | 4.0 | 3.0 | 4.2 |
| | 2020 | 14.97 | 42 | 40.8 | 81.7 | 77 | 43 | 31.1 | 66 | 0.479 | 4.4 | 4.5 | 3.1 | 4.6 |
| Average | | 14.95 | 36 | 42.1 | 80.3 | 67 | 36 | 30.4 | 73 | 0.424 | 4.0 | 4.0 | 3.0 | 4.2 |
| 300-09-8 | 2018 | 13.16 | 31 | 47.8 | 80.3 | 49 | 16 | 30.1 | 32 | 0.370 | 3.8 | 3.6 | 3.4 | 2.9 |
| | 2019 | 16.82 | 32 | 37.1 | 77.8 | 79 | 39 | 45.1 | 15 | 0.497 | 4.0 | 3.8 | 2.7 | 4.6 |
| | 2020 | 15.62 | 32 | 49.0 | 80.8 | 80 | 72 | 42.9 | 12 | 0.720 | 4.8 | 4.7 | 3.1 | 4.7 |
| Average | | 15.20 | 32 | 44.6 | 79.6 | 69 | 42 | 39.4 | 20 | 0.529 | 4.2 | 4.0 | 3.1 | 4.1 |
| 188-09-2 | 2018 | 12.08 | 30 | 42.8 | 81.1 | 46 | 60 | 28.1 | 47 | 0.385 | 4.5 | 4.4 | 3.6 | 2.4 |
| | 2019 | 16.00 | 34 | 36.6 | 81.8 | 85 | 56 | 38.9 | 49 | 0.420 | 3.7 | 3.9 | 2.9 | 4.5 |
| | 2020 | 14.04 | 32 | 39.7 | 80.4 | 66 | 58 | 33.5 | 48 | 0.402 | 4.1 | 4.1 | 3.2 | 3.4 |
| Average | | 14.16 | 32 | 39.7 | 81.1 | 66 | 58 | 33.5 | 48 | 0.402 | 4.1 | 4.2 | 3.2 | 3.4 |
| 219-09-8 | 2018 | 12.03 | 34 | 44.4 | 79.3 | 44 | 22 | 29.3 | 41 | 0.462 | 3.5 | 3.7 | 3.2 | 3.2 |
| | 2019 | 15.35 | 34 | 37.2 | 79.3 | 77 | 42 | 37.4 | 36 | 0.523 | 4.3 | 4.3 | 2.9 | 4.7 |
| | 2020 | 14.87 | 41 | 45.0 | 81.6 | 81 | 70 | 34.7 | 44 | 0.782 | 4.8 | 4.8 | 3.3 | 4.1 |
| Average | | 14.08 | 37 | 42.2 | 80.0 | 67 | 45 | 33.8 | 40 | 0.589 | 4.2 | 4.3 | 3.1 | 4.0 |
| 272-08-9 | 2018 | 14.99 | 37 | 39.0 | 81.1 | 78 | 52 | 36.0 | 68 | 0.499 | 4.5 | 4.6 | 3.0 | 4.6 |
| | 2019 | 14.67 | 35 | 36.2 | 80.1 | 76 | 32 | 36.3 | 49 | 0.391 | 4.3 | 4.3 | 2.7 | 4.7 |
| | 2020 | 15.34 | 39 | 41.9 | 82.3 | 81 | 72 | 36.6 | 86 | 0.609 | 4.7 | 4.8 | 3.2 | 4.4 |
| Average | | 15.00 | 37 | 39.0 | 81.2 | 79 | 52 | 36.3 | 68 | 0.500 | 4.5 | 4.6 | 3.0 | 4.6 |
| 47-11-1 | 2018 | 15.32 | 39 | 46.3 | 81.5 | 80 | 56 | 36.4 | 58 | 0.635 | 4.2 | 4.6 | 3.0 | 4.8 |
| | 2019 | 15.03 | 36 | 40.8 | 79.7 | 81 | 36 | 35.0 | 67 | 0.517 | 4.4 | 4.3 | 2.8 | 4.7 |
| | 2020 | 15.61 | 42 | 51.8 | 83.4 | 80 | 75 | 37.8 | 49 | 0.753 | 4.0 | 5.0 | 3.2 | 4.8 |
| Average | | 15.32 | 39 | 46.3 | 81.6 | 80 | 56 | 36.4 | 58 | 0.635 | 4.2 | 4.6 | 3.0 | 4.8 |
| 228-11-17 | 2018 | 15.58 | 38 | 42.1 | 81.2 | 68 | 52 | 36.9 | 41 | 0.575 | 4.6 | 4.7 | 3.0 | 4.7 |
| | 2019 | 15.38 | 39 | 38.5 | 78.8 | 52 | 45 | 36.4 | 49 | 0.491 | 4.3 | 4.5 | 2.9 | 4.8 |
| | 2020 | 15.78 | 38 | 45.7 | 83.9 | 85 | 58 | 37.5 | 33 | 0.659 | 4.8 | 4.9 | 3.1 | 4.7 |
| Average | | 15.58 | 38 | 42.1 | 81.3 | 68 | 52 | 36.9 | 41 | 0.575 | 4.6 | 4.7 | 3.0 | 4.8 |