

RELATIONSHIPS BETWEEN MORPHOMETRIC AND QUALITY PARAMETERS IN WHEAT GRAINS

Volkan YEŞİL¹, Vali ABDİYEV², Özgür TATAR³

¹Ege University, Graduate School of Natural and Applied Sciences, Environmental Sciences,
İzmir, Türkiye

²Azerbaijan State Agricultural University, Gence, Azerbaijan

³Ege University Faculty of Agriculture Department of Field Crops, İzmir, Türkiye

Corresponding author email: volkanyesil35@gmail.com

Abstract

Wheat is a staple food grain that plays a vital role in daily diets worldwide. Therefore, even minor changes in wheat production and quality hold significant importance globally, particularly in today's context, where food crises are a pressing concern. While the effects of various environmental factors on wheat yield and quality have been extensively studied, research on the variation in quality traits of seeds from wheat plants exposed to the same environmental conditions remains limited. In this study, the quality traits and amino acid contents of wheat seeds grown under identical conditions were comparatively analyzed based on their size. The results showed that protein content, sedimentation value, and gluten levels were highest in medium-sized seeds, whereas starch content was found to be higher in large seeds. Moreover, essential amino acids crucial for human health were observed at the highest levels in smaller seeds of the same variety.

Key words: wheat, morphometric traits, quality parameters, seed size.

INTRODUCTION

Among cereal crops, wheat has a significantly larger cultivation area and higher production volume compared to others, as a result of being a fundamental source of calories (Reynolds and Braun, 2022; FAO, 2024).

Wheat production and the quality of the harvested product depend on various environmental factors (Woggoner, 1969). Numerous studies have demonstrated the impact of environmental factors such as precipitation (Tatar et al., 2020), air temperature (Mahdavi et al., 2022), and soil nutrient content (Fangmeier et al., 1999) on wheat yield and quality. Although the effects of environmental factors and genetic differences on grain characteristics and quality have been extensively studied, research on the variation within the same seed lot remains limited. In this context, morphometric differences like grain size and weight distribution are hypothesized to play a crucial role in determining the resulting flour properties and nutritional aspects within the same harvest (Aydoğan et al., 2014).

Wheat grain morphology is not only crucial for yield attributes but also influences grain quality

parameters such as nutritional composition and milling performance. In fact, grain size and shape have been shown to directly affect the end-use quality and market value of wheat (Gegas et al., 2010). Recognizing these influences provides essential context for linking physical grain characteristics with quality metrics in modern cultivars, underscoring the importance of studying their interrelationships. Hence, this study aims to reveal the differences in composition and quality of bread wheat seeds obtained from the same harvest, but classified by their grain size, shedding light on the importance of in-lot variability and its implications for wheat utilization.

MATERIALS AND METHODS

The experiment was conducted at the Department of Field Crops, Faculty of Agriculture, Ege University. As plant material, a total of 500 g of bread wheat (*Triticum aestivum* L.) seeds obtained from the same field and the same growing season were used. From these seeds, 100 seeds were sampled in four replications, and the thousand grain weight (TGW) was determined. The seeds with

calculated TGW values (500 g) were classified into three categories based on their weight: small, medium, and large (Table 1).

Table 1. The ranges used in the classification process of bread wheat (*Triticum aestivum* L.) seeds (500 g) based on their TGW into three categories are as follows

Classification:	Ranges Based on Grain Weights
Small grains	<TGW x 0.95
Medium grains	TGW x 0.95 ~ TGW x 1.05
Large grains	>TGW x 1.05

The classification process was conducted using a precision balance, with each seed weighed individually (Figure 1).

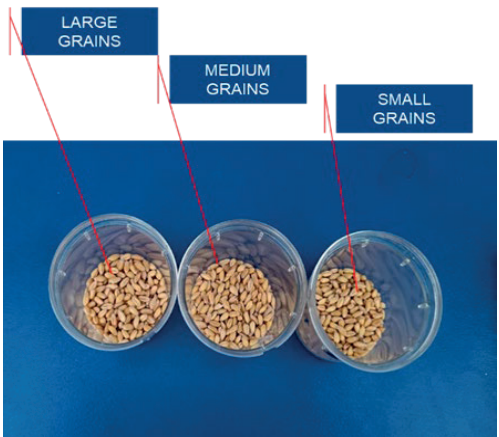


Figure 1. Image of the classification process of bread wheat (*Triticum aestivum* L.) seeds based on their TGW

After the separation process, TGW measurements were repeated for each group (small, medium, and large grains). In the obtained three seed groups, the following values were determined using an NIR spectrometer:

- 1) quality parameters: Wet gluten (%), Protein (%), Sedimentation (mL), Falling number (s), Hectolitre (g/L), Fat (%), Fiber (%);
- 2) amino acids: Leucine, Phenylalanine, Isoleucine, Egg + Cysteine, Arginine, Valine.

RESULTS AND DISCUSSIONS

Thousand Grain Weight (TGW)

The TGW values of *Triticum aestivum* L. seeds classified as small, medium, and large are presented in Figure 2. The TGW values of the classified seeds were found to be 53.3 g for large grains, 44.1 g for medium grains, and 37.4 g for small grains.

The obtained TGW values indicate that the classification performed by individually weighing the seeds (Table 1) is reflected in the TGW values of each group. As a result of the classification, the TGW of medium-sized seeds was 17.9% higher than that of small seeds, while large seeds had a 42.5% higher TGW compared to small seeds. These values and the observed differences between the groups were considered sufficient for comparing quality traits and grain composition data.

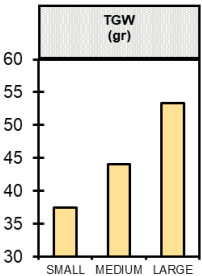


Figure 2. Thousand Grain Weight (TGW) values of *Triticum aestivum* L. seeds classified as small, medium, and large

Grain Quality Characteristics

The values of wet gluten (%), protein content (%), sedimentation (mL), and falling number (s) for *Triticum aestivum* L. seeds classified as small, medium, and large are presented in Figure 3.

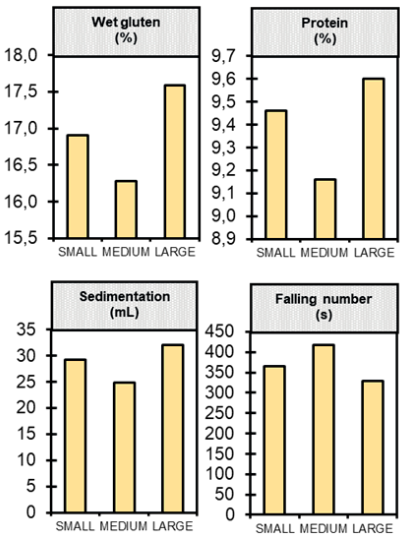


Figure 3. Wet gluten (%), protein content (%), sedimentation (mL), and falling number (s) values of *Triticum aestivum* L. seeds classified as small, medium, and large

Several studies have demonstrated that as grain weight decreases in wheat, there is a decline in protein content, gluten, and sedimentation values (Mahdavi et al., 2022). For instance, Aydoğ̃an et al. (2014) reported in a multi-cultivar study that as grain size decreased, the protein content and dry gluten content of wheat increased, whereas larger grains showed higher sedimentation values. This inverse relationship between grain size and protein concentration is also supported by other research: Wang and Fu (2020) observed that when kernel size decreased in durum wheat, the protein content rose significantly (from 14.1% up to 18.6% in the smallest kernels). Generally, smaller or lighter kernels within a single variety have been associated with higher protein content and stronger gluten, whereas larger kernels often have slightly lower protein but can show good sedimentation values depending on protein quality (Aydoğ̃an et al., 2014; Sahin et al., 2013). These trends are thought to arise because larger grains allocate more endosperm (mostly starch) during development, whereas smaller grains have a higher proportion of germ and aleurone layer which contain protein-rich tissues (Okur & Onel, 2024).

In the present study, when comparing the smallest and largest grain fractions, a similar pattern was observed in part: the large grains had lower protein percentage than the small grains (9.6% vs. an intermediate value of ~9.4% in small grains, based on the figures), consistent with the idea that very large kernels are more starchy. However, the medium-sized grains did not conform to the expected trend and actually exhibited the lowest protein, gluten, and sedimentation values among the three groups. This deviation is noteworthy. A possible explanation is related to the position of grains on the wheat spike. Within a single spike, grains that develop in different positions (top, middle, bottom) receive varying amounts of nutrients and assimilates. Boz et al. (2012) found that grain position significantly affects grain quality: grains from the middle of the spike were the largest, while protein content increased from the top to the bottom of the spike. It is also possible that the single variety used in this study has a unique allocation of resources among grains that does not strictly follow grain size. Genetic variation can modulate the relationship between

grain size and quality traits. Thus, the lower protein and gluten in medium-sized grains (relative to both small and large) may reflect a complex interaction of developmental timing and genetic factors in this particular wheat lot. Further research isolating grains by their position on the spike, in addition to size, could clarify this anomaly.

In general, it is known that as the thousand grain weight (TGW) decreases in wheat, the hectoliter weight (HW) increases (Tatar et al., 2020). This is because smaller grains often pack more densely, filling a given volume more completely than larger grains. In our results, when only the small and large grain groups were considered, the expected inverse relationship between TGW and hectoliter weight was observed: the small grains had a relatively higher hectoliter weight than the very large grains (Figure 4), which is consistent with the literature. However, the medium-sized grains did not follow the same trend, showing a hectoliter weight that did not exceed that of the small grains. This could be related to their overall shape or density.

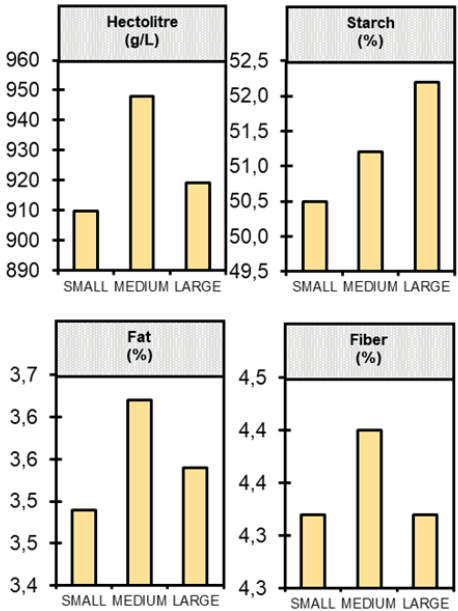


Figure 4. Hectoliter weight (g/L), starch (%), fat (%), and fiber (%) values of *Triticum aestivum* L. seeds classified as small, medium, and large

Starch content was found to increase proportionally with TGW. The large grains had the highest starch percentage, while smaller

grains had less starch. This can be explained by the fact that as grain size increases, the proportion of starchy endosperm in the seed also increases, diluting other components. The trends in the results align with this: large grains (heaviest) showed the highest starch content, consistent with their greater endosperm development. Conversely, small grains, having less endosperm, showed slightly lower starch percentages and higher relative protein. The literature supports this inverse relationship between starch and protein concentrations; as one increases, the other tends to decrease due to a dilution effect in the grain composition (Okur & Onel, 2024).

Erbaş Köse et al. (2013) observed that as TGW decreases in wheat grains, there is a corresponding decrease in fixed oil (fat) and fiber content. In other words, smaller grains were reported to have lower oil and fiber than larger grains in that study. However, in the present study, we did not observe a clear trend for oil (fat) and fiber content with respect to grain size (Figure 4). The fat and fiber percentages were relatively similar across small, medium, and large grains, without a statistically significant pattern. This discrepancy could be due to varietal differences or the narrow range of grain sizes in our classification. It is possible that the wheat variety examined does not exhibit significant variation in bran (outer layer) proportions between medium and small grains. Given that fiber is predominantly concentrated in the bran and oil in the germ, fractions with similar bran-to-germ ratios would likely have comparable fiber and fat contents (Erbaş Köse et al., 2013). Additionally, minor differences may not have been detected due to the sensitivity of NIR measurements. These findings suggest that compositional parameters do not uniformly vary with grain size; fiber and fat contents may remain relatively constant across different seed sizes within a single variety, whereas protein and starch contents exhibit more pronounced differences.

Grain Amino Acid Content

The amino acid contents of *Triticum aestivum* L. seeds classified as small, medium, and large based on thousand grain weight (TGW) are presented in Figure 5.

An analysis of amino acid composition revealed that the contents of leucine, phenylalanine, and

isoleucine were slightly lower in medium-sized grains compared to both small and large grains. In contrast, the levels of Egg+Cys (methionine plus cysteine), arginine, and valine clearly decreased as grain size increased. In other words, for methionine+cysteine, arginine, and valine, the smallest grains had the highest concentrations, and the largest grains had the lowest, with medium grains in between. These trends suggest that smaller wheat seeds, despite having overall less mass and protein, contained a higher proportion of certain essential amino acids.

Esfandiari and Abdoli (2016) reported that, in addition to protein content, the biological properties of wheat grains, such as amino acid composition, are of great importance for nutrition. Similarly, Labanauskas et al. (1981) stated that the amino acid content of wheat varies significantly depending on environmental factors. The results indicate that not only environment (García del Moral et al., 2007) but also grain size (within the same environment) can influence the amino acid profile of the grain.

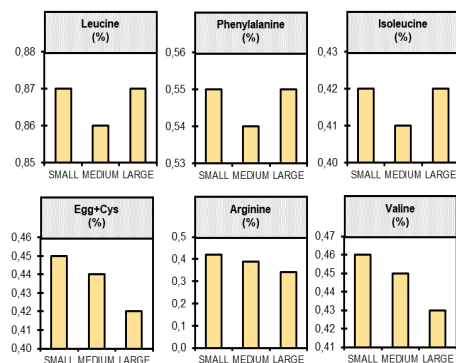


Figure 5. Leucine (%), phenylalanine (%), isoleucine (%), Egg+Cys (%), arginine (%), and valine (%) values of *Triticum aestivum* L. seeds classified as small, medium, and large

The obtained results clearly demonstrated that as TGW increases, the contents of Egg+Cys, arginine, and valine decrease. However, no significant change was observed in leucine, phenylalanine, and isoleucine levels in relation to TGW. One possible explanation for why smaller grains had higher percentages of certain amino acids is the distribution of protein types within the grain. Wheat grain proteins can be broadly categorized into gluten proteins

(prolamins, which are low in some essential amino acids) and non-gluten proteins (albumins and globulins, which often have more balanced amino acid profiles) (Adgunkar et al., 2023). Smaller grains might have a relatively larger contribution of proteins from the bran and germ (which are richer in lysine, arginine, and have higher proportions of some essential amino acids) as opposed to the endosperm storage proteins (Metcalfe et al., 2022).

CONCLUSIONS

According to the literature, smaller wheat grains (compared across different genotypes or conditions) tend to have higher protein content and consequently higher gluten and sedimentation values. However, in the present study these quality parameters did not strictly follow the expected trend by grain size. In particular, the medium-sized grains exhibited lower protein, gluten, and sedimentation values than anticipated (the highest values were observed in the large grain fraction, while the smallest grains showed intermediate levels). This may be due to unique patterns of protein accumulation as the grain develops in different positions on the spike within the same variety. It is plausible that grains developing in the central parts of the spike (which in our case might correspond to the large-size group) achieved both large size and high protein, whereas grains from other positions (making up the medium group) did not. Further detailed studies, sampling grains by both position and size, are needed to confirm this interpretation and to generalize the findings.

Despite the unexpected dip in protein and gluten for the medium group, the obtained results did confirm, in line with the literature, that starch accumulation is higher in larger grains and that protein concentration is relatively higher in smaller grains. We also observed that the content of certain essential amino acids such as methionine+cysteine, arginine, and valine decreased as TGW increased, whereas no significant change was observed in leucine, phenylalanine, and isoleucine levels in relation to grain weight. These findings suggest that grain size can influence not only the quantity of protein and starch in wheat, but also the quality of protein in terms of its amino acid composition.

In summary, this study highlights that even within a single wheat cultivar harvested under uniform conditions, there are notable differences in quality parameters between small, medium, and large seeds. Understanding these intra-varietal variations can be important for seed grading, milling, and nutritional evaluation. For instance, separating or blending grain fractions by size might be a strategy to tailor flour blends for specific purposes (high-gluten flour vs. high-starch uses) if such quality differences are consistent. Future research should explore the mechanisms behind these differences - especially the role of spike physiology and source-sink relationships in determining grain composition. Moreover, expanding the analysis to more varieties and growing conditions would indicate how universal these relationships are. Such knowledge could contribute to wheat breeding and post-harvest processing strategies aimed at optimizing both yield and grain quality.

REFERENCES

- Adgunkar, N. U., Padte, S., Vimal Raj, G. J., Govindaraju, K., & Kumar, S. (2023). Isolation, characterization, and utilization of wheat bran protein fraction for food application. *Journal of Food Science and Technology*, 60(2), 464–473. <https://doi.org/10.1007/s13197-022-05617-8>
- Aydoğan, S., Şahin, M., Akçacık, A. G., & Yakışır, E. (2014). Effect of different grain size on the quality of bread wheat. *Selcuk Journal of Agriculture and Food Sciences*, 1, 27–33.
- Boz, H., Gerçekaslan, K. E., Karaoğlu, M. M., & Kotancılar, H. G. (2012). Differences in some physical and chemical properties of wheat grains from different parts within the spike. *Turkish Journal of Agriculture and Forestry*, 36, 309–316. <https://doi.org/10.3906/tar-1102-41>
- Erbaş Köse, O. D., Mut, Z., Kardeş, Y. M., & Akay, H. (2013). Grain-bran quality parameters and agronomic traits of bread wheat cultivars. *Turkish Journal of Field Crops*, 28, 269–278. <https://doi.org/10.17557/tjfc.1336316>
- Esfandiari, E., & Abdoli, M. (2016). Wheat biofortification through zinc foliar application and its effects on wheat quantitative and qualitative yields under zinc deficient stress. *YYU Journal of Agricultural Science*, 26, 529–537.
- Food and Agriculture Organization of the United Nations (FAO). (2024). *Statistics Divisions of Food and Agriculture Organization of the United Nations (FAOSTAT)*. Rome.

- Fangmeier, A., Temmerman, L., Mortensen, L., Kemp, K., Burke, J., Mitchell, R., Oijen, M., & Weigel, H.-J. (1999). Effects on nutrients and on grain quality in spring wheat crops grown under elevated CO₂ concentrations and stress conditions in the European multiple-site experiment 'ESPACE-wheat'. *European Journal of Agronomy*, 10, 215–229. [https://doi.org/10.1016/S1161-0301\(99\)00012-X](https://doi.org/10.1016/S1161-0301(99)00012-X)
- Fowler, D. B. (2003). Crop nitrogen demand and grain protein concentration of spring and winter wheat. *Agronomy Journal*, 95, 260–265. <https://doi.org/10.2134/agronj2003.2600>
- García del Moral, L. F., Rharrabti, Y., Martos, V., & Royo, C. (2007). Environmentally induced changes in amino acid composition in the grain of durum wheat grown under different water and temperature regimes in a Mediterranean environment. *Journal of Agricultural and Food Chemistry*, 55(20), 8144–8151. <https://doi.org/10.1021/jf063094q>
- Gegas, V. C., Nazari, A., Griffiths, S., Simmonds, J., Fish, L., Orford, S., et al. (2010). A genetic framework for grain size and shape variation in wheat. *Plant Cell* 22, 1046–1056. doi: 10.1105/tpc.110.074153
- Labanauskas, C. K., Stolzy, L. H., & Handy, M. F. (1981). Protein and free amino acids in wheat grain as affected by soil types and salinity levels in irrigation water. *Plant and Soil*, 59, 299–316. <https://doi.org/10.1007/BF02184202>
- Mahdavi, S., Arzani, A., Maibody, S. M., & Kadivar, M. (2022). Grain and flour quality of wheat genotypes grown under heat stress. *Saudi Journal of Biological Sciences*, 29(10), 103417. <https://doi.org/10.1016/j.sjbs.2022.103417>
- Metcalfe, M. C., Estrada, H. E., & Jones, S. S. (2022). Climate-Changed Wheat: The Effect of Smaller Kernels on the Nutritional Value of Wheat. *Sustainability*, 14(11), 6546. <https://doi.org/10.3390/su14116546>
- Okur, Y., & Onel, S. (2024). Multi-year assessment of wheat quality parameters and climatic interactions: Implications for the commodity market. *Preprints*. <https://doi.org/10.20944/preprints202412.0045.v1>
- Reynolds, M. P., & Braun, H. J. (2022). *Wheat improvement, food security in a changing climate*. Springer Cham. <https://doi.org/10.1007/978-3-030-90673-3>
- Sahin, M.; Gocmen Akcacik, A.; Aydogan, S.; Ozer, E. Ekmeklik Bugday Tane Boyutunun Kalite Ozellikleri Uzerine Etkisi. *Anadolu Ege Tarimsal Arastirma Enstitusu Dergisi* 2013, 23, 1–8.
- Tatar, Ö., Çakalogulları, U., Aykut Tonk, F., İstipliler, D., & Karakoç, R. (2020). Effect of drought stress on yield and quality traits of common wheat during grain filling stage. *Turkish Journal of Field Crops*, 25, 236–244.
- Wang, K., & Fu, B. X. (2020). Inter-relationships between test weight, thousand kernel weight, kernel size distribution and their effects on durum wheat milling, semolina composition and pasta processing quality. *Foods*, 9(9), 1308. <https://doi.org/10.3390/foods9091308>
- Woggoner, W. (1969). Environmental manipulation of higher yields. In Eastin, J. D., Haskins, F. A., Sullivan, C. Y., & Van Bavel, C. H. M. (Eds.), *Physiological aspects of crop yield* (pp. 343–370). American Society of Agronomy.
- Yılmaz, H., Karataş, R., Demirel, F., Soysal, S., Türkoğlu, A., Yılmaz, A., & Çiftçi, V. (2024). Variations in protein, gluten, Zeleny sedimentation and yield of certain wheat (*Triticum aestivum* L.) cultivars under different climatic conditions. *Euphytica*, 220, 190. <https://doi.org/10.1007/s10681-024-03446-8>