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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Turkish Noodle (Erişte) Quality of Different Local Durum Wheat Varieties: Case Study of Lakes Region, Türkiye*

Farklı Yerel Durum Buğday Çeşitlerinin Erişte Kalitesi: Göller Bölgesi Örneği, Türkiye

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Abstract

Wheat flour noodles are a staple in the diets of many countries, and their popularity has increased in recent years. The main component of noodles is wheat flour; therefore, the qualitative attributes of noodles are predominantly dependent on the quality of wheat used in their production. This study aimed to evaluate and compare the quality of noodles made from ten different local durum wheat varieties (LDW) sourced from the Lakes Region of Türkiye. The study measured various parameters like moisture, ash, color, breaking strength, deformation, and texture profile analysis (TPA) of noodles made from LDW flours. Moreover, the optimum cooking time (OKT), cooking loss (CL), swelling volume (SV), water absorption (WA), and sensory attributes of noodles were assessed. Regarding moisture and ash content, the noodles were found to have values ranging from 6.76 to 10.51% and 2.29 to 2.77, respectively. The noodles had an average brightness of 87.24, a redness of 1.26, and a yellowness of 17.74. Ak Buğday, Ankara 98, and Gediz 75 varieties demonstrated higher levels of yellowness than the other varieties. The Kızıltan91, Çeşit1252, and Ak Buğday cultivars showed more resistance to breakage while lower levels of deformation. Significant effects (P<0.01) of LDW on the TPA of cooked noodles were identified. Sert Buğday and Kunduru varieties had the lowest OCT (10.29 min), while Ak Buğday and Kızıltan 91 varieties had the highest value (average 12.48 min). The CL and SV of cooked noodles varied from 7.85 (Ankara 98) to 10.39% (Sert buğday) and 110% (Burgaz) to 259.20% (Sert Buğday) respectively. The noodles with the highest SV, Sert Buğday and Gediz 75, also had higher WA. Ankara 98, with the lowest SV, had the lowest WA. The Burgaz and Kunduru cultivars were deemed unfavorable in terms of general acceptability. As a result, we can conclude that Hard Wheat and Gediz 75 durum wheat flours offer good noodle quality; thus, these varieties can be suggested for making handmade or commercial noodles.

Keywords: Wheat for pasta, Noodle texture, Cooking quality, Cooking loss

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Öz

Birçok ülkenin diyetinin önemli bir parçası olan buğday unu eriştelerinin son yıllarda popülaritesi artmıştır. Eriştenin ana bileşeni buğday unudur; bu nedenle erişte kalitesi büyük ölçüde üretiminde kullanılan buğdayın kalitesine bağlıdır. Bu çalışmanın amacı, Türkiye'nin Göller Bölgesi'nden temin edilen on farklı yerel durum buğdayı çeşidinden (YDB) üretilen eriştelerin kalitesini değerlendirmek ve karşılaştırmaktır. Çalışma, YDB unlarından yapılan eriştelerin nem, kül, renk, kopma mukavemeti, deformasyon ve tekstür profil analizi (TPA) gibi çeşitli parametrelerinin ölçülmesini içermektedir. Ayrıca, eriştelerin optimum pişirme süresi (OPS), pişirme kaybı (PK), hacim artışı (HA), su absorbsiyonu (SA) ve duyusal özellikleri değerlendirilmiştir. Eriştelerin nem ve kül değerleri sırasıyla %6.76-10.51 ve 2.29-2.77 arasında, ortalama parlaklık, kırmızılık ve sarılık değerleri ise 87.24, 1.26 ve 17.74 olarak bulunmuştur. Ak Buğday, Ankara 98 ve Gediz 75 çeşitleri diğer çeşitlere kıyasla daha yüksek sarılık değerleri göstermiştir. Kızıltan91, Çeşit1252 ve Ak Buğday çeşitleri kırılmaya karşı daha fazla direnç gösterirken deformasyon seviyeleri daha düşük olarak ölçülmüştür. YDB çeşitlerinin pişmiş eriştelerin TPA'leri üzerinde önemli etkileri ($P<0.01$) tespit edilmiştir. Sert Buğday ve Kunduru çeşitlerinin en düşük OPS (10.29 dk)'ne, Ak Buğday ve Kızıltan 91 çeşitlerinin ise en yüksek OPS (ortalama 12.48 dk)'ne sahip olduğu saptanmıştır. Pişmiş eriştelerin PK ve HA değerleri sırasıyla %7.85 (Ankara 98) ile %10.39 (Sert buğday) ve %110 (Burgaz) ile %259.20 (Sert Buğday) arasında değişmiştir. En yüksek HA'na sahip olan Sert Buğday ve Gediz 75 erişteleri aynı zamanda daha yüksek SA'na sahipken en düşük HA'na sahip Ankara 98 ise en düşük SA değeri göstermiştir. Burgaz ve Kunduru çeşitleri genel kabul edilebilirlik açısından en düşük puanları almışlardır. Sonuç olarak, Sert Buğday ve Gediz 75 durum buğdayı unları ile yapılan eriştelerin daha üstün kalite özellikleri gösterdikleri belirlenmiştir. Bu nedenle, bu çeşitler el yapımı veya ticari erişte yapımı için önerilebilir.

Anahtar Kelimeler: Makarnalık buğday, Erişte tekstürü, Pişme kalitesi, Pişme kaybı

1. Introduction

Wheat is a major cereal crop, with a global production of around 772 million tons (Anonymous, 2024a). Durum wheat (*Triticum durum or Triticum turgidum* subsp*. durum*) is the tenth most extensively cultivated cereal crop in the world, with a production of 40 million tons (Saini et al., 2023). Major durum wheat producers the European Union, Canada, Türkiye, Mexico, the United States, Algeria, Morocco, and Kazakhstan. Durum wheat production of Türkiye reached 4.3 million tons in 2023 (Anonymous, 2024b).

Different varieties of durum wheat are cultivated in Türkiye and worldwide, owing to variations in growing circumstances, soil properties, fertilization practices, environmental factors, climate, and genetic factors. The price of durum wheat is higher than that of bread wheat because it is a more valuable variety of wheat grown in specific parts of the world. In addition to its economic value, durum wheat is highly valued for its relatively high concentration of yellow pigments, low levels of lipoxygenase activity, higher protein content, and strong gluten. Durum wheat is the optimal raw material for manufacturing pasta products, including long and dried short-dried pasta, fresh and sheeted pasta, macaroni, noodles, and vermicelli. Food products other than pasta, such as couscous, flat bread (unleavened bread), bulgur, frekeh, durum wheat bread, and a puffed durum wheat ready-to-eat breakfast cereal are also made from durum wheat (Elias, 1995; Kezih et al., 2014; Hammami and Sissons, 2020; Labuschagne et al., 2023; Saini et al., 2023).

Noodles play an important role in Asian countries' daily diets. On the other hand, their global popularity has increased since they are easy to prepare, offer appealing sensory qualities, can be stored for a long time, are inexpensive, and can be cooked quickly and easily (Yazıcı et al., 2021).

Turkish noodle (erişte), which have made for years, also plays a significant role in Turkish cuisine. Noodles in Noodle Standard (TS-12950) are defined as a product that is dried, boiled, steamed, or ready for direct consumption by kneading the dough prepared after adding wheat flour, salt (such as sodium carbonate, potassium carbonate, and sodium phosphate), egg, and water, and processing it following by technique (TSE, 2003).

Flours from *Triticum aestivum* and *Triticum durum* wheat are commonly used in noodle production. Consequently, product quality depends primarily on the quality of the wheat used. The wheat should be clean and sound, with a high grain weight, uniform grain size, and hardness (Hou and Kruk, 1998; Yazıcı et al., 2021). In Türkiye, as in other parts of the world, modern varieties of *Triticum aestivum* and *Triticum durum* are generally used for food production. However, Türkiye is one of the first areas where wheat was cultivated, and it is the origin of the genes that are responsible for the local and ancient wheat varieties that have attracted a great deal of interest in recent years (Özkan and Gül, 2024).

Furthermore, in Türkiye, there is a growing number of Pioneer organizations, farmers, and newly settled communities that are cultivating local wheat cultivars (Yıldız and Özkaya, 2024). In their study, Durmaz and Aktaş (2023) concluded that local durum wheat varieties showed better characteristics in terms of plant height, thousand grain weight, peduncle length, biological yield, days to spike and protein ratio when compared to modern breeding varieties. They also identified numerous local varieties that have the potential to serve as a valuable gene source, particularly in research aimed at enhancing grain protein content and biological output.

Wheat flour significantly influences the quality attributes of noodles, including their surface appearance, texture, color, and cooking properties (Nagao, 1996). The primary factors used to evaluate the quality of noodle flour are the amount of ash, protein content and quality, color, damaged starch content, particle size and starchiness, and the rheological properties of the dough (Hou and Kruk, 1998). Noodles prepared from flours containing a significant quantity of damaged starch require a longer cooking time and experience reduced water penetration. As the quantity of solid substances released into the water during cooking rises, it of sticky noodles that have undesirable qualities for consumption (Moss et al., 1987). In noodle production, adding 1-2% salt strengthens the noodle dough and reduces the stickiness of the noodles (Bean et al., 1974).

Based on the most recent data (Anonymous, 2024c), Türkiye is the second-largest exporter of pasta in the world, following Italy. In addition to pasta, Türkiye has also started exporting noodles. Both products' exports have a significant impact on the national economy. Hence, it becomes essential to investigate the suitability of local durum wheat varieties for noodle production, as well as the technological quality of noodles made from these varieties, in order to enhance the overall quality of noodle production. Thus, the purpose of this study was to guide both domestic and international producers by examining the noodle quality of local durum wheat varieties.

The production of high-quality noodles is only possible with quality durum wheat varieties. Since the developing noodle sector needs to determine whether or not the varieties that are used in the manufacturing of pasta are suitable for the production of noodles in Türkiye, which is the leading producer of durum wheat in the world, to our knowledge, there have been no studies on the noodle quality of local durum wheat varieties cultivated in the Lakes region. Therefore, this study aimed to evaluate the suitability of durum wheat from the Göller Region, a prominent durum wheat producer in Türkiye, for noodle production by conducting noodle quality testing.

2. Materials and Methods

2.1. Materials

10 different local durum wheat samples obtained from Isparta, Burdur, and Afyonkarahisar provinces of the Lakes Region were used as material. Three varieties, namely Çeşit 1252, Gediz75, and Kızıltan91, were acquired from pasta companies, while the remaining seven varieties, including Ak Buğday, Ankara98, Burgaz, Durbel, Gökala, Kunduru, and Sert Buğday, were bought from local growers. In order to represent the whole wheat mass, about 10 kg of local wheat varieties were taken in accordance with the sampling method. These samples were then put in cotton bags and transported to the laboratory. Next, the impurities included in the wheat samples were effectively eliminated through the process of sieving and manual removal.

2.2. Tempering and milling of wheat samples

The tempering procedure involved the addition of water in accordance with the specified quantities outlined in AACC Method 26-95.01 (AACC, 2010), with the aim of reaching a moisture content of 16-17% in the wheat prior to milling. Cold tempering was carried out at room temperature for 48 hours, with stirring every 5 hours. Following the completion of the tempering procedure, the wheat samples were then ground into flour using a laboratory-grade flour milling equipment (Ekin Gıda, Ankara). After the milling process, the flours were stored in sealed packaging at ambient temperature for three weeks to allow maturation.

2.3. Noodle making method

Noodles were made by kneading 500 g of flour, 5 g of salt, and drinking water according to the amount specified on the farinograph for each type of durum wheat flour for ten minutes in a mixer (Hobart N50CE model, Hobart Corporation, USA). The dough was after that divided into 100 g equal portions, manually rolled, and allowed to rest in plastic bags at ambient temperature for 20 minutes. After resting, the dough was subjected to a preliminary thinning process with the help of a rolling pin. Subsequently, it was gradually thinned in a household noodle machine (Imperia, Italy) and kept at room temperature for 5 minutes to prevent sticking, then cut into noodle strips. The noodles were placed on perforated trays so they did not touch each other and dried at room temperature for 24 hours. The dried noodles were placed in glass jars and stored in the refrigerator at +4°C until further analysis.

2.4. Noodle analysis

The noodles' width, length, and thickness were measured using a digital caliper. Noodle samples were also analyzed for moisture (AACC Method, 44-01.01, AACC, 2010) and ash (AACC Method, 08-01.01, AACC, 2010). The colors of raw and cooked noodle samples were measured by colorimetry (Minolta CR 410, MinoltaCo Ltd., Tokyo, Japan) using Hunter L* (Lightness: Darkness L*=0 black, L*=100 white), a* (redness: +a*= red, - a*= green) and b* (yellowness: +b*=yellow, -b*=blue) color scales.

2.5. Determination of breaking strength and deformation of dried noodles

Breaking strength (N) and deformation (mm) of individual dried noodle strips were determined on a texture analyzer (TA.XT Plus, Stable Micro Systems Ltd., Godalming, Surrey, UK) using a 0.8 mm broad blade probe with a 50 kg load cell and a head speed of 1 mm s^{-1}. The breaking strength of the dried noodles was measured as the force (kg) required to break each strip of dried noodles.

2.6. Texture profile analysis (TPA) of cooked noodles

TPA of cooked noodles wasa was performed by using a texture analyzer (TA.XT Plus, Stable Micro Systems Ltd., Godalming, Surrey, UK) according to Park and Baik (2002), Khatkar, and Kaur (2018) with minor modifications. The noodle samples were cooked to their OCT, cooled with tap water for one minute, and filtered through a Buhner funnel. The water remaining on the surface of the noodle strips was gently removed with a paper towel, placed as a single strip on the table of the texture analyzer, and compressed twice using a 1.27 mm diameter sphere probe at a head speed of 2 mm s^{-1} for TPA. Hardness (g), adhesiveness (g.sec), springiness, cohesiveness, gumminess, chewiness, and resilience parameters were determined by TPA analysis.

2.7. Determination of optimum cooking time (OCT)

The OCT of the noodles was determined according to the AACC Method, 66-50.01 (AACC, 2010). According to this method, 10 g of noodle sample was added to 200 ml of distilled water boiling on the heating plate, and when it began to boil, the time with the help of a stopwatch. The samples were mixed with a glass drumstick in such a way that they were not damaged, and the loss of water during the analysis was compensated by the addition of boiling water. At 30-second intervals, a strip was taken and squeezed and crushed between 2 glass plates, and this process was continued until the white center disappeared in the middle of the noodles crushed between the glass plates. The time from the start was recorded as the OCT.

2.8. Determination of the cooking loss (CL)

25 g of dry noodles were added into 250 ml of boiling distilled water, the mouth of the beaker was covered with a watch glass, and the noodles were cooked until their OCT by stirring occasionally. At the end of the OCT, the beaker's contents were filtered through the Buhner funnel and cooked when the dripping from the funnel stopped. The noodles were placed back into the cooking vessel, washed with 90 ml of water, stirred gently, and filtered through the same funnel again. The cooking and washing water were combined, and some water was added to make the volume up to 350 ml. 50 ml of this mixture was taken into a pre-dried and tared beaker. After evaporation in a water bath, it was dried to constant weight in an oven at 98°C and weighed (Özkaya and Özkaya, 2005).

2.9. Determination of swelling volume (SV)

After the noodles were cooked, drained, and left for a few minutes, they were placed in a 250 ml measuring cylinder containing 150 ml of water, and the increase in the water level was recorded. The same method was applied to uncooked noodles. The SV was determined by dividing the water displacement of cooked noodles by the water displacement of an equal amount of uncooked noodle noodles by the water displacement of an equal amount of uncooked noodles (Özkaya and Özkaya, 2005; Khatkar and Kaur, 2018).

2.10. Determination of water absorption (WA)

25 g of dry noodles were added into 250 ml of boiling distilled water, and the beaker was covered with a watch glass. The beaker was covered with a watch glass, and the noodles were cooked until their OCT. At the end of the cooking time, the cooked and drained noodles were weighed after waiting for a few minutes and the water absorption (weight gain) was calculated in % by taking into account the uncooked weight (Özkaya and Özkaya, 2005). The WA is the difference in the weight of cooked noodles versus uncooked noodles, expressed as the percentage of weight of uncooked noodles.

2.11. Sensory analysis

The noodles cooked to the optimum cooking time and drained were evaluated by 10 panelists using a 5-point hedonic scale (1 point: I did not like it at all, 5 points: I liked it very much). In sensory analysis, the noodles were evaluated in appearance (pasty and stick together), odor, mouthfeel, taste/aroma, and overall acceptability.

2.12. Statistical analysis

The data reported are an average of three replications. The data obtained for all measured properties of the noodle samples were subjected to the Duncan multiple comparison test using analysis of variance (ANOVA) with the SPSS package program (SPSS 18.0 software for Windows).

3. Results and Discussion

3.1. Chemical properties of noodles

The moisture and ash content of noodles obtained from LDW flours are given in *Table 1*. When the mean values of moisture and ash contents were analyzed, it was determined that there were statistically significant differences between them (P<0.01).

Table 1. Moisture and ash values of noodles[1]

Durum Wheat Varieties	Moisture (%)	Ash (%)
Ak Buğday	8.16^{d}	2.41^{cd}
Ankara98	7.38^{e}	2.65^{ab}
Burgaz	9.58^{b}	2.69^{ab}
Çeşit1252	8.83^{c}	2.74^{a}
Durbel	9.53^{b}	2.64^{ab}
Gediz75	8.90^{c}	2.77^{a}
Gökala	8.45^{cd}	2.29^{d}
Kızıltan91	6.76^{f}	2.39^{cd}
Kunduru	10.51^{a}	2.52^{bc}
Sert Buğday	8.93^{c}	2.50^{bc}

[1.] The differences between the values shown with the same letter in the column are insignificant according to the 0.01 confidence limit.

The moisture content of the noodles ranged from 6.76% in the Kızıltan91 to 10.51% in the Kunduru. The variations in moisture content among the noodles may be attributed to their different amounts of water absorption. Water was added to each wheat flour in the noodle production process at the rate specified in the farinograph. However, all noodles meet the moisture content requirement, as they are below the maximum moisture level of 13% established in the TS 12950 (TSE, 2003) noodle standard. The findings in this study coincide with the results of Dirim and Koç (2019), which reported the moisture content of regular Turkish noodles as 9.69±0.92%.

The Gediz 75 exhibited the greatest ash value of 2.77%, while the Gökala had the lowest ash value of 2.29%. The noodle samples were found to be non-compliant with the TS 12950 noodle standard due to their ash values exceeding the specified ash limit of 1.0% for plain noodles. This is because the grinding process was carried out in a laboratory-type mill with 4 four rollers (2 crushing and two refining rollers), and the bran-endosperm separation could not be fully realized. It is possible to produce more refined flour with a reduced ash content and noodles that meet standards if the milling is done in commercial mills. that probably, the excessive amount of salt utilized in the preparation of the noodles is another factor that contributed to the high ash content of the noodles.

Although the moisture content of the noodles lined up with the results that were reported in the literature, the ash content was observed to be greater in comparison to the relevant literature (Eyidemir, 2006; Öztürk, 2007; Demir, 2008; Aydın, 2009; Ramya et al., 2015).

3.2. Physical properties of noodles

The noodle doughs were cut by hand into regular sizes after they had been rolled out to the desired thickness. In light of this, there was no significant variation between the values of the noodles' width, length, and thickness. The noodles' mean width, length, and thickness were measured as 6.02±0.02, 120.27±0.37, and 1.55±0.04, respectively.

3.3. Colors of raw and dried noodles

Color (L*, a*, b*) values of raw and dried noodles obtained from durum wheat flours are given in *Table 2*. There was a statistically significant difference between the color values of noodles (p<0.01). The raw nodules obtained from the Ak buğday variety had a brighter color to the other types, which aligns with the wheat's name (Ak buğday=White Wheat). Conversely, the noodles produced from the Gediz 75 type had the lowest brightness level. As the noodles lost water with drying, the samples became slightly dull and yellow. Compared to the remaining noodles, the Kunduru noodles had a higher water content, resulting in a diminished intensity of the yellow color. This can probably be attributed to the high water activity of the Kunduru sample. Due to the fact that there is an inverse correlation between the amount of water activity and the Hunter b levels. Specifically, the Hunter b values declined as water activity increased (Rhim and Hong, 2011).

Table 2. Colors of raw and dried noodles[1]

Durum Wheat Varieties	Raw			Dried		
	L*	a*	b*	L*	a*	b*
Ak Buğday	92.72[a]	2.12[a]	16.25[d]	88.42[c]	2.18[a]	20.50[b]
Ankara98	91.82[c]	1.05[d]	14.11[g]	89.09[b]	2.17[a]	21.38[a]
Burgaz	90.37[e]	1.26[c]	16.74[c]	83.88[h]	0.33[g]	18.19[c]
Çeşit1252	91.13[d]	1.28[c]	14.02[g]	86.31[f]	0.84[e]	16.18[e]
Durbel	91.09[d]	1.44[b]	17.53[b]	87.28[e]	1.02[d]	17.94[c]
Gediz75	89.61[f]	1.44[b]	19.41[a]	85.54[g]	1.06[d]	20.51[b]
Gökala	92.20[b]	1.44[b]	13.74[h]	88.01[cd]	1.42[c]	15.68[e]
Kızıltan91	92.26[b]	1.42[b]	14.65[f]	89.73[a]	1.81[b]	15.50[e]
Kunduru	90.56[e]	1.29[c]	15.74[e]	87.73[de]	0.72[f]	14.45[f]
Sert Buğday	91.19[d]	1.31[c]	15.84[e]	86.39[f]	1.00[d]	17.10[d]

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

One of the main criteria in evaluating the quality of durum wheat is the bright yellow color exhibited by pasta products, compared to their cooking characteristics and flavor (Aalami et al., 2007). Upon evaluating the impact of the tested durum wheats on the yellow color values of noodles, it was determined that the Ak Buğday, Ankara 98, and Gediz 75 varieties exhibited higher yellowness values than the others. Consequently, these varieties can be utilized in both pasta and noodle production. Besides this, it can be inferred from the high yellow color value that these kinds also have a high carotenoid content. The biological and nutritional value of grains with high levels of carotenoid pigments is enhanced by their provitamin activity, specifically vitamin A, as their antioxidant activity (Malchikov and Myasnikova, 2020).

The Ankara98 and Akbuğday noodles had a higher level of redness, as indicated by the a* value, in comparison to the other kinds. *L**, *a**, and *b** values of flours and noodles produced from these flours exhibit variation among different durum wheat cultivars, which can be attributed to the influence of environmental factors on kernel development. Similar to our results, L, a and b values of flours obtained from different Indian durum wheat varieties were reported (Kaur et al., 2015) to range from 90.92 to 92.25, 0.30 to 0.73 and 13.66 to 17.50, respectively.

3.4. Breaking strength and deformation of dried noodles

There were statistically significant differences ($p<0.01$) between the breaking stress and deformation values of the noodles (*Table 3*).

Table 3. Breaking strength and deformation of dried noodles[1]

Durum Wheat Varieties	Breaking stress (kg mm$^{2-1}$)	Deformation (mm)
Ak Buğday	4.98[a]	32.44[e]
Ankara98	4.37[b]	32.90[de]
Burgaz	3.78[bc]	33.06[de]
Çeşit1252	3.53[cd]	33.83[cd]
Durbel	3.06[d]	34.86[c]
Gediz75	2.35[e]	35.08[bc]
Gökala	1.53[f]	36.28[ab]
Kızıltan91	0.88[g]	36.31[ab]
Kunduru	0.78[g]	36.95[a]
Sert Buğday	0.46[g]	37.02[a]

[1] The differences between the values shown with the same letter in the same column are insignificant according to the 0.01 confidence limit.

The breaking stress values of the noodles were observed to vary between 0.46 kg mm^{2-1} (Kunduru) and 4.98 kg mm^{2-1} (Kızıltan 91). An inverse relationship was found between breaking stress and deformation. The samples displaying high breaking stress demonstrated low deformation values, whereas the samples with low breaking stress had high deformation values. Due to the fact that noodles are dried foods, they have a very long shelf life. However, this may cause breakage in the noodle during storage, transportation and sale. For this reason, it is desirable that the noodles have a firm and break-resistant texture. Hence, it can be suggested that Kızıltan91, Çeşit1252, and Ak Buğday cultivars having higher breaking resistance but lower deformation value is better appropriate for the production of noodles and pasta.

3.5. TPA of cooked noodles

Textural characteristics, such stickiness and firmness, play a crucial role in determining the quality of cooked pasta. A good pasta should maintain its firm structure, resist surface disintegration, and provide a satisfying chewy bite (Cubadda et al., 2007). TPA results of noodle samples are given in *Table 4*. The Gediz 75 noodle presented the highest hardness value, at 528.01 g. Following closely behind were Burgaz, Kızıltan91, Çeşit 1252, and Sert Buğday noodles, with hardness values of 510.85, 507.84, 507.74, and 505.64, respectively. Conversely, the Kunduru variety exhibited the least hardness, measuring 387.39 g. In contrast to the findings of our research, the firmness values of Indian durum wheat varieties were found to be lower (ranging from 2.33 to 4.31 N) in a study carried out by Kaur et al. (2015). The fact that the environment in which wheat is grown plays a significant role in determining the quality of noodles is demonstrated by this difference. The hardness of fresh cooked noodles is influenced by various elements, such as starch, damaged starch, protein, and moisture content (Tang et al., 2019). Hardness is negatively correlated with an increase in moisture content. As in the Kunduru example, the noodles showed a softer structure as the moisture content increased.

Table 4. Texture profile analysis of cooked noodles[1]

Durum Wheat Varieties	Hardness (g)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	Adhesiveness (g.s)
Ak Buğday	419.51^{d}	0.97^{ab}	0.69^{a}	295.30^{d}	287.38^{d}	0.53^{ab}	6.65^{d}
Ankara98	453.10^{c}	0.96^{ab}	0.71^{a}	317.13^{c}	305.47^{c}	0.50^{ab}	11.95^{c}
Burgaz	510.85^{b}	0.97^{ab}	0.69^{a}	335.37^{b}	327.48^{b}	0.41^{b}	8.04^{d}
Çeşit1252	507.74^{b}	0.96^{ab}	0.66^{a}	302.18^{d}	290.29^{d}	0.47^{ab}	10.83^{c}
Durbel	444.87^{c}	1.16^{a}	0.69^{a}	334.94^{b}	396.21^{a}	0.59^{a}	6.83^{b}
Gediz75	528.01^{a}	0.69^{bc}	0.69^{a}	357.36^{a}	346.46^{b}	0.49^{ab}	9.16^{d}
Gökala	452.56^{c}	0.75^{bc}	0.75^{a}	347.74^{a}	333.90^{b}	0.59^{a}	12.37^{c}
Kızıltan91	507.84^{b}	0.74^{bc}	0.74^{a}	346.22^{a}	327.75^{b}	0.59^{a}	18.94^{b}
Kunduru	350.38^{e}	0.70^{bc}	0.70^{a}	271.53^{e}	264.70^{e}	0.48^{ab}	7.86^{d}
Sert Buğday	505.64^{b}	0.66^{c}	0.66^{a}	320.67^{c}	300.17^{c}	0.39^{b}	23.79^{a}

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

The Durbel variety displayed the lowest springiness value of 0.66, while the hard wheat variety displayed the highest springiness value of 1.16. There was no significant difference in the cohesiveness of the noodles. In the case of gumminess, Kunduru has shown the lowest value (271.53), while Gediz 75 (357.36), Gökala (347.74), and Kızıltan 91 (346.22) have shown higher values for gumminess. Chewiness varied between 396.21 and 264.70. The chewiness of the Kunduru sample was found to be the lowest. The resilience of the noodles varied only slightly. The noodle samples of the Ak Buğday variety had the lowest adhesiveness (g.s.) compared to the noodle samples of the Sert Buğday variety, which had the maximum adhesiveness. The cohesiveness, springiness, chewiness and adhesiveness results are by those reported by Kaur et al. (2015).

3.6. Cooking quality of noodles

Cooking quality is the primary characteristic consumers value greatly in durum wheat pasta and noodles. *Table 5* presents the OCT, CL, SV, and WA of noodles. Statistical differences were found between the OCT of noodles

($p<0.01$). When the OCT of the noodles obtained from durum wheat flours was analyzed, it was observed that Sert Buğday and Kunduru varieties had the lowest value (10.29 min). In comparison, Ak Buğday and Kızıltan 91 varieties had the highest values (12.49 min) and (12.47 min), respectively. These OCTs are higher than those reported (Kaur et al., 2015) for the noodles prepared from Indian durum wheat flour. The difference in the OCTs of LDW flour noodles can be attributed to genetic and environmental factors.

Table 5. OCT, CL, SW, and WA noodles[1]

Durum Wheat Varieties	OCT (Min)	CL (%)	SV (%)	WA (%)
Ak Buğday	12.49[a]	8.12[cd]	190.37[bcd]	149.62[def]
Ankara98	12.19[b]	7.85[d]	110.00[e]	130.85[g]
Burgaz	11.18[d]	8.49[bcd]	150.00[d]	139.89[fg]
Çeşit1252	11.24[d]	8.76[bcd]	218.50[ab]	174.32[b]
Durbel	11.87[c]	8.32[cd]	200.00[bc]	150.65[de]
Gediz75	11.45[d]	9.60[ab]	232.57[ab]	184.02[a]
Gökala	11.23[d]	8.51[bcd]	196.67[bc]	160.70[c]
Kızıltan91	12.47[a]	8.57[bcd]	170.00[cd]	149.07[ef]
Kunduru	10.87[e]	9.21[bc]	152.20[d]	159.23[cd]
Sert Buğday	10.29[e]	10.39[a]	259.20[a]	189.01[a]

[1]The differences between the values shown with the same letter in the same column are insignificant according to 0.01 confidence limit.

[2]: OCT: Optimum cooking time, [3]CL: Cooking loss, [4]SV: Swelling volume, [5]WA: Water absorption

The CL is widely recognized as a significant determinant of pasta quality, exerting a notable influence on consumer approval. The significant cooking loss indicated a limited cooking tolerance and excessive stickiness of noodles, which is generally undesirable in noodle production. The CL values exhibited a range of 7.85 to 10.39%. The Ankara 98 noodle had the lowest CL, whereas the Sert buğday noodle demonstrated the highest CL. The Turkish noodle standard (TS 12950, TSE, 2003) states that the quantity of substance that should be lost during cooking, also known as CL, should not exceed 10%. In light of this, all other types of noodles, except Sert Buğday noodles, are by the standard in terms of CL. It is desirable that the amount of substances that pass into the water in the noodles be low and that the noodles keep their shape without falling apart during cooking. Thus, it can be concluded that all types of noodles, except Sert Buğday, exhibit favorable qualities about this characteristic. However, lower CL 6.0 to 6.7% and 5.65 to 7.10% were reported by Abuhammad et al. (2012) and Evlice (2022), respectively, for durum wheat pasta. Meanwhile, Deng et al. (2017) reported similar CL results (ranging from 8.9 to 10.7%) for whole wheat spaghetti among the 36 durum genotypes. The observed disparity in CL can be attributed to variations in the quantity and quality of gluten in durum wheat varieties. A negative correlation exists between the firmness of the noodles and the quantity of substances released into the water during the cooking process (Petitot et al., 2010). The variations in nature, genotype, quantity, and quality of gluten proteins and the drying process could account for the disparities observed in our study.

A large volume increase in noodles while cooking is desirable. A low volume increase value means the noodles absorb little water during cooking, resulting in a complex product (Bhattacharya et al., 1999). Significant statistical differences were observed in the SV of the noodles ($p<0.01$). The SV values showed a range from 110% (Burgaz) to 259.20% (Sert Buğday). According to quality assurance laboratories of numerous noodle manufacturers, a high-quality noodle must absorb an adequate amount of water throughout the cooking process in order to achieve a minimum mass gain of 100% (Hatcher, 2010). Therefore, based on the fact that all of the studied noodles had a SV exceeding 100%, we can infer that it is feasible to manufacture high-quality noodles using all durum wheat varieties investigated in our study. Dirim and Koç (2019) found a considerably greater SV (267.50%) in comparison to our study. The variations in Turkish noodle formulas could be the cause of the discrepancies in the results. The presence of eggs in noodle production may affect the volume increase. By incorporating eggs into the noodle formulations examined in our study, it is potentially possible to produce noodles with an increased SV, mainly due to the fact that the addition of egg albumin protein enhances the cooking quality of noodles, ensuring a firm texture and reinforcing the network that retains the starch while cooking (Khouryieh et al., 2006).

Regarding the WA, the values varied between 130.85 and 189%. Simultaneously with the SV, the Sert Buğday and Gediz 75 noodles, which had the highest SV, showed more WA. Conversely, the Ankara 98, which had the lowest SV, revealed the lowest WA. WA is influenced by factors such as wheat's protein content and cooking time. Nevertheless, certain writers have reported water absorption levels comparable to or greater than the data we obtained. For instance, pasta samples prepared from 24 durum wheat genotypes (Evlice, 2022) showed values ranging from 197 to 274%, higher than ours. Differences in WA values can be attributed to variations in genotypes and disparities in the methods of noodle and pasta production and drying. WA, which refers to the percentage increase in weight during cooking, is a crucial factor for noodle manufacturers when selling noodles that are either parboiled or fresh. A noodle that can absorb a more significant amount of water during a specific cooking period while still retaining its desired textural qualities will be considered a more attractive and more profitable product (Hou et al., 1998). Based on this, we can conclude that Sert Buğday and Gediz 75 durum wheat flours, with their high WA and SV, offer good noodle quality and have significant potential for use in fresh noodles.

3.7. Sensory analysis of noodles

The findings obtained as a result of sensory evaluation of the noodle samples by the panelists are given in *Figure 1*.

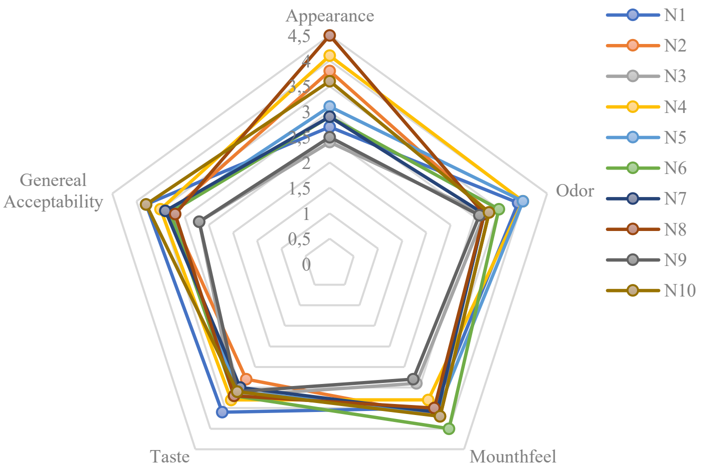

Figure 1. Sensory ratings for the noodles
N1: Ak Buğday, N2: Ankara98, N3: Burgaz, N4: Çeşit1252, N5: Durbel, N6:Gediz75, N7: Gökala, N8:Kızıltan91, N9: Kunduru, N10: Sert Buğday

Upon comparing the samples based on their appearance, it was found that the Burgaz variety had the lowest value of 2.40, followed by Kunduru with a value of 2.50. However, there was no significant statistical difference between the two. Conversely, the Kızıltan 91 variety had the greatest appearance value of 4.50. The low appearance values of the noodle samples made from the flours derived from Burgaz and Kunduru wheat varieties can be attributed to fragmentation, an undesirable outcome that occurs during the cooking process. The noodles made from Variety 1252, Durbel, and Ak Buğday flours were the most preferred in terms of odor. Durbel achieved the highest grade in mouthfeel, while Burgaz and Kunduru obtained low scores in this aspect. The kind of white wheat was the most favored in terms of taste. The Burgaz and Kunduru cultivars received low ratings in terms of overall acceptability. There was no significant disparity in the overall acceptability ratings of other variants.

According to TS 12950, noodles should have a unique taste, smell, and color before and after cooking. Additionally, they must be devoid of bitter, sour, moldy, or any foreign tastes. Furthermore, noodles should be free from visible foreign matter and odors and not be dirty or damaged (TSE, 2003). This led to the conclusion that except Kunduru and Burgaz, other tested varieties can produce noodles that meet TSE standards.

4. Conclusions

Durum wheat products have been experiencing increasing demand around the world. Noodles are one of these products. Wheat flour is the primary raw material for Turkish noodles (erişte). Therefore, it is important to study the suitability of locally grown Durum wheat varieties for noodle production to facilitate the growth of the noodle industry and enhance both domestic and international trade. Based on this, some physical, chemical, and technological qualities of local durum wheat varieties grown in the Lakes Region of Türkiye were revealed (results are not given within the scope of this study), and noodle quality was tested by making noodles.

Consequently, it was concluded that the flours derived from Sert Buğday and Gediz 75 wheat varieties exhibited favorable protein content, grain hardness, grain size, wet gluten, and gluten index values (specific results of these values were not provided in this study). Additionally, the noodles made from these flours demonstrated an excellent volume increase and water absorption values, offered good noodle quality, and had significant potential for use in Turkish noodle (erişte) production. However, further studies can be conducted to determine whether these varieties are suitable for using other durum wheat products, such as pasta.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Gül, H.; Design: Gül, H., Öztürk, A.; Data Collection or Processing: Gül, H., Öztürk, A.; Statistical Analyses: Gül, H., Öztürk, A.; Literature Search: Gül, H., Öztürk, A.; Writing, Review and Editing: Gül, H.

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