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Research Article

Some quality characteristics of selected durum wheat (*Triticum durum*) landraces

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Abstract: Durum wheat (*Triticum durum*) is primarily used for the production of high-quality pasta products because of its certain superior characteristics. Wheat landraces are locally adapted diverse populations evolved through natural selection and are invaluable genetic resources for breeding programs. The search for new genetic resources all around the world has been underway to develop high-quality durum wheats. The purpose of this study was therefore to determine the pasta quality-associated characteristics of 12 durum wheat landraces (Bağacak, Beyaziye, İskenderiye, Sorgül, Karakılçık, Beyaz Buğday, Ağ Buğdayı, Bintepe, Havrani, Çalıbasan, Hacı Halil, and Akçakale) compared to 2 well-established high-quality durum wheat cultivars, Kyle and Zenit. Protein content and quality, pigment content, activities of oxidative enzymes (lipoxygenase, polyphenol oxidase, and peroxidase), kernel size, and endosperm vitreousness were measured as the major quality parameters. The landraces had significant differences ($P < 0.05$) in their quality characteristics. Of the landraces, Akçakale, Havrani, and Çalıbasan were found to be quite promising for the processing of so-called al dente cooking pasta products, as judged by their elevated protein quantity and gluten quality. With respect to pigment content and oxidative enzymes that are central to the bright yellow color of pasta products, however, the landraces Havrani, Hacı Halil, and Sorgül were found to have great potential. In brief, several landraces have potential for high-quality pasta processing, while a few others can be used for breeding purposes.

Key words: Durum, landrace, macaroni/pasta, quality, wheat

Introduction

Durum wheat (*Triticum durum*) is preferred for the production of pasta or macaroni products, mainly because of its elevated level of yellow pigments and appropriate protein and gluten characteristics (Hoseney 1994; Bushuk 1998; Troccoli et al. 2000). It has been well established in durum wheat that protein quantity and gluten quality are widely responsible for the so-called al dente pasta cooking characteristics, whereas yellow pigments and such oxidative enzymes as lipoxygenase (LOX), polyphenol oxidase (PPO), and peroxidase (POD) are effective on the color of pasta products (Troccoli et al. 2000; Aalami et al. 2007). In addition to color and protein characteristics, kernel size and vitreousness are also important in durum wheat quality, as they are strongly related to semolina yield, bright yellow appearance of semolina,

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and cooking properties of pasta products (Hoseney 1994; Bushuk 1998; Troccoli et al. 2000; Dziki and Laskowski 2005).

The gluten quality of durum wheat, i.e. suitability for pasta processing, is commonly evaluated by sodium dodecyl sulfate (SDS) sedimentation volume and gluten index (GI) tests, whereas specific gliadin and glutenin proteins associated with gluten quality are respectively determined by acidic polyacrylamide gel electrophoresis (A-PAGE) and SDS polyacrylamide gel electrophoresis (SDS-PAGE) techniques (Feillet et al. 1989; Kovacs et al. 1995; Porceddu et al. 1998; Pena 2000, Sissons et al. 2005; Cubadda et al. 2007; Sakin et al. 2011a, 2011b). Of the gliadin proteins, γ-gliadin 45, genetically linked with LMW-2 glutenins, is highly correlated with al dente cooking characteristics of pasta, whereas γ-gliadin 42, genetically linked with LMW-1 glutenins, is associated with poor pasta-cooking characteristics (Feillet et al. 1989; Pogna et al. 1990; Troccoli et al. 2000; D'Ovidio and Masci 2004; Edwards et al. 2007). It is therefore essential that durum wheat genotypes with high protein content accompanied by γ-gliadin 45/LMW-2 proteins be used in order to obtain al dente cooking pasta products (Troccoli et al. 2000; Sakin et al. 2011a, 2011b). For the production of pasta goods with bright yellow color, however, wheat genotypes that are high in yellow pigments but low in oxidative enzymes should be utilized (Aalami et al. 2007; Sakin et al. 2011b). Indeed, the search for new genetic resources has been underway all over the world in order to develop high-quality durum wheat genotypes.

Turkey possesses rich genetic resources and suitable ecological regions for durum wheat production (Şehirali and Özgen 1987). In addition to registered cultivars, many durum wheat landraces have been grown to some extent in the rural areas of Turkey. However, limited research has been conducted on the specific gliadin and glutenin proteins (Eser 1996; Sakin et al. 2011b) or the yellow pigments and oxidative enzymes (Pekin and Çakmaklı 1987; Coşkun and Ercan 2003; Sakin et al. 2011b) of durum wheat genotypes grown in Turkey. Altıntaş et al. (2008) reported that the genetic diversity of commonly grown registered durum wheat cultivars of Turkey was too narrow, since the great majority of the cultivars were bred from CIMMYT germplasm. Other researchers (Dreisigacker et al. 2004; Karagöz and Zencirci 2004; Zencirci and Karagoz 2005) reported that Turkish wheat landraces host a broad genetic diversity with unique and markedly different traits. Those data imply that the narrow genetic base of durum wheat in Turkey could be broadened using local landraces. It is well known that landraces are locally adapted diverse populations evolved through natural selection and that they are invaluable genetic resources contributing to many breeding programs around the world because of their homozygous nature with heterogeneous agronomic and quality traits (Allard and Bradshaw 1964; Feldman and Sears 1981; Hart 2001; Jones et al. 2008; Newton et al. 2010). The purpose of this study was therefore to investigate the pasta quality-associated characteristics of selected Turkish durum wheat landraces compared to 2 well-established high-quality durum wheat cultivars.

Material and methods

Materials

A total of 14 durum wheat genotypes (12 landraces and 2 registered cultivars) were included in the study. Durum landraces (Bağacak, Beyaziye, İskenderiye, Sorgül, Karakılçık, Beyaz Buğday, Ağ Buğdayı, Bintepe, Havrani, Çalıbasan, Hacı Halil, and Akçakale) were obtained from various institutions in Turkey (Field Crops Department of Çukurova University, Adana; Aegean Agricultural Research Institute, İzmir; and Southeast Agricultural Research Institute, Şanlıurfa). Of the registered durum cultivars, Kyle, a Canadian wheat cultivar well known for its superior pasta-cooking quality, was obtained from the Semiarid Prairie Agricultural Research Center, Canada, whereas Zenit, a distinguished wheat of Italian origin known for its prominent yellow pigment content, was obtained from the Southeast Agricultural Research Institute, Şanlıurfa, Turkey. The landraces and registered cultivars were grown in the experimental field of the Soil and Water Research Institute, Tokat, Turkey, during the growth years of 2007 and 2008. Marquis wheat, used as the A-PAGE standard, was obtained from the Central Research Institute of Field Crops, Ankara, Turkey. Kyle or Avonlea wheat that was used as a control for the γ-gliadin 45 protein was acquired from the Semiarid Prairie Agricultural Research Center, Canada.

Methods

All quality measurements were carried out using milled samples on a laboratory mill to pass through a 1.0-mm screen (Sakin et al. 2011a, 2011b). The moisture content of the wheat was determined by oven drying at 130 °C for 1 h by AACC method 44-15A (AACC 2000), and all analytical results were corrected to 14% moisture basis. The protein content of the wheat was assayed through the Kjeldahl procedure (N × 5.7) by AACC method 46-10. Gluten index (GI) was determined using the Glutomatic System (Perten Instruments, Sweden) according to AACC method 38-12A. SDS sedimentation volumes were measured by AACC method 56-70, and specific sedimentation volumes were calculated by dividing the SDS sedimentation volumes by the protein contents.

Yellow-colored pigment (mainly carotenoid) contents of the wheat were assayed using their water-saturated n-butanol extracts with spectroscopic measurements at 435.8 nm by AACC method 14-50. LOX activities were determined by the spectroscopic measurement of the conjugated diene formation upon the reaction of wheat extracts with linoleic acid substrate as described by Sakin et al. (2011a, 2011b). One unit of LOX activity (EU) was described as 1.0 unit min^{-1} change in the absorbance under the assay conditions and reported as EU g^{-1} wheat. PPO activities were determined through the method of Coseteng and Lee (1987) as slightly modified by Aalami et al. (2007), where color changes in the mixture of wheat extract-catechol substrate were monitored at 420 nm. One unit of PPO activity was described as 0.1 unit min^{-1} change in the absorbance under the assay conditions and reported as EU g^{-1} wheat. POD activities were measured according to the method of Aparicio-Cuesta et al. (1992) as slightly modified by Aalami et al. (2007), where colored product formation upon reaction of wheat extracts with *o*-dianisidine substrate in the presence of hydrogen peroxide was monitored at 460 nm. One unit of POD activity was described as 1.0 unit min^{-1} change in the absorbance under the assay conditions and reported as EU g^{-1} wheat.

Wheat genotypes were screened for γ-gliadin 42 or γ-gliadin 45 proteins using the A-PAGE technique as described originally by Bushuk and Zillman (1978) and later modified by Khan et al. (1985) and Köksel et al. (2000). For this purpose, 5 kernels were randomly selected from each genotype and ground separately using a mortar and pestle. Each ground kernel was transferred to a 2-mL centrifuge tube containing about 3-fold 70% aqueous ethanol, which was then vortexed thoroughly, left at room temperature for 30 min with intermittent vortexing (10-min intervals) for protein extraction, and centrifuged (>10,000 rpm for 10 min) to obtain a clear supernatant. Upon appropriate pretreatments, the extracts were loaded onto a precast A-PAGE system, run at 15 °C for 3-4 h at 500 V, stained with Coomassie Brilliant Blue R-250 dye preparation, and then evaluated as described by Bushuk and Zillman (1978) and Khan et al. (1985). For the identification of the gliadin proteins, Marquis wheat was used as the standard, whereas Kyle or Avonlea wheat was used as a control for γ-gliadin 45 protein.

Grain physical properties of thousand-kernel weight and kernel vitreousness were respectively determined as per Köksel et al. (2000) and Sakin et al. (2011b).

The data obtained by the randomized complete design with 3 replications were subjected to analysis of variance (ANOVA). Whenever the differences were significant ($P < 0.05$), Duncan's multiple range test was applied to separate the means.

Results

Protein content and gluten quality

Protein contents of the genotypes ranged from 10.7% to 16.8% with a mean of 13.1%, and differences were statistically significant ($P < 0.05$) (Table 1). With the exception of İskenderiye, Sorgül, Beyaz Buğday, and Bintepe, the landraces accumulated quite high levels of protein. Protein quality data for the genotypes, which differed significantly ($P < 0.05$), are listed in Table 1. SDS sedimentation and specific sedimentation volumes of the genotypes ranged from 20.5 to 38.0 mL (mean: 25.7 mL) and from 1.46 to 3.04 mL (mean: 1.99 mL), respectively, whereas high-quality cultivars Zenit and Kyle had SDS sedimentation and specific sedimentation volumes of 28.4 and 27.3 mL and of 2.43 and 2.17 mL, respectively. The landraces were also screened for the

Table 1. Protein content and gluten quality of selected Turkish durum wheat landraces[a].

Wheat genotype	Protein content (N × 5.7; %)		Sedimentation volume (mL)		Specific sedimentation volume (mL)		Gluten index		γ-Gliadin type
Bağacak	11.8	*ab**	20.5	*a**	1.74	*a-d**	61	*e**	γ-42
Beyaziye	14.9	*cde*	21.8	*ab*	1.46	*a*	42	*a-e*	γ-45
İskenderiye	11.0	*a*	20.5	*a*	1.86	*bcd*	38	*a-e*	γ-45
Sorgül	11.3	*ab*	21.3	*a*	1.88	*cde*	51	*cde*	γ-45
Karakılçık	13.7	*a-d*	21.5	*a*	1.58	*abc*	55	*de*	γ-45
Beyaz Buğday	10.7	*a*	26.0	*bc*	2.43	*f*	21	*ab*	γ-45
Ağ Buğdayı	15.0	*cde*	27.2	*cd*	1.85	*bcd*	32	*a-d*	γ-42
Bintepe	11.4	*ab*	21.3	*a*	1.87	*bcd*	26	*abc*	γ-42
Havrani	15.7	*de*	31.8	*de*	2.02	*de*	44	*a-e*	γ-45
Çalıbasan	16.8	*e*	32.8	*e*	1.95	*de*	41	*a-e*	γ-45
Hacı Halil	14.1	*b-e*	21.3	*a*	1.51	*ab*	47	*b-e*	γ-42
Akçakale	12.5	*abc*	38.0	*f*	3.04	*g*	96	*f*	γ-45
Zenit	11.7	*ab*	28.4	*cde*	2.43	*f*	50	*cde*	γ-45
Kyle	12.6	*abc*	27.3	*cd*	2.17	*f*	65	*e*	γ-45
Range	*10.7-16.8*		*20.5-38.0*		*1.46-3.04*		*21-96*		-
Mean	*13.1*		*25.7*		*1.99*		*47.8*		

[a]Values are based on 14% moisture basis.
*Different letters in a column indicate significant difference (P < 0.05).

presence or absence of γ-gliadin 42 and γ-gliadin 45 proteins. Of the 12 landraces, 8 genotypes possessed the γ-gliadin 45 protein associated with improved pasta-cooking quality, whereas 4 genotypes contained the γ-gliadin 42 protein linked with poor pasta-cooking characteristics. Typical A-PAGE gel pictures of 2 landraces are given in the Figure.

Pigment content and activities of oxidative enzymes

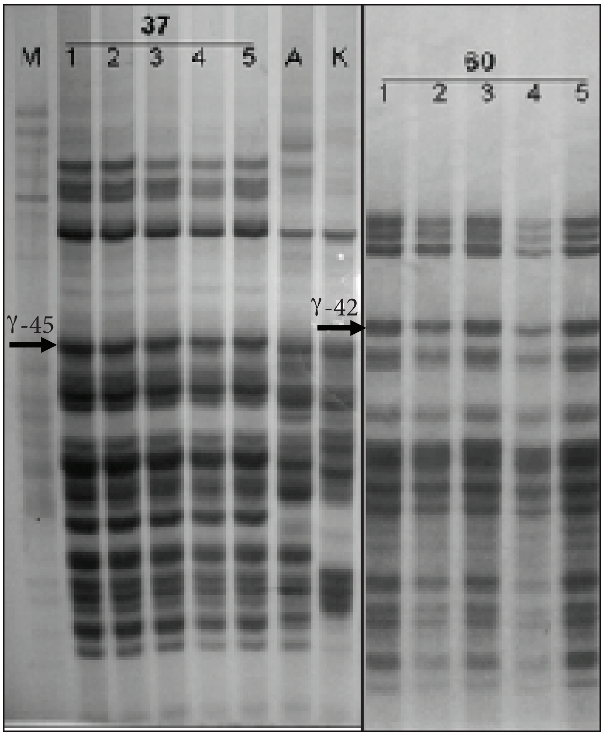
Yellow pigment contents and activities of the oxidative enzymes (LOX, PPO, POD) are listed in Table 2. Pigment contents of the genotypes ranged from 3.67 to 8.37 mg kg^{-1} with a mean of 5.53 mg kg^{-1}. Cultivar Zenit, a well-known high-pigment cultivar of Italian origin (Sakin et al. 2011b), contained the highest level of pigment (8.37 mg kg^{-1}) in this study. The activity of the LOX, an enzyme responsible for color-bleaching in pasta products (Borrelli et al. 1999, 2003; Troccoli et al. 2000; Aalami et al. 2007), ranged from 21.4 to 37.4 EU g^{-1} with a mean of 27.5 EU g^{-1} (Table 2). In terms of PPO and POD enzymes, which cause darkening of pasta products through the oxidation of phenolic substances (Taha and Sagi 1987; Fraignier et al. 2000; Aalami et al. 2007), the genotypes had activities ranging from 7.5 to 12.8 EU g^{-1} and from 64.6 to 133.4 EU g^{-1}, respectively (Table 2).

Kernel physical properties

The thousand-kernel weights and endosperm vitreousness of the wheats are presented in Table 2. Thousand-kernel weights of the genotypes ranged from 42.3 to 56.2 g with a mean of 48.9 g, whereas endosperm vitreousness varied between 92.5% and 99.3% with a mean of 97.6%.

Discussion

Durum wheat protein content and gluten characteristics have a decisive role in pasta-cooking properties (Feillet et al. 1989; Bushuk 1998; Troccoli et al. 2000). For the production of high-quality pasta products, durum wheat is generally expected to contain about 13% protein (Özkaya and Özkaya 1993; Hoseney 1994; Elgün and Ertugay 1995). In this study, protein contents of the genotypes were found to vary



(a) (b)

Figure. Selected A-PAGE gel pictures of durum wheat landraces: (a) İskenderiye, (b) Ağ Buğdayı (M = Marquis as A-PAGE standard, A = Avonlea as control, K = Kyle as control).

from 10.7% to 16.8% (Table 1). Other researchers (Genç et al. 1993; Sözen and Yağdı 2005; Sakin et al. 2011a, 2011b) reported protein levels ranging from 10.9% to 13.8% for Turkish durum wheat genotypes grown in different environmental conditions. It is noteworthy that the landraces Beyaziye, Ağ Buğdayı, Havrani, Çalıbasan, and Hacı Halil accumulated quite high levels (>14%) of protein.

The viscoelastic and cohesive nature of gluten proteins, i.e. gluten quality, is to a large extent genetically controlled (Payne et al. 1982; Bushuk 1998; Porceddu et al. 1998; Troccoli et al. 2000). It has been widely recognized that SDS sedimentation volume is influenced by both protein content and gluten quality, while specific sedimentation volume, which is the ratio of SDS sedimentation volume to protein content, was mostly affected by gluten quality (Cubadda et al. 2007; Sakin et al. 2011b). In this study, SDS sedimentation and specific sedimentation volumes of the genotypes ranged from 20.5 to 38.0 mL and from 1.46 to 3.04 mL (Table 1). In other studies, SDS sedimentation volumes of durum wheat genotypes grown in Turkey were determined to vary between 19.5 and 31.3 mL (Sözen and Yağdı 2005) and 17.3 and 28.7 mL (Sakin et al. 2011b) with specific sedimentation volumes between 1.60 and 2.52 mL (Sakin et al. 2011b). It is apparent that the landraces Beyaz Buğday, Havrani, Çalıbasan, and especially Akçakale were of comparable protein quality to Zenit and Kyle. As for GI, which somewhat reflects gluten quality (Cubadda et al. 2007; Edwards et al. 2007), the genotypes had values varying from 21 to 96 with an average of 47.8 (Table 1). Among the landraces, Akçakale, Bağacak, and Karakılçık had GI values comparable to those of Kyle and Zenit. With few exceptions, specific sedimentation volumes and GI values of the genotypes showed a similar trend (Table 1), which was also observed in durum wheat by Pena (2000) and Cubadda et al. (2007).

The relationship between γ-gliadin type and certain gluten quality parameters are presented in Table 3. Although mean protein contents of the landraces with γ-gliadin 45 and 42 were quite similar (13.3% vs. 13.1%), the landraces containing γ-gliadin 45 demonstrated higher mean SDS sedimentation volume (26.7 mL vs. 22.6 mL), specific sedimentation volume (2.03 mL vs. 1.74 mL), and GI values (48.5 vs. 41.7). These results are in agreement with the previous findings that durum wheats carrying γ-gliadin 45 protein were better suited for pasta products with superior cooking quality (Nachit et al. 1995; Pena 2000; Edwards et al. 2007; Sakin et al. 2011b). Overall assessment of protein content, SDS sedimentation and specific sedimentation volumes, GI, and γ-gliadin type indicate that Akçakale, Havrani, and Çalıbasan landraces are quite promising for high-quality pasta production.

The color of pasta products is mainly influenced by yellow-colored pigments and such oxidative enzymes as LOX, PPO, and POD (Kruger and Reed 1988; Troccoli et al. 2000; Coşkun and Ercan 2003; Aalami et al. 2007). For the production of bright yellow pasta products, durum wheats with high pigment content and low oxidative enzyme activity are required (Aalami et al. 2007; Sakin et al. 2011b). It is generally reported that the pigment contents of durum wheats fluctuate between 4 and 8 mg kg^{-1} (Köksel et al. 2000; Troccoli et al. 2000). Of the

Table 2. Physical properties, pigment contents, and oxidative enzymes of selected Turkish durum wheat landraces[a].

Wheat genotype	Thousand-kernel weight (g)		Kernel vitreousness (%)		Pigment content (mg kg^{-1})		Lipoxygenase (LOX) activity (EU g^{-1})		Polyphenol oxidase (PPO) activity (EU g^{-1})		Peroxidase (POD) activity (EU g^{-1})	
Bağacak	52.1	*c-f**	96.6	*b**	5.27	*cde**	28.2	*ef**	9.7	*bc**	110.4	*b-e**
Beyaziye	47.7	*bc*	98.5	*bcd*	5.11	*c*	25.3	*cd*	9.2	*bc*	114.3	*b-e*
İskenderiye	49.9	*cde*	98.2	*bcd*	5.45	*e*	33.1	*h*	12.8	*e*	133.4	*de*
Sorgül	53.4	*ef*	99.3	*d*	5.98	*g*	24.2	*abc*	10.3	*cd*	107.1	*bcd*
Karakılçık	42.3	*a*	99.2	*cd*	5.39	*de*	30.2	*fg*	11.3	*d*	117.8	*cde*
Beyaz Buğday	55.4	*f*	97.0	*bcd*	3.67	*a*	22.2	*ab*	7.5	*a*	64.6	*a*
Ağ Buğdayı	50.0	*cd*	98.5	*bcd*	5.18	*cd*	37.4	*i*	8.6	*ab*	130.1	*de*
Bintepe	56.2	*def*	97.4	*bcd*	5.17	*cd*	31.4	*gh*	9.8	*bc*	112.1	*b-e*
Havrani	47.9	*bc*	98.0	*bcd*	6.18	*h*	27.7	*def*	8.5	*ab*	88.8	*abc*
Çalıbasan	47.0	*bc*	97.5	*bcd*	5.64	*f*	30.5	*fgh*	11.5	*de*	128.5	*de*
Hacı Halil	49.1	*bc*	96.9	*bc*	6.06	*gh*	24.4	*bc*	8.5	*ab*	114.4	*b-e*
Akçakale	48.0	*bc*	98.5	*bcd*	4.07	*b*	23.5	*abc*	10.2	*cd*	85.4	*ab*
Zenit	42.4	*a*	92.5	*a*	8.37	*i*	21.4	*a*	11.3	*d*	121.3	*de*
Kyle	43.4	*ab*	97.6	*bcd*	5.89	*g*	25.7	*cde*	9.7	*bc*	75.1	*a*
Range	*42.3-56.2*		*92.5-99.3*		*3.67-8.37*		*21.4-37.4*		*7.5-12.8*		*64.6-133.4*	
Mean	*48.9*		*97.6*		*5.53*		*27.5*		*9.9*		*107.4*	

[a]Values are based on 14% moisture basis.
*Different letters in a column indicate significant difference (P < 0.05).

landraces, Havrani, Hacı Halil, Sorgül, and Çalıbasan prevailed with higher pigment contents, whereas Sorgül, Beyaz Buğday, Havrani, Hacı Halil, and Akçakale were found to have lower activities of the oxidative enzymes. Other researchers also reported that durum wheat genotypes grown in Turkey (Coşkun and Ercan 2003) and India (Aalami et al. 2007) exhibited large variations in pigment contents and oxidative enzymes. When judged by pigment contents and the activities of the oxidative enzymes that are central to the color of pasta products, the landraces Havrani, Hacı Halil, and Sorgül have great potential to produce yellow-colored pasta products.

Kernel size, hardness, and vitreousness are among the physical features that effectively determine end-use quality of durum wheat (Hoseney 1994; Bushuk 1998). High-quality durum wheat is expected to have larger kernels with hard and vitreous endosperm in order to obtain semolina with higher yield and brightness (Hoseney 1994; Elgün and Ertugay 1995; Bushuk 1998; Troccoli et al. 2000; Dziki and Laskowski 2005). It is evident from the physical data

Table 3. Relationship between γ-gliadin type and protein quality of selected Turkish durum wheat landraces[a].

γ-Gliadin type	Mean protein content (N × 5.7; %)	Mean sedimentation volume (mL)	Mean specific sedimentation volume (mL)	Mean gluten index
γ-Gliadin 45 *(n = 8)*	13.3	26.7	2.03	48.5
γ-Gliadin 42 *(n = 4)*	13.1	22.6	1.74	41.5

[a]Values are based on 14% moisture basis.

(Table 2) that all landraces included in this study were of adequate kernel size and vitreousness required for semolina milling and pasta processing.

Quality characteristics of 12 durum wheat landraces were investigated in comparison with those of 2 high-quality durum wheat cultivars, namely Kyle and Zenit. The landraces Akçakale, Havrani, and Çalıbasan were found to be quite promising for superior pasta-cooking characteristics as judged by their elevated protein contents and gluten qualities. With respect to pigment content and oxidative enzymes that are central to the bright yellow color of pasta products, however, landraces Havrani, Hacı Halil, and Sorgül were found to be of great potential. On the whole, several durum wheat landraces have potential for high-quality pasta processing, while a few others can be used for breeding purposes.

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