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Identification and evaluation of alveograph dough parameters of some bread wheat (*Triticum aestivum* L.) genotypes

Bazı ekmeklik buğday (*Triticum aestivum* L.) genotiplerinin alveograf hamur parametrelerinin tespiti ve değerlendirilmesi

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ABSTRACT

Alveograph analysis has long been one of the important methods in determination of bread making quality of wheat genotypes. Sixty-four bread wheat genotypes were analyzed for five alveograph parameters including alveograph energy (W, 10^{-4} joule) (AE), dough strength (P, mm), elasticity (L, mm) index of swelling (G, cm^3), alveograph configuration ratio (P/L), protein content (PC) and hardness (HRD). Genotype means of AE ranged from 155.4 $x10^{-4}$ J to 444.7 $x10^{-4}$ J. Ocoroni86/Pewit3 reached the highest AE value with 444.7 $x10^{-4}$ J. Pamukova-97 was in the same statistical group with 426.5 $x10^{-4}$ J AE value. Genotype means of P ranged from 50.0 mm to 162.9 mm. Aköz/Galil had the highest P value with162.9 mm. Genotype means of L ranged from 40.6 mm to 180.8 mm. Sunco/Pastor had the highest L value with 180.8 mm. Genotype means of G ranged from 14.35 cm^3 to 29.98 cm^3. Sunco/Pastor had the highest G value with 29.98 cm^3. Genotype means of P/L ranged from 0.29 to 3.77. Aköz/Galil had the highest P/L rate with 3.77. The genotype means of protein content (PC) ranged from 10.6% to 14.2%. Genotypes with 13% or more PC in this study were Pamukova-97/Arostor, Pewit-3, Aldane and Ocoroni-86/Pewit-3. The mean HRD values of the genotypes ranged from 46.5% to 68.0. The sisters of Adana-99/Sultan-95 (Genotypes 16 and 17) and Pamukova-97/Sönmez were the hardest grained genotypes in the study. The produced information will be useful for bread wheat breeding programs attempting to improve high quality bread wheat cultivars.

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ÖZ

Buğday genotiplerinin ekmek yapım kalitesinin belirlenmesinde alveografik analizler uzun süredir önemli yöntemlerden biri olmuştur. Alveograf enerjisi (W, 10-4 joule) (AE), hamur mukavemeti (P, mm), esneklik (L, mm), şişme indeksi (G, cm^3), alveograf dahil olmak üzere beş alveograf parametresi için altmış dört ekmeklik buğday genotipi analiz edilmiştir. Alveograf konfigürasyon oranı (P/L), protein içeriği (PC) ve sertlik (HRD). AE genotip ortalamaları 155.4 ile 444.7x10-4 J arasındadır. Ocoroni86/Pewit3, 444.7 x10-4 J ile en yüksek AE değerine ulaşmıştır. Pamukova-97, 426.5 x10-4 J AE değeriyle aynı istatistik grubunda yer almıştır. P genotip ortalamaları 50.0 mm ile 162.9 mm arasındadır. Aköz/Galil, 162.9 mm ile en yüksek P değerine sahip bulunmuştur. L genotip ortalamaları 40.6 mm'den 180.8 mm'ye kadar değişmiştir. Sunco/Pastor, 180.8 mm ile en yüksek L değerine sahip olmuştur. G genotip ortalamaları 14.35 cm^3 ile 29.98 cm^3 arasındadır. Sunco/Pastor 29.98 cm^3 ile en yüksek G değerine sahip bulunmuştur. P/L oranı genotip ortalamaları 0.29 ila 3.77 arasında belirlenmiştir. Aköz/Galil 3.77 ile en yüksek P/L oranına sahip bulunmuştur. Protein içeriğinin (PC) genotip ortalamaları % 10.6 ile % 14.2 arasında belirlenmiştir. Bu çalışmada % 13 veya daha fazla PC içeren genotipler, Pamukova-97/Arostor, Pewit-3, Aldane ve Ocoroni-86/Pewit-3 olmuştur. Genotiplerin ortalama HRD değerleri % 46.5 ile 68.0 arasında değişmektedir. Kardeş hatlar Adana-99/Sultan-95 (Genotipler 16 ve 17) ve Pamukova-97/Sönmez çalışmadaki en sert genotipler olarak belirlenmiştir. Elde edilen bilgiler, yüksek kaliteli ekmeklik buğday çeşitlerini geliştirmede yoğun çaba harcayan buğday yetiştirme programları için çok yararlı olacaktır.

1. Introduction

The Alveograph is a tool for wheat flour quality measurement. It was developed in 1920 in France by Marcel Chopin (Chopin 1921). Basically, it measures the flexibility of the dough produced from the flour, by inflating a bubble in a thin sheet of the dough until it ruptures (Chopin 1921, Chopin 1927, Bailey 1940). Later, the method has been named as Chopin Alveograph, and it has been one of the prominent methods in the determination of breadmaking quality of wheat genotypes for many years in a wide range of countries since it was introduced (Bailey 1940; Khattak et al. 1974; Rasper et al. 1986; Bettge et al. 1989; Bordes et al. 2008; Boros et al. 2009). The alveograph test was also suggested for breeding studies in Turkey (Kaya and Şahin 2015).

Among the all alveograph parameters, AE (W) value has been considered for assessing the quality in most of the breadmaking quality studies (Bloksma 1957, Faridi and Rasper 1987). Chen and D'Appolonia (1985) stated that three alveograph values (P, L and AE) are important in assessing the quality. They reported that only the P value was negatively correlated with flour protein, wet gluten, and loaf volume. According to Chen and D'Appolonia (1985), the alveograph L and AE values measured breadmaking potential accurately and produced an acceptable predictor of the end-use bread baking quality of the flour. According to Bettge et al. (1989), considering market classes of the samples the three alveograph factors (P, L, and AE in addition to flour protein and hardness) can predict the functionality of the flour as represented by cookie diameter, loaf volume, or specific volume. Bettge et al. (1989) stated that alveograph value L is alone may predict a major part of the functional properties of proteins in loaf volume formation. According to Mailhot and Patton (1988), P and L values of the dough are the two important characteristics need to be considered in bread making quality. Codina et al. (2011) explained importance of P value in the model of wet gluten content prediction and stated P value as one of the best predictors of the gluten deformation index. Mironeasa and Codina (2013) reported that alveographic parameters L and G are predictive for rheological behavior of wheat dough. Indrani et al. (2007) announced that G and W were the best indicators of overall quality of parotta. W energy value has also been an important parameter in Turkey for evaluating wheat quality in breeding studies (Şahin et al. 2009, Aydoğan et al. 2012).

The alveograph test measures essentially the force required to blow and break a bubble of dough. P value indicates tenacity of the dough. It is the force required to blow the bubble of dough and is indicated by the maximum height of the curve. Weak gluten flour has lower P values. P value is expressed in millimeters (mm). L value indicates extensibility of the dough (maximum volume of air that the bubble is able to contain) before the bubble breaks. L value is indicated by the length of the curve and is expressed in millimeters (mm). P/L Ratio is the configuration of the curve and is the balance between dough strength and extensibility. W value (dough baking strength) indicates the area under the curve. It is a combination of dough strength (P value) and extensibility (L value) and is expressed in joules ($x10^{-4}$). G value is swelling index. It measures dough extensibility and represents the square root of the air volume needed to inflate the dough until rupture. G value is expressed in cubic centimeter (cm^3) or milliliter (mL). Both quantity and quality of protein are quite important for bread-making and they may significantly influence the dough strength properties of wheat flours (Pena 2002). Therefore, protein is one of the most important quality factors in determining bread quality. The amount of the protein content is calculated as percentage. Grain hardness is important for the flour industry because of its important effects on grinding and baking performance (Bettge et al. 1995). Hardness, PSI (Particle Size Index) of the grains is expressed as percentage.

Biplot of the genotype-by-trait has been suggested as a statistical tool for evaluating cultivars based on especially multiple traits and for identifying superior lines (Dehghani et al. 2008; Mishra et al. 2015). Biplot of the genotype-by-trait explains superior genotypes with favourable traits effect. Therefore, it would be useful for the breeding new genotypes for each target entry. It is also used for genetic variability and relationship among the genotypes.

The aim of this article to reveal and evaluate alveograph dough parameters of some bread wheat genotypes including protein and hardness quality values and revealing the interrelationships of these quality traits. The provided information will be useful for quality based bread wheat breeding programs.

2. Materials and Methods

2.1. Materials

Possessing different quality traits, sixty four genotypes were used in the study. Twenty-one of them were advanced lines from the MRI (Maize Agricultural Research Institute-Sakarya) wheat breeding program. Thirty of them were cultivars from other research institutions and different countries including CIMMYT (International Wheat and Maize Improvement Center-Mexico) genotypes and other 13 genotypes were lines from crossing blocks of MRI breeding program and cultivars of MRI.

2.2. Methods

This research was carried out in the fields of MRI and the quality laboratories of Field Crops Central Research Institute-Ankara and MRI under Republic of Turkey Ministry of Food, Agriculture and Livestock. The study materials were planted in 1 m long 30 ear-row plots in November 2011 in the fields of MRI in Sakarya. To maintain seed purity 25 ears from each genotype were isolated with paper bags. Non-homogeneous or mixed rows were discarded. Remained rows were harvested and threshed in July 2012. Using the cleaned seeds of each genotype the trial was planted in Pamukova field of MRI in November 2012 in a 8x8 partially balanced lattice design with three replicates. The plot size of the trial was 12.5 m^2 (1mx12.5m) in planting and it was reduced to 10 m^2 in harvest for exclusion of border effect. The trial planting area with an altitude of 73 m in Pamukova has clay loam soil having medium organic matter with pH 7.64 and with a mean season rainfall of 486 mm. During the growing season monthly the minimum and maximum temperatures were 5.5 and 22.4 °C, respectively. The rows were fertilized with 80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} at the planting and 70 kg N ha^{-1} in spring at tillering. Using the seeds of the genotypes obtained from the trial, alveograph quality analyses were conducted in the quality laboratory of Field Crops Central Research Institute, Ankara and protein content and hardness analyses were conducted in the quality laboratory of MRI. Each sample from the plots was tested two times during the quality tests.

Alveograph tests were conducted according to ICC Standard No: 121 (ICC 2008) using Chopin Alveograph NG (France) instrument. Milling process was conducted according to AACC Method No: 26-21 and 26-31 (Anonymous 2000). Grain samples were cleaned and conditioned to 16.5% moisture for 12 h and milled using laboratory scale Buhler mill (model MLU 202D, AG, Uzwil, Switzerland). Protein amount analyses were performed according to AACC Method 46-30 (Crude Protein / Combustion Method) on a Velp Scientifica model NDA-701 Dumas Nitrogen Analyzer protein determination device (Anonymous 2000). Hardness, PSI (Particle Size Index) of the grains were determined as percentage, according to Williams and Sobering (1986). Twenty five g grain samples from each wheat genotype were crushed using a crushing mill (Perten 3100) having 1 mm sieve spacing. The hardness analyses were conducted using a RO-TAP Testing Sieve Shaker (Retsch AS200Tap). From the crushed grain samples 10 g were put onto 75 µm sieve and 50 *g* of wheat grain were added onto crushed samples for easy sieving. The shaker was adjusted for 10 minutes. The amount of the sample under the sieve were weighed and the obtained value was calculated as percentage. The HRD values were eavluated according to AACC Method 55-30 (Anonymous 2000). Variance and principle component analyses were conducted using the JMP version 11.0 packet statistical program (Anonymous 2013).

3. Results

In this study, highly significant ($P<0.001$) differences were found among the genotypes for all five alveograph parameters, protein and hardness values. The mean dough alveograph energy values of wheat genotypes in the study varied from 155.4 to 444.7 $x10^{-4}$ J (Table 1). The genotypes Ocoroni 86/Pewit3 (Genotype (Gn3) with 444.7 $x10^{-4}$ J AE value and Pamukova-97 (Gn36) with 426.5 $x10^{-4}$ J AE value reached the highest AE value and shared the same statistical group (a). The genotypes Lancer (Gn38) and Çetinel-2000 (Gn58) were only the two genotypes having lower AE value (155.4 $x10^{-4}$ J and 158.9 $x10^{-4}$ J, respectively) than 160 $x10^{-4}$ J. The mean AE value of the all genotypes was 275.2 $x10^{-4}$ J.

The mean P values of the genotypes in the present study varied from 50.0 mm to 162.9 mm. The mean P value of trial was 106.2 mm. The genotypes Aköz/Galil (Gn18) (162.9 mm), Pamukova-97 (Gn.36) (162.36 mm), Gönen-98 (Gn51) (159.61 mm) Aköz/Dariel (Gn19) (156.6 mm), Dariel (Gn27) (156.6 mm), Galil (Gn29) (156.2 mm) reached the highest P value and shared the same statistical group (a). On the other hand, the genotypes had the lowest P values were Gn46 (60.8 mm), Gn59 (59.1 mm), Gn13 (56.8 mm), Gn9 (55.6 mm), Gn14 (55.4 mm) and Gn58 (50.0 mm).

Table 1. The names and the origin of the genotypes used in the study.

No	Genotype	Origin	No	Genotype	Origin
1	Pamukova-97/Sönmez	Advanced Line	33	Ocoroni 86	CIMMYT
2	Tnmu/3/HD2206/Hork//Buc/Bul	Advanced Line	34	Pastor	CIMMYT
3	Ocoroni 86/ Pewit3	Advanced Line	35	Pewit3	CIMMYT
4	Tahirova2000/Zornitcha	Advanced Line	36	Pamukova-97	MRI-Cultivar
5	Tahirova2000/Zornitcha	Advanced Line	37	Prostor	CultivarTR
6	Ağrı/Bjy"S"//Vee"S"/Mmtc/4/LL/3/Orso/Akv/Ska	Advanced Line	38	Sibia/Milan	MRI-Line
7	Pamukova-97/Arostor	Advanced Line	39	Sönmez	CultivarTR
8	Pamukova-97/Arostor	Advanced Line	40	Stozher	CultivarBG
9	Momtc/4/LL/3/Orso//Akv/Ska/Prostor	Advanced Line	41	Sultan-95	CultivarTR
10	Stozher/3/Kal/Mus//Har	Advanced Line	42	Sunco	CultivarAU
11	Sunvale/Sultan95	Advanced Line	43	Sunvale	CultivarAU
12	Stozher//Sibia/Milan	Advanced Line	44	Tahirova-2000	MRI-Cultivar
13	Stozher//Sibia/Milan	Advanced Line	45	Tinamou	CIMMYT
14	Sunco/Pastor	Advanced Line	46	Yakar-99	CultivarTR
15	Doğu-88/Ziyabey98	Advanced Line	47	Ziyabey-98	CultivarTR
16	Adana-99/Sultan95	Advanced Line	48	Zornitcha	CultivarBG
17	Adana-99/Sultan95	Advanced Line	49	Basribey-95	CultivarTR
18	Aköz/Galil	Advanced Line	50	Osmaniyem	CultivarTR
19	Aköz/Dariel	Advanced Line	51	Gönen-98	CultivarTR
20	Bau/Kauz// Tahirova2000	Advanced Line	52	Pehlivan	CultivarTR
21	Tahirova-2000/Yakar	Advanced Line	53	Aldane	CultivarTR
22	Adana-99	Cultivar-TR	54	Flamura 85	CultivarTR
23	Ağrı/Bjy"S"//Vee"S"	MRI-Line	55	Tosunbey	CultivarTR
24	Aköz	Cultivar-TR	56	Konya-2002	CultivarTR
25	Arostor	Cultivar-BG	57	Harmankaya-99	CultivarTR
26	Bau/Kauz	MRI-Line	58	Çetinel-2000	CultivarTR
27	Dariel	Cultivar-TR-IL	59	Yıldız 98	CultivarTR
28	Lancer	Cultivar-TR	60	Bezostaya-1	MRI-RU
29	Galil	Cultivar-TR-IL	61	Momtchil	MRI-BG
30	HD2206/Hork//Buc/Bul	MRI-Line	62	Bandırma-97	MRI-Cultivar
31	Kal/Mus//Har	MRI-Line	63	Beşköprü	MRI-Cultivar
32	Momtc/4/LL/3/Orso/Akv/Ska	MRI-Line	64	Hanlı	MRI-Cultivar

The mean L values of the genotypes ranged from 40.6 to 180.8 mm. The mean L value of the all genotypes was 78.2 mm. The genotypes Sunco/Pastor (Gn14) (180.8 mm), sisters Stozher//Sibia/Milan (Gn13) (160.8 mm) and Stozher//Sibia/Milan (Gn12) (158.7 mm), Aköz (Gn24) (150.8 mm), Arostor (Gn25) (134.4 mm), Çetinel-2000 (Gn58) (127.6 mm) and Momtc/4/LL/3/Orso//Akv/Ska/Prostor (Gn9) (125.8 mm) reached the highest L values. However, the genotypes G29, G51, G23, G19, G27 and G29 had the lowest L values under 50 mm L value.

The mean G values of the genotypes ranged from 14.4 to 30.0 cm^3. The trial mean of G value was 19.3 cm^3. The genotypes Sunco/Pastor (Gn14) (30.0 cm^3), Stozher//Sibia/Milan (Gn13) (28.1 cm^3), Stozher//Sibia/Milan (Gn12) (27.9 cm^3), Aköz (Gn24) (27.2 cm^3), Arostor (Gn25) (25.5 cm^3), Çetinel-2000 (Gn58) (25.2 cm^3) reached the highest G values. Contrarily, the genotypes Gn29, Gn51, Gn23, Gn19, Gn27, Gn18 had the lowest L values within the range of 14-16 cm^3.

P/L configuration ratio of the genotypes in the present study ranged from 0.3 to 3.8. The trial mean of P/L ratio was 1.6. The genotypes Galil (Gn29) (3.1), Pamukova-97 (Gn36) (3.1), Aköz/Dariel (Gn19) (3.3), Gönen-98 (G51) (3.4), Dariel (Gn27) (3.4) and Aköz/Galil (Gn18) (3.8) had the highest P/L values. Conversely, the genotypes Gn9 (0.5), Gn12 (0.4), Gn24 (0.4), Gn58 (0.4), Gn13 (0.3), Gn14 (0.3), had the lowest P/L values.

The genotype means for protein content (PC) ranged from 10.6% to 14.2% (Table 2). The trial mean of PC was 11.8%. The genotype Ocoroni-86/Pewit-3 (Gn3) reached the highest PC with 14.2%. The genotypes having over 13% PC were Aldane (Gn53), Pewit-3 (Gn35) and Pamukova-97/Arostor (Gn7) followed Ocoroni-86/Pewit-3 (Gn3) with 13.8%, 13.3% and 13.3% PC, respectively. Sönmez (Gn39) genotype was the genotype with the lowest PC with 11.6%.

The mean HRD values of the genotypes ranged from 46.5% to 68.0. The trial mean of hardness was 54.6%. In this study those with low values in terms of hardness are considered to be harder. Yakar-99 (Gn46) was the genotype with the softest grain with 68.0%. Pamukova-97/Arostor (Gn8) followed Yakar-99 having 2nd softest grain with 66.7% HRD. In contrast, Adana-99/Sultan-95 (Gn16) advanced line was genotype having the hardest grain with 46.5%. The other hardest grained genotypes were the sister of Adana-99/Sultan-95 (Gn17) with 46.81% and Pamukova-97/Sönmez (Gn1) with 47.1%, Tnmu/3/HD2206/Hork//Buc/Bul (Gn2) with 47.1% and Dariel (Gn27) with 47.3%.

The biplot graph (Figure 1) indicates the relationships of 64 wheat genotypes for alveograph parameters, PC and HRD. The first two PCA's (Principle Component 1 and 2) and explained 81.3% of the total variation of the relationships between the genotypes and the quality traits in this study. The alveograph values P, L, G and P/L indicated a large variation among the genotypes. In contrast, AE, PC and HRD indicated relatively little variations among genotypes.

4. Discussion

The alveograph is one of the trusty tools to reveal the quality of wheat flour and among the all alveograph parameters alveograph energy (AE) value has key role for assessing the quality of the breadmaking quality. Williams et al. (1988) classified dough AE values as very weak for 0-50 J, weak for 50-100 J, medium for 100-200 J, medium strong for 200-300 J, strong for 300-400 J and very strong for over 400 J. According to Pomeranz (1987) the AE value of standard flour is around $141x10^{-4}$ J. Some other researchers suggested that the AE value of standard flour is characterized in range 160-200 $x10^{-4}$ J (Bordes et al. 2008; Pagani et al. 2006). Considering these studies, determined AE values of all studied genotypes in this study were almost in the range of standard flour or higher than those of standard flour (Table 1).

Usually, P dough resistance values are considered as standard wheat quality for 60-80 mm, very good wheat quality for 80-100 mm and extra strong wheats for over 100 mm j (Bordes et al. 2008; Aldovrandi and Vitali 1995). Seven genotypes had standard wheat quality, 13 genotypes had very good wheat quality. However, 39 genotypes out of 64 had P value over 100 mm indicating extra strong wheat quality. The genotypes Aköz/Galil (Gn18) (162.9 mm), Pamukova-97 (Gn36) (162.4 mm), Gönen-98 (Gn51) (159.6 mm) Aköz/Dariel (Gn19) (156.6 mm), Dariel (Gn27) (156.6 mm), Galil (Gn29) (156.15 mm), Flamura-85 (Gn54) (152.0 mm) were the genotypes having highest P dough tenacity values representing extra strong wheats. However, Yıldız-98 (Gn59) (59.1 mm), Stozher//Sibia/Milan (Gn13) (56.8 mm), Momtc/4/LL/3/Orso//Akv/Ska/Prostor (Gn 9) (55.6 mm), Sunco/Pastor (Gn14) (55.4 mm), Çetinel-2000 (Gn58) (50.0 mm) were the genotypes under the standard P values.

Extensibility value, L is also an important alveograph parameter in prediction of wheat flour quality. According to Bettge et al. (1989), L value has a key role in the prediction of functional properties of proteins of both soft and hard wheat flours. Flours having 100 mm L value are considered as good in breadmaking quality (Bordes et al. 2008; Hadnađev et al. 2011). On the other hand, biscuit production requires higher L values. Thirteen genotypes had L values around 100 mm (80-111 mm) representing standard bread making quality. The number of genotypes having L values over 111 mm was 7 which may be evaluated in biscuit production. Sunco/Pastor (Gn14) alone formed group 'a' with 180.8 mm L value. On the other hand, L values of 28 genotypes remained within the range of 60-80 mm representing good wheat quality. However, 16 genotypes had L values under 60 mm expressing strong wheat quality.

Since the two alveograph parameters give information about elasticity of the wheat dough, swelling index (G) and extensibility (L) are usually related. Codină et al. 2010 and Mironeasa and Codina (2013) reported high correlations (*r*= 0.875 and *r*= 0.997, respectively) between G value and L value. An average value of G parameter, 20 cm^3 may be considered for standard wheat flour quality (Pomeranz 1987; Bilgin and Korkut 2005). Fourteen genotypes had G values around 20 cm^3 (19-21 cm^3) representing standard bread making quality. The number of genotypes having G values over 21 cm^3 was 13 which may be suggested for biscuit production. Twenty one genotypes remained in the range of 17-19 cm^3 expressing good wheat quality. However, 16 genotypes had G values lower than 17 cm^3 representing strong wheat quality.

P/L configuration ratio defines resistance/elasticity ratio of wheat dough. It is one of the significant parameters in defining wheat flour quality and is also commonly used in wheat trade (Bordes et al. 2008; Hadnađev et al. 2011). According to their P/L values wheat flours may be grouped for industrial usage (Bordes et al. 2008; Aldovrandi and Vitali 1995; Hadnađev et al. 2011). Wheat flours having P/L value in the range 0.40-0.80

Table 2. Alveograph (AE) values with protein content (PC) and hardness index (HRD) of the genotypes.

No	AE	‡	No	P	‡	No	L	‡	No	G	‡	No	P/L	‡	No	PC	‡	No	HRD	‡
3	444.70	a	18	162.90	a	14	180.83	a	14	29.98	a	18	3.77	a	3	14.23	a	46	68.04	a
36	426.45	a	36	162.36	a	13	160.82	b	13	28.11	ab	27	3.42	ab	53	13.78	a	8	66.70	a
35	357.52	b	51	159.61	a	12	158.67	b	12	27.88	ab	51	3.41	ab	35	13.32	b	59	64.52	b
19	350.21	b	19	156.60	a	24	150.83	bc	24	27.15	bc	19	3.33	ab	7	13.28	b	24	63.72	bc
31	343.64	bc	27	156.58	a	25	134.43	cd	25	25.52	cd	36	3.09	bc	2	12.92	bc	58	63.52	bcd
53	343.51	bcd	29	156.15	a	58	127.64	de	58	25.18	cd	29	3.06	bc	36	12.89	bcd	41	63.05	b-e
16	329.60	cde	54	152.04	ab	9	125.84	de	9	24.87	de	23	3.01	bcd	13	12.77	cde	7	62.54	c-f
51	328.50	c-f	56	145.11	bc	3	111.64	ef	3	23.52	def	56	2.82	bcd	50	12.71	cde	12	61.93	c-f
43	327.32	c-f	23	141.11	bcd	35	105.27	fg	35	22.71	efg	54	2.77	cde	21	12.64	c-f	37	61.73	def
22	326.57	c-f	61	139.00	cde	4	101.38	fgh	4	22.20	fgh	61	2.68	cde	19	12.59	c-g	9	61.64	ef
54	323.87	c-g	45	131.07	def	8	98.99	fgh	8	22.02	f-i	45	2.55	def	45	12.58	c-h	63	61.25	ef
29	322.72	d-h	62	129.44	efg	33	95.89	f-i	33	21.80	f-j	55	2.30	efg	4	12.45	d-i	14	60.83	fg
42	321.66	e-i	55	126.50	fgh	47	92.78	g-j	47	21.43	f-k	60	2.11	fgh	44	12.42	e-i	25	60.80	fg
27	312.54	e-j	60	124.96	fgh	2	91.50	g-k	2	21.05	g-l	48	2.09	fgh	8	12.36	e-j	13	59.17	gh
18	309.31	e-k	43	123.65	fgh	41	89.61	g-l	41	20.85	g-m	62	2.08	fgh	14	12.35	e-j	33	57.82	hi
61	308.42	f-l	16	121.55	f-i	7	88.09	g-m	7	20.70	g-m	17	2.05	fgh	60	12.33	e-j	42	57.40	hij
17	305.95	g-l	3	121.19	f-k	59	86.78	g-n	59	20.57	g-n	11	1.95	ghi	54	12.23	f-k	64	56.96	ijk
10	305.16	g-l	53	120.88	f-k	63	86.51	h-o	63	20.39	h-o	53	1.90	g-j	12	12.23	f-l	47	56.64	i-l
40	302.30	h-l	10	120.52	f-k	1	83.97	h-p	1	20.38	h-p	64	1.90	g-j	38	12.21	f-m	53	56.61	i-l
60	300.93	ı-m	22	119.91	g-l	40	79.93	i-r	40	19.85	i-r	43	1.86	g-k	48	12.17	g-n	54	56.31	i-m
55	300.88	j-m	31	119.62	g-m	6	79.55	i-r	6	19.78	j-r	16	1.86	g-k	61	12.16	g-n	55	56.27	i-m
8	298.20	j-n	17	119.28	g-m	42	77.73	i-s	46	19.58	k-s	31	1.85	g-l	5	12.12	h-o	32	56.14	i-n
33	293.66	j-o	42	118.10	h-n	46	77.26	j-s	32	19.42	k-t	10	1.82	h-l	18	12.10	i-o	57	56.11	i-n
11	293.22	j-o	35	116.57	h-o	32	77.20	j-s	42	19.41	k-t	52	1.80	h-m	10	12.05	i-p	56	55.82	j-o
34	292.91	j-o	11	115.79	h-o	38	76.48	j-s	38	19.40	k-u	15	1.76	h-n	32	12.03	i-p	52	55.78	j-o
38	292.58	j-o	34	112.23	i-o	30	74.63	j-t	37	19.19	l-u	21	1.74	h-n	24	11.94	j-r	60	55.54	k-p
57	291.22	k-p	57	111.73	i-p	37	74.11	k-u	30	19.06	l-u	22	1.74	h-n	9	11.92	j-s	43	55.14	k-p
56	291.02	k-p	48	111.65	i-p	26	72.34	l-v	26	18.93	l-v	49	1.70	h-o	20	11.85	k-s	19	54.87	l-r
15	287.94	l-p	52	111.38	i-p	50	71.61	l-v	50	18.78	m-y	28	1.70	h-o	33	11.83	k-t	40	54.69	m-s
6	282.03	m-r	30	110.67	j-p	43	71.49	m-y	57	18.64	m-z	34	1.69	h-o	16	11.78	l-u	36	54.67	m-s
23	280.87	m-r	49	110.37	k-p	39	70.75	m-y	39	18.63	m-z	57	1.67	h-p	43	11.75	m-u	61	54.60	m-s
12	279.00	n-s	15	109.23	l-r	57	70.73	m-y	44	18.47	n-A	30	1.57	i-r	42	11.71	o-v	39	54.32	n-t
45	278.96	n-s	38	109.06	l-r	44	69.75	n-y	43	18.44	n-B	42	1.56	i-r	17	11.71	o-v	20	54.26	o-t
2	274.71	o-t	40	108.83	m-r	10	68.26	o-z	20	18.40	n-B	20	1.49	i-s	49	11.70	n-v	4	54.15	o-t
30	274.28	o-t	6	107.54	n-r	20	67.85	p-z	5	18.37	n-B	38	1.49	i-s	40	11.68	o-y	18	53.69	p-u
7	273.74	o-t	32	106.80	o-s	5	67.71	p-z	10	18.28	o-B	32	1.45	j-t	22	11.61	p-y	21	53.25	r-v
14	273.38	o-t	21	106.08	o-t	15	67.00	p-A	22	18.22	o-B	26	1.42	k-t	26	11.58	p-z	28	53.10	r-y
32	271.99	p-u	20	106.03	o-t	34	66.67	p-A	34	18.18	o-C	50	1.40	k-t	6	11.55	r-A	11	52.95	s-z
62	263.30	r-v	26	101.11	p-u	16	66.44	p-A	16	18.10	r-C	40	1.38	l-t	34	11.51	r-B	44	52.59	t-A
64	261.84	r-y	50	99.06	r-u	22	66.33	p-A	15	17.89	r-D	6	1.34	m-u	31	11.47	s-C	31	52.25	t-B
13	260.26	s-y	63	96.05	s-v	60	65.16	r-A	49	17.87	r-D	39	1.34	m-u	28	11.46	s-D	10	51.69	v-C
63	258.40	s-y	44	96.04	t-v	49	64.80	r-A	31	17.79	r-D	44	1.33	n-u	30	11.38	t-E	49	51.44	y-D
50	257.41	t-y	64	94.12	u-y	31	64.77	r-A	62	17.75	r-D	63	1.25	o-v	1	11.38	t-E	45	51.41	y-D
37	254.21	t-z	39	91.57	u-z	62	64.45	r-A	60	17.70	r-D	5	1.22	p-y	11	11.35	u-F	50	51.32	y-D
20	251.78	u-A	2	90.68	u-z	52	63.31	r-B	52	17.63	r-D	37	1.17	r-z	57	11.35	u-F	35	51.24	z-D
41	247.82	v-B	37	90.27	u-z	53	62.41	r-C	53	17.52	s-D	35	1.16	r-z	25	11.32	u-G	29	51.02	A-F
26	244.52	v-B	1	87.86	v-A	11	60.25	s-C	11	17.25	t-E	3	1.10	r-A	46	11.30	v-G	3	51.01	A-E
49	244.43	v-B	5	85.80	v-A	21	59.66	s-D	21	17.17	u-E	1	1.07	s-A	55	11.23	y-H	15	50.93	A-F
44	241.94	y-C	28	84.82	y-A	54	57.23	t-E	17	16.82	v-E	2	1.06	s-A	29	11.23	y-H	22	50.46	B-F
52	237.00	z-C	7	84.49	y-A	17	57.06	t-E	54	16.74	y-E	7	1.01	t-A	47	11.15	z-İ	5	50.36	C-G
4	232.49	A-C	33	84.33	y-A	55	55.88	u-E	55	16.57	z-F	33	0.91	u-B	59	11.12	z-İ	30	49.93	C-H
25	228.77	B-D	4	83.00	z-B	36	55.67	v-E	36	16.37	A-F	4	0.88	u-B	41	11.10	B-İ	38	49.76	D-H
39	221.17	C-E	8	77.30	AB	28	55.21	v-E	48	16.29	A-F	8	0.79	v-C	64	11.09	B-İ	23	49.25	E-İ
24	210.35	D-F	25	72.49	BC	45	54.22	v-E	45	16.29	A-F	46	0.76	y-D	15	11.04	C-J	6	49.22	F-İ
21	209.45	D-G	41	65.71	CD	61	54.17	v-E	28	16.29	A-F	59	0.75	z-D	27	11.01	D-K	34	48.61	G-J
46	203.26	E-H	47	64.61	CD	48	54.02	v-E	61	16.25	B-F	41	0.71	z-E	37	10.97	E-K	51	48.41	HİJ
48	198.45	F-H	24	63.44	CD	64	52.95	y-E	64	16.02	C-F	25	0.66	A-E	23	10.97	E-K	62	47.86	İJK
1	195.16	F-H	12	62.05	CD	56	50.48	z-E	56	15.83	D-F	47	0.66	A-E	52	10.91	F-K	48	47.65	İJK
5	194.74	F-H	46	60.82	DE	29	48.42	A-E	29	15.73	D-F	9	0.48	B-E	58	10.88	G-K	26	47.46	İJK
59	188.79	G-H	59	59.14	DE	51	46.39	B-E	19	15.26	EF	12	0.44	B-E	62	10.84	H-K	27	47.34	JK
9	186.00	H	13	56.81	DE	23	44.61	C-E	51	15.13	EF	24	0.40	C-E	63	10.82	H-K	2	47.11	JK
47	185.63	H	9	55.61	DE	19	44.55	C-E	23	15.02	EF	58	0.40	C-E	51	10.69	İJK	1	47.05	JK
58	158.94	I	14	55.44	DE	27	41.50	D-E	27	14.50	F	13	0.31	DE	56	10.61	JK	17	46.81	JK
28	155.36	I	58	50.01	E	18	40.57	E	18	14.35	F	14	0.29	E	39	10.56	K	16	46.48	K
CV%=	4.24			5.82			13.37			6.49			6.34			2.21			1.90	
$LSD_{(0.05)}$=	20.82			11.01			18.54			2.22			0.45			0.47			1.85	
MEAN=	275.20			106.17			78.17			19.30			1.64			11.82			54.61	

‡: Values with the same letter are not significantly different (P<0.05).

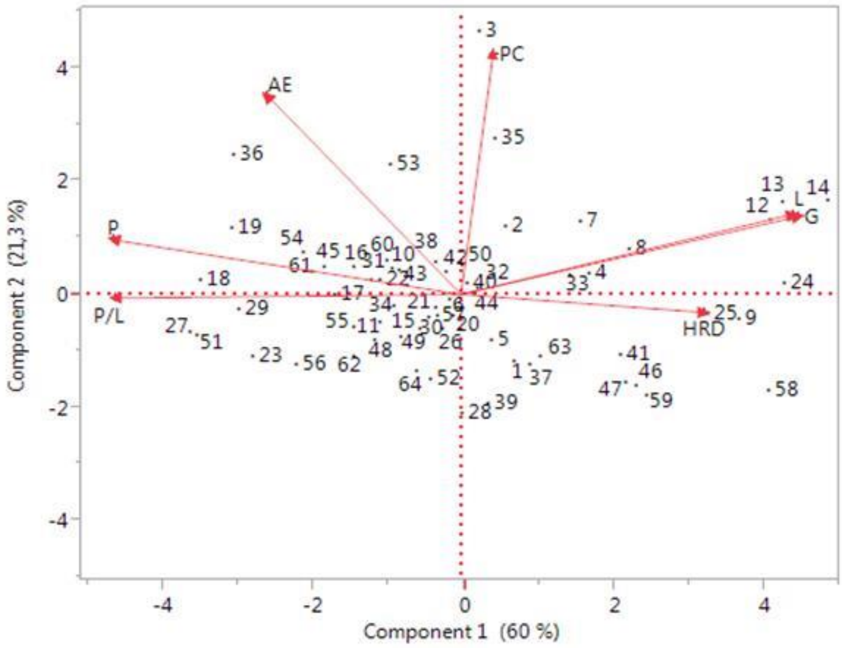

Figure 1. The biplot indicating the relations among the genotypes and the quality traits.

is suitable for bakery production (Bordes et al. 2008; Hadnađev et al. 2011; Codină et al. 2010). P/L ratio 0.50 indicates resistant/very elastic or less resistant/moderate elastic wheat dough and the ratio of 1.50 indicates very strong/moderately extensible dough. However, wheat flour relevant for confectionary products should exhibit lower P/L value than 0.50. Nine genotypes had 0.50-1.0 P/L value in the study representing standard wheat quality. The number of genotypes remaining in the range of 1.0-2.0 was 33 representing good breadmaking quality. Sixteen genotypes had P/L value over 2.0 expressing strong flour wheats. Only 6 genotypes had lower than 0.50 P/L values suggesting biscuit or cracker making quality.

As a result of overall evaluation of the determined alveograph parameters in this study, present wheat genotypes may be separated into 3 groups; weak quality wheats, standard (moderate) quality wheats and strong quality wheats. The strong wheats were Aköz/Galil (Gn18), Dariel (Gn27), Pamukova-97 (Gn36), Gönen-98 (Gn51), Aköz/Dariel (Gn19), Galil (Gn29), Flamura-85 (Gn54), Momtchil (Gn61), Bezostaya-1 (Gn60), Tosunbey (Gn55), Aldane (Gn53), Konya-2002 (Gn56) Adana-99/Sultan95 (Gn16), Sunvale (Gn43), Sunvale/Sultan95 (Gn11). The weak wheats were Sunco/Pastor (Gn14), sisters of Stozher//Sibia/Milan (Gn13 and Gn12), Çetinel-2000 (Gn58), Aköz (Gn24), Momtc/4/LL/3/Orso//Akv/Ska/Prostor (Gn9), Ziyabey-98 (Gn47), Yıldız-98 (Gn59), Yakar-99 (Gn46), Sultan-95 (Gn41), Ocoroni-86 (Gn33), sisters of Pamukova-97/Arostor (Gn8 and Gn7), Tahirova2000/Zornitcha (Gn5), Arostor (Gn25). The remaining 34 genotypes were moderate quality wheats (Gn 1, 2, 3, 4, 6, 9, 10, 15, 16, 20, 21, 22, 23, 26, 28, 30, 31, 34, 35, 37, 38, 39, 40, 42, 44, 45, 48, 49, 50, 52, 57, 62, 63, 64).

In a study for evaluation of alveograph values of some bread wheat genotypes improved for the Central Anatolia, Şahin et al. (2009) reported that the average P, AE and P/L values of the genotypes were low in the rainfed environmental conditions comparing to those of the genotypes in the irrigated environmental conditions. However, L and G mean values of the genotypes in the rainfed conditions were higher. In the present study P, AE and P/L mean values of the genotypes were higher and L and G mean values were lower than the mean values of the genotypes in Central Anatolia. The P, AE and P/L mean values of the genotypes in this study were also found higher than the mean values of the genotypes reported by some other researchers (Bilgin and Korkut 2005; Hruskova and Famera 2003; Osella et al. 2008). One of the reasons in the difficulties of obtaining high quality wheats may be environment rather than the failures during genotype selection. According to Kaya and Şahin (2015), AE and P/L were primarily controlled by E (environment), although G (genotype) and GEI (GxE interaction) also had significant effects. The alveograph values P, AE and P/L in the present study seem high comparing to the various results indicating that the genotypes included in the study were mostly strong wheats. The higher alveographic quality may be explained by environment (one year result), better genotypes (more than half of the genotypes were registered cultivars), and growth habit of the genotypes. Spring, winter and alternative growth habit genotypes were included together in the study. Maghirang et al. (2006) reported that all alveograph test parameters were significantly higher for spring wheat flours than for winter wheat flours, excluding the mean configuration ratio.

Köksel et al. (2000) classified wheat flours according to protein as bulgur (>13%), bread (10-13%) and biscuits and crackers (<10%). Similarly, Pena (2002) classified breads as leavened (>13%), flat and steamed (10-13%) and cookies, cakes, pastries (<10%). All genotypes in this study yielded PC above 10%. Genotypes with 13% or more PC in this study were Pamukova-97/Arostor, Pewit-3, Aldane and Ocoroni-86/Pewit3. In a study conducted by Kaya and Akçura (2014) in Central Anatolia, the PC of the genotypes varied between 10.1% and 13.2% and the mean PC of all genotypes was 11.6%. Aktaş and Baloch (2017) reported the mean PC range of their genotypes from 11.7% to 14.8% in the three location of Southeastern Region of Turkey.

Wheat genotypes may be classified in 8 groups according to their grain hardness (Anonymous 2000), extra soft (>78% PSI), very soft (73-78% PSI), soft (65-72% PSI), medium soft (57-64% PSI), medium hard (49-64% PSI), hard (40-48% PSI), very hard (29-39% PSI) and extra hard (<29% PSI). Overall hardness evaluation of the genotypes suggested that, 15.6% of the genotypes (10) were in the range of 40-48% HRD and accepted as hard, 59.4% of the genotypes (38) were in the range of 49-56% HRD and accepted as medium hard, 21.9% of the genotypes (14) were in the range of 57-64% HRD and accepted as medium soft and 3.1% of the genotypes (2) were in the range of 65-72% HRD and accepted as soft grained genotypes. According to the results of this study the softest grained genotypes were Yakar-99 (Gn46) and Pamukova97/Arostor (Gn8) and the hardest genotypes were Adana/Sultan (Gn16 and Gn17), Pamukova97/Sönmez (Gn1) and Tnmu/3/HD2206/Hork//Buc/Bul (Gn2).

Considering hardness, the present study showed similarity with previous studies in Central Anatolia conditions. Aydoğan et al (2013) found that, from 21 studied genotypes 11 were medium soft, 9 were medium hard, 1 was very hard class with the range of 38-63.5%. In the same study the trial mean was 56.70%. Kaya ve Akçura (2014) also reported from medium hard (48%) to medium soft (60%) HRD values with 55% HRD trial mean in Central Anatolia conditions. Majority of the genotypes in this study remained medium hard or medium soft hardness class. It seems that most of the Turkish wheat genotypes are located into medium hard to medium soft hardness class.

The relationship of 64 genotypes with the wheat quality traits may be easily explained through Principle Component Analysis (PCA). Vector length of the traits represents the magnitude of its effect (Yan and Tinker 2005). The alveograph values P, L, G and P/L had long vectors suggesting a large variation among the genotypes. In contrast, AE and PC had shorter and HRD had the shortest vectors suggesting relatively little variations among genotypes. Basically, two traits are positively correlated if the angle between their vectors is < 90°, negatively correlated if the angle is > 90°, and independent if the angle is 90° (Dehghani et al. 2012). Accordingly, AE correlated positively with PC, P and P/L traits, HRD correlated positively with L and G traits (high HRD values indicate softer grained genotypes), PC correlated positively with L and G traits. There was no correlation between PC and HRD. Non-correlation of PC and HRD has been stated in previous studies. Salmanowicz et al. (2012) reported uncertain correlation between HRD and PC. Kaya and Akçura (2014) found no correlation between HRD and PC in the biplot analysis. HRD negatively correlated with AE, P and P/L traits. The response of the L and G traits were almost the same. According the biplot graph the genotypes 36, 53, 19, 35, and 3 had better AE values, 18 and 19 had better P values, 18, 27 and 51 had better P/L values, 12, 13 and 14 had better L and G values, 3, 35, and 53 had better PC values, and 9, 24 and 25 had higher HRD values indicating softer grain structure.

5. Conclusion

Due to diversity of wheat growing areas of Turkey, wheat crops are produced in different agro-ecological conditions. As a result of these variations in wheat production the quality of wheat flours from the harvested wheat product are usually variable and causes marketing difficulties for wheat millers. Millers solve the quality problems by blending the different wheat flours to meet the flour specifications of their customers. For this, the most of the modern mills have lab facilities to analyze the flours of the wheat crops and provide facilities for storing and blending flour to ensure uniform flour quality. Therefore, using flours of strong wheats, flour from standard or weak wheats may be improved to provide necessary uniform quality. The results revealed the quality status of the present genotypes in the study. The findings of this study will be useful for not only the world wheat breeders who want to develop new wheat cultivars having high yield and high quality but also the world wheat millers who wish to produce wheat flours meeting the market demands.

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