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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Investigation of Grain Yield and Biscuit Quality Capacities of Soft Bread Wheat (*T. aestivum* L.) Advanced Lines*

Yumuşak Ekmeklik Buğday (*T. aestivum* L.) İleri Hatlarının Tane Verimi ve Bisküvilik Kalite Kapasitelerinin İncelenmesi

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Abstract

The study was carried out with a total of 24 bread wheat genotypes including 20 advanced lines and 4 check varieties (Gerek79, Carisma, Bayraktar2000, and Artico) with soft grain structure and four replications according to the randomized complete block design in Hamidiye and Karabayır locations of Eskişehir during the 2014-2015 growing season. In the study, grain yield, thousand grain weight, test weight, kernel hardness, Zeleny sedimentation value, ash content and protein content were investigated in the genotypes. According to the results of the analysis of variance performed for the traits examined in the study, the differences between location, bread wheat genotypes and interaction averages were found to be statistically significant, except for Zeleny sedimentation value and protein content, respectively. It is understood that there is a wide variation between genotypes and locations for other traits, except for the protein ratio trait. While location effects are higher than genotype effects for thousand grain weight, test weight, ash content and protein content, genotype effects are higher than location for single kernel characterization system and Zeleny sedimentation value. The mean grain yield of biscuit wheat genotypes ranged from 4425 kg ha^{-1} to 2000 kg ha^{-1}. Considering the trial quality results; it was observed that there was a high rate of variation between genotypes for thousand grain weight (32.67-48.61 g), test weight (82.40-75.25 kg hl^{-1}), kernel hardness (17.08-39.68), Zeleny sedimentation value (20.63-33.00 ml) and ash content (0.478% - 0.610%), respectively. While BİS-3, BİS-6, BİS-9, BİS-18, BİS-21 and BİS-22 were best-performed lines for grain yield, BİS-3, BİS-9, BİS-11, BİS-12, BİS-13 and BİS-19 were the prominent lines for biscuit-making quality trait. It was concluded that it would be appropriate to include these lines in yield trials before registration as a variety of candidates.

Keywords: Soft bread wheat, Grain yield, Kernel characterization, Biscuit quality, Advanced line

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Öz

Bu araştırma, 2014-2015 yetiştirme döneminde Eskişehir İli Hamidiye ve Karabayır lokasyonlarında yumuşak tane yapısına sahip 20 ekmeklik buğday ileri hattı ve 4 standart ekmeklik buğday çeşit (Gerek79, Carisma, Bayraktar2000 ve Artico) olmak üzere toplam 24 ekmeklik buğday genotipi ile tesadüf blokları deneme desenine göre dört tekrarlamalı olarak yürütülmüştür. Çalışmada, genotiplerde tane verimi, bin tane ağırlığı, test ağırlığı, tane sertliği, Zeleny sedimantasyon değeri, kül oranı ve protein oranı araştırılmıştır. Araştırmada incelenen özellikler açısından gerçekleştirilen varyans analizi sonuçlarına göre, sırasıyla Zeleny sedimentasyon değeri ve protein oranı hariç lokasyon, ekmeklik buğday genotipleri ve interaksiyon ortalamaları arasındaki farklılıklar istatistiki olarak önemli bulunmuştur. Protein oranı özelliği dışında diğer özellikler için genotip ve lokasyonlar arasında oldukça geniş bir varyasyon bulunduğu anlaşılmaktadır. Bin tane ağırlığı, hektolitre ağırlığı, kül oranı ve protein oranı özellikleri için lokasyon etkilerinin genotip etkilerine oranla daha yüksek olmasına karşılık tane sertliği ve Zeleny sedimantasyon değeri özellikleri için ise genotip etkilerinin lokasyona oranla daya yüksek olduğu görülmektedir. Bisküvilik buğday genotiplerinin ortalama tane verimi 4425 kg ha^{-1} ile 2000 kg ha^{-1} arasında değişmiştir. Denemenin kalite sonuçları göz önüne alındığında; bin tane ağırlığı (32.67-48.61 g), hektolitre ağırlığı (82.40-75.25 kg hl^{-1}), tane sertliği (17.08-39.68), Zeleny sedimantasyon değeri (20.63-33.00 ml) ve kül oranı (%0.478-%0.610) için genotipler arasında yüksek oranda varyasyon olduğu görülmüştür. BİS-3, BİS-6, BİS-9, BİS-18, BİS-21 ve BİS-22 tane verimi açısından en yüksek performansa sahip hatlar iken, BİS-3, BİS-9, BİS-11, BİS-12, BİS-13 ve BİS-19 incelenen bisküvilik kalite özelikleri bakımından öne çıkan hatlar olmuştur. Bu hatların çeşit adayı olarak tescil öncesi verim denemelerine alınmasının uygun olacağı sonucuna varılmıştır.

Anahtar Kelimeler: Yumuşak ekmeklik buğday, Tane verimi, Tane karakterizasyonu, Bisküvilik kalitesi, İleri hat

1. Introduction

Cereals are the agricultural product group with the highest cultivation area and production amount in the world. Cereals such as wheat, rice, oats and barley are the cool climate cereals most commonly used as food worldwide (Das et al., 2011). Among these, wheat is the most important crop for production and consumption. Wheat is ground into flour from which various bakery products such as biscuits, bread, chapatti, pita and cakes (Khatkar and Schofield, 1997; Singh and Khatkar, 2005).

Turkey occupies 3.5% of the world's wheat cultivation area. 66.4% (15.5 million hectares) of our agricultural lands, excluding fallow areas, are reserved for field agriculture. Cereals are sown in approximately 71% of this area (11.1 million hectares). Among cereal cultivation areas, wheat ranks first with a share of 62% (TUIK, 2021). While 2.6 million tons of production and 921 kg ha^{-1} yield were achieved in a 2.8 million ha cultivation area in 1930, 21 million tons of production and 2.234 kg ha^{-1} wheat yield were achieved in a 9.4 million ha cultivation area in 2000. While a production amount of 20.6 million tons and a mean yield of 2710 kg ha^{-1} was achieved in a wheat production area of 7.6 million ha in 2016, a production amount of 20.5 million tons and a mean yield of 2970 kg ha^{-1} was achieved from a wheat cultivation area of 6.9 million ha in 2021 (TUIK, 2021).

Although the biscuit and cake industries are relatively small wheat users, they are industries with high value-added potential. The total world biscuit market has a capacity of around 7.4 billion dollars (Anonymous, 2015). Turkey's share in this market varies from year to year, but on the mean, it is around 3-4%. This is very low for Turkey, which is an agricultural country. To take the place it deserves in the biscuit world market, we first need quality raw materials and constant production at the same standard quality (Atlı, 1999). For this purpose, it is very important to encourage and recommend the cultivation of wheat varieties suitable for biscuit making (Öztürk and Özdağ, 1993). To achieve this aim, it is primarily necessary to breed new wheat varieties that have superior biscuit properties or to determine the suitability of existing ones (Şahin et al., 2012). The need for specialized breeding programs that will provide quality raw materials and develop high-yield varieties for the biscuit industry is increasing day by day (Karaduman, 2013; Karaduman et al.,2018; Karaduman et al., 2021).

Factors affecting wheat quality are generally divided into two groups: physical and chemical properties. Chemical properties such as protein content, SDS-sedimentation value and gluten strength, and physical properties such as grain glassiness, color, weight, shape and hardness are frequently used to evaluate wheat grain quality (Gaines et al., 1996).

The main purpose of this study, which was carried out in two locations in Eskişehir with 20 advanced wheat lines that were improved and selected for biscuit quality in the Wheat Breeding Program of the Transitional Zone Agricultural Research Institute in Eskişehir, was to examine the changes in the grain yield and some biscuit quality traits of the genotypes and to evaluate the performance of the lines for the characters, and to identify promising lines that may be candidates for registration and new gene resources that have the potential to be used in biscuit wheat breeding studies.

2. Materials and Methods

The research material was sown in two locations, under rainfall conditions of Eskişehir, according to a randomized complete block design (RCBD) with 4 replications. In the research, 20 advanced lines of bread wheat with a soft grain structure, developed by the Transition Zone Agricultural Research Institute, and 4 commercially preferred check varieties, two of which were domestic (Gerek 79 and Bayraktar 2000) and two of which were of foreign origin (Carisma and Artico), were used as materials (for full material see Erenler et al., 2022).

The study was carried out with the randomized complete block design (RCBD) with 4 replications in two locations (Hamidiye and Karabayır) during the 2014-2015 wheat growing season. When the long-term average data for Eskişehir Province between September and June were analyzed, it was found that there was an average temperature of 8.2°C and a total of 327.6 mm precipitation. The mean temperature (9.1°C) and total precipitation (579.5 mm) in the year of the experiment were higher than the long-term. The soil of the experimental area in Hamidiye was clay-loam, slightly alkaline (pH 7.31), salt-free (0.02%) and low in organic matter (0.9%). The soil of the experimental area in Karabayır was clay, slightly alkaline (pH 7.62), salt-free (0.03%) and low in organic matter (0.9%).

Sowing was done with a plot seeder in plots 5 m long and 0.85 m wide with 500 seeds per square meter. In the experiments, 30 kg pure N and 70 kg $P_2 0_5$ were given per hectare with sowing. Also, 60 kg of pure N per hectare was given in the spring before the stem elongation period. Each experimental plot as 4.08m² was harvested with a plot combine.

Grain yield (GY) (kg ha^{-1}) was calculated as 4.08 m² by removing the plants at 0.50 m from the beginning and the end as an edge effect in the plots sown in 6 rows in the experiment, and the grain yield of this plot was converted into hectare yield and found in kilograms. Thousand grain weight (TGW) and test weight (TW) were determined according to the method suggested by Özkaya and Özkaya (2005) and the results were given as grams and kg hl^{-1} on dry matter, respectively. Kernel hardness (KH) was determined using the (Perten Instruments Springfield.IL) Single Kernel Characterization System (SKCS) device (Anonymous, 2008). Protein content (PC) (%) was determined in whole grain flour samples using the Near FOSSNIRS 6500 device. The device was calibrated using the LEC FP628 operating according to the Dumas method (AACC Method 46-30) (AACC, 2000; Elgün et al., 2002). Zeleny sedimentation value (ZSV) (ml) was determined according to the ICC-Standard No 116 method (Anonymous, 1981). Ash content (AC) (%) was determined according to the method indicated by Özkaya and Özkaya (2005).

The data obtained from the experiments carried out in two locations were subjected to analysis of variance according to the two-factor RCBD, and then it was checked whether the differences between genotypes were statistically significant or not by using the LSD (Least Significant Difference) test according to the method recommended by Steel and Torrie (1960) using 3.00/EM version MSTAT package program.

3. Results and Discussion

The differences between the mean values of the genotypes were found to be statistically significant according to the variance analysis results for the characters, except for the protein content in Hamidiye and Karabayır locations in Eskişehir (*Table 1*).

Table 1. Mean squares of source of variation (SOV) for the characters

SOV	Replication (R)	Location (L)	Genotype (G)	GxL Interaction	Error
Df	3	1	23	23	141
TGW	3.760	3699.102**	128.414**	25.266**	3.726
TW	1.303	1995.630**	31.630**	20.513**	2.281
KH	6.756	173.280**	303.209**	335.580**	3.530
ZSV	17.419	0.005	63.770**	71.962**	6.823
AC	0.005	0.245**	0.007**	0.008**	0.002
PC	1.404	13.483*	0.573	0.666	0.547
GY	2143.535	238431.021**	28734.988**	39969.488**	1478.708

Df: degree of freedom, *significant at the %5 level, **significant at the 1% level

The results of the significance test performed on the data regarding grain yield and quality characteristics obtained from the experiments carried out in the Hamidiye and Karabayır locations of Eskişehir Province are given in *Table 2*. The means in *Table 2* are obtained from the combined analysis of the locations.

Because of an indicator affecting milling quality (Protic et al., 2007), seed quality affecting pre-harvest germination, seed potential, seedling development and plant performance (Afshari et al., 2011), an important component of grain yield (Simpson, 1968) and due to it is used to determine the density of seeds to be sown per unit area, thousand grain weight is considered as one of the versatile characters that should be emphasized in breeding studies.

The mean thousand grain weights of the genotypes obtained from the experiments carried out in two locations during the 2014-2015 growing period when the research was conducted varied between 32.67 g and 48.61 g, and the mean thousand grain weights of the lines were found to be higher than those of the check varieties. Among the lines, BİS-11 (48.61 g) and BİS-23 (42.78 g) gave the highest thousand grain weight. BİS-22, BİS-19 and BİS-12 were other lines with high thousand grain weights (*Table 2*). Our results are similar to the findings of the studies carried out by Karaduman (2013) and Şahin et al. (2012) to investigate the biscuit quality characteristics of soft bread wheat lines.

Table 2. Means and their importance for the grain yield and quality characteristics of the genotypes

Genotypes	TGW (g)	TW (kg hl^{-1})	KH	ZSV (ml)	Ash content (%)	PC (%)	GY (kg ha^{-1})
BİS-1	34.29 kl	78.97 de	17.08 k	25.88 c-g	0.534 c-h	12.04	3238 fg
BİS-2	37.34 ghi	78.58 def	19.84 j	25.38 d-g	0.610 a	12.42	3016 gh
BİS-3	37.08 hi	81.35 ab	23.57 gh	26.50 c-f	0.478 h	11.96	3761 cde
BİS-4	36.24 ijk	75.25 h	30.24 cd	33.00 a	0.571 a-g	12.39	2879 ghi
BİS-6	32.67 lm	76.37 gh	24.96 fg	29.00 bc	0.550 b-g	12.38	3524 def
BİS-7	34.09 klm	76.84 fgh	25.05 fg	27.25 c-f	0.546 b-g	12.03	3296 efg
BİS-8	40.11 c-f	81.11 abc	26.35 ef	25.88 c-g	0.545 b-g	12.16	3384 efg
BİS-9	40.84 b-e	78.76 def	24.11 fgh	24.50 e-h	0.585 a-d	11.87	3896 bcd
BİS-11	48.61 a	81.24 ab	23.24 gh	28.38 bcd	0.543 b-g	11.75	3346 efg
BİS-12	41.69 bcd	79.14 cde	24.41 fgh	27.38 cde	0.526 e-h	11.89	3225 fg
BİS-13	37.14 ghi	75.33 h	29.43 d	23.88 f-ı	0.596 ab	12.75	2000 j
BİS-14	36.85 hij	80.00 bcd	27.83 de	26.88 c-f	0.550 b-g	12.15	2538 hi
BİS-16	39.38 d-h	79.36 b-e	27.79 de	26.25 c-g	0.591 ab	12.22	3298 efg
BİS-17	39.66 c-g	78.98 de	20.47 ıj	27.63 b-e	0.588 abc	12.63	2949 ghi
BİS-18	34.49 jkl	78.87 de	39.68 a	27.50 b-e	0.554 a-g	12.44	3539 def
BİS-19	41.09 bcd	81.23 ab	23.51 gh	21.63 hı	0.529 d-h	12.15	3198 fg
BİS-21	35.99 ijk	78.00 efg	36.18 b	24.63 e-h	0.525 fgh	12.02	3671 c-f
BİS-22	42.04 bc	81.08 abc	39.12 a	25.88 c-g	0.575 a-f	11.91	4425 a
BİS-23	42.78 b	82.40 a	29.74 d	25.38 d-g	0.533 c-h	12.38	2909 ghi
BİS-24	32.68 lm	77.59 efg	38.14 ab	26.38 c-f	0.575 a-f	12.31	2673 hi
Mean of Lines	***38.25***	***79.02***	***27.54***	***26.46***	***0.48***	***12.19***	***3283***
Gerek79	38.16 f-i	80.31 bcd	22.77 ghı	22.88 ghı	0.515 gh	12.39	4059 abc
Carisma	31.69 m	77.92 efg	24.10 fgh	21.63 hı	0.546 b-g	12.70	2490 ij
Bayraktar2000	38.49 e-i	81.07 abc	32.42 c	30.88 ab	0.583 a-e	12.10	4080 abc
Artico	32.53 lm	76.88 fgh	22.36 hı	20.63 ı	0.561 a-g	12.30	4361 ab
Mean of Check varieties	***35.22***	***79.04***	***25.41***	***24.00***	***0.55***	***12.37***	***3748***
LSD$_{0.01}$	2.547	1.993	2.479	3.447	0.057		50.740

Values followed by the same letter(s) are not significantly different at the 1% probability level according to LSD test

Although believed to be a good indicator of end-use quality, test weight has little effect on milling and baking quality measurements in wheat (Kelman and Qualset, 1993). Its only significant effect is on flour yield (Souza et al., 2012). However, although test weight is not frequently used by millers as a potential estimator of flour yield because the impact of the environment is quite high (Carson and Edwards, 2009), high test weight is accepted as an indicator of the general density and solidity of the grain and is still a quality character that is considered in the classification of wheat (Williams et al., 1986). The genotypes had test weight means ranging from 82.40 kg hl^{-1} to 75.25 kg hl^{-1} (*Table 2*). Kurt and Yağdı (2013) determined that test weights of bread wheat advanced lines varied between 68.33-81.07 kg hl^{-1} in their study. It is seen that there is no significant difference between the test weight means of line and check varieties. Our findings are similar to the results of the study conducted by Karaduman and Ercan (2011), in which they examined the yield and some grain characteristics of advanced soft bread wheat lines selected for biscuit production in dry and wet conditions.

The grain structure of wheat is divided into hard and soft (Souza et al., 2012). Whether the grain is soft or hard can be determined by measuring the starch amylose content using the Single Kernel Characterization System (SKCS). This device measures grain weight and volume, crushing resistance and kernel hardness and provides reliable measurement (Dobraszczyk et al., 2002). Low SKCS values indicate a softer endosperm structure and high TDKS values indicate harder endosperm structure (Carter et al., 2012). Endosperm structure, or the relative hardness or softness of a grain, can be defined as a measure of resistance to deformation. This definition is based on the measurement of hardness by SKCS, which measures the force required to break individual grains of a sample between two surfaces, taking into account the weight, diameter and moisture of the grains. SKCS hardness means of genotypes varied between 17.08 and 39.68 in the study (*Table 2*). While the mean hardness of the lines is 27.54, the mean of check varieties is calculated as 25.41. BİS-18 and BİS-22 lines gave the highest hardness mean. These lines were followed by BİS-24 and BİS-21 lines. Along with BİS-1 and BİS-2 lines, BİS-3, BİS-6, BİS-7, BİS-8, BİS-9, BİS-11, BİS-12, BİS-14, BİS-16, BİS-17 and BİS 19 lines had the lowest mean hardness indicate that may be suitable lines in terms of biscuit quality due to their low hardness levels. There are similarities between our results and Morris et al. (2005) results, where the mean values of hardness values of thirty varieties of wheat were found to be between 11.8-49.9 and the general mean was 24.0.

Since the Zeleny sedimentation test reflects differences in both protein content and gluten quality and is heritable (Bushuk, 1982), it provides the opportunity for reliable selection by identifying quality lines in early or advanced generations (Kitterman and Barmore, 1969). The mean Zeleny sedimentation values of the genotypes varied between 20.63 ml and 33.00 ml (*Table 2*). The mean of the lines was calculated as 26.46 ml, and the lowest and highest means were obtained from BİS-19 line and BİS-4 lines, respectively. The mean of the varieties used as standard was calculated as 24.00 ml. The mean of the lines was higher than the mean of the varieties. It is understood that BİS-13, BİS-19 and BİS-9 lines have lower Zeleny sedimentation value results than other biscuit lines and check varieties for the desired soft wheat grain characteristics. Low gluten content and weak gluten network structure allow the dough to spread more easily during baking (Zheng et al., 2020). Since the Zeleny sedimentation test reflects heritable differences in both protein content and gluten quality, it appears that these lines can be evaluated with confidence. Kurt Polat and Yagdı (2017) results of Zeleny sedimentation value between 25 ml and 39.0 ml support to our findings.

The ash content, which varies depending on the amount of bran in the flour, is a criterion that shows the final evaluation quality of the flour. Since the ash content is higher in the husk part of the wheat, a high amount of ash in the flour indicates that too much bran is mixed into the flour and indicates that the quality of the flour is low (Ertugay, 1982). The mean ash content of the genotypes varied between 0.478% and 0.610%. BİS-2 gave the highest mean ash content among the lines (0.610%) followed by BİS-13 (0.596%) and BİS-16 (0.591%) genotypes (*Table 2*). BİS-3, BİS-12, BİS-21 and BİS-19 lines gave the lowest mean ash content, respectively. It is seen that the ash content of BİS-3 line is lower than other biscuit lines and check varieties and these lines can be evaluated for high biscuit-making flour quality. Our findings are similar to the research results of Al-Saleh and Brennan (2012), who stated that the ash content was between 0.63% and 0.72%, and the result of Karaduman (2013), who determined the ash amount to be 0.43% on the mean.

Grain protein content in wheat is the most important quality criterion in terms of milling and baking (Feil, 1997), and the most effective data to be used in determining the tannin quality and especially the purpose for which wheat will be used is the amount of protein (Godwin et al., 1999). Cereal protein content, especially seed storage protein, has a major impact on quality by influencing the viscoelastic properties of wheat dough through the formation of a gluten network (Zhou et al., 2018). Although the differences between the protein means of the genotypes were not found to be statistically significant, it is generally seen that the mean protein content of the lines is relatively lower than that of the check varieties (*Table 2*). Among the lines, BİS-11, BİS-9, BİS-12, BİS-22, BİS-3, BİS-21, BİS-7 and BİS-1, which have a lower protein content than other lines and check varieties, maybe the most appropriate lines for biscuit-making traits. There are similarities between our results and the findings of Şahin et al. (2012), who determined the protein content of biscuit wheat as 13.63% on mean, between 11.65% and 15.54%, and Keçeli et al. (2017), who determined it to be 12.65% on the mean.

In wheat breeding programs, the primary goals include the development of new varieties with high grain yield per unit area as well as grain quality. Genotype means varied between 4425 kg ha^{-1} and 2000 kg ha^{-1} (*Table 2*). The mean grain yield of the lines was found to be lower than that of check varieties. When the individual and combined significance test results of the locations are evaluated for the grain yield feature; it is seen that BİS-22, BİS-9 and BİS-3 have the highest grain yield among the lines and above the mean of check varieties. In addition to these lines, it is understood that BİS-6, BİS-18 and BİS-21 can be evaluated as other high-yield lines in terms of grain yield. Our results are supported by the findings of Şahin et al. (2012) and Karaduman et al. (2016).

4. Conclusions

As a result of the research, the differences between the genotype means for the examined traits, except for the protein content, were statistically significant. The means of the genotypes were 4425 kg ha^{-1} to 2000 kg ha^{-1} for grain yield, 32.67 to 48.61 g for TGW, 82.40 to 75.25 kg hl^{-1} for TW, 17.08 to 39.68% for SKCS hardness, 20.63 ml to 33.00 ml for ZSV, 0.478% and 0.610% for ash content and 11.75% and 12.70% for PC. While BİS-3, BİS-6, BİS-9, BİS-18, BİS-21 and BİS-22 were best-performed lines for grain yield, BİS-1, BİS-3, BİS-9, BİS-11, BİS-12, BİS-19, BİS-21, BİS-22 and BİS-23 were the lines that were suitable in terms of biscuit quality traits.

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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: Bilgin, O.; Design: Bilgin, O., Başer, İ., Balkan, A.; Data Collection or Processing: Erenler, S.; Statistical Analyses: Bilgin, O.; Literature Search: Bilgin, O., Erenler, S., Balaban Göçmen, D.; Writing, Review and Editing: Bilgin, O., Erenler, S., Başer, İ., Balkan, A., Balaban Göçmen, D.

References

AACC (2000). Approved Methods of the AACC, 10th ed. Methods 08-01, 44-16, 46-30, 56-10, 56-11, and 56-61A. Cereals & Grains Association, St. Paul, MN, U.S.A.

Afshari, H., Eftekhari, M., Faraji, M., Ebadi, A. G. and Ghanbarimalidareh, A. (2011). Studying the effect of 1000 grain weight on the sprouting of different species of *Salvia* L. grown in Iran. *Journal of Medicinal Plants Research,* 5(16): 3991-3993.

Al-Saleh, A. and Brennan, C. S. (2012). Bread wheat quality: Some physical, chemical and rheological characteristics of syrian and english bread wheat samples. *Foods,* 1(1):3-17.

Anonim (2015). Bisküvi. T.C. Ekonomi Bakanlığı, İhracat Genel Müdürlüğü Tarım Ürünleri Daire Başkanlığı, Sektör Raporları, https://eb.ticaret.gov.tr/portal/content/conn/UCM/uuid/dDocName:EK-235392 (Accessed Date: 05.01.2019).

Anonymous (1981). ICC Standards. International Association for Cereal Chemistry, Vienna.

Anonymous (2008). USDA/ARS – Western Wheat Quality Laboratory E-202 Food Science & Human Nutrition Facility, http://www.wsu.edu/~wwql/php/wheat-wrn.php (Accessed Date: 22.06.2008).

Atlı, A. (1999). Wheat and Products Quality. *Symposium on Problems and Solutions of Cereal Cultivation in Central Anatolia*; 498-506, Konya, Türkiye. (In Turkish).

Bushuk, W. (1982). Grains and Oilseeds. 3rd Edition. Canadian International Grains Institue, Winnipeg, Manitoba.

Carson, G. R. and Edwards, N. M. (2009). Criteria of Wheat and Flour Quality. In Wheat Chemistry and Technology (4th Edition*)*, AACC International, Inc., St. Paul, U.K.

Carter, A. H., Campbell, K. G., Morris, C. F. and Kidwell, K. K. (2012). Chromosomes 3B and 4D are associated with several milling and baking quality traits in a soft white spring wheat (*Triticum aestivum* L.) population. *Theoretical and Applied Genetics,* 124:1079-1096.

Das, A., Raychaudhuri, U. and Chakraborty, R. (2011). Cereal based functional food of Indian subcontinent: A review. *Journal of Food Science and Technology,* 49(6): 665-672.

Dobraszczyk, B. J., Whitworth, M. B., Vincent, J. F. V. and Khan, A. A. (2002). Single kernel wheat hardness and fracture properties in relation to density and the modelling of fracture in wheat endosperm. *Journal of Cereal Science,* 35: 245-263.

Elgün, A., Ertugay, Z., Kotancılar, H. G. and Certel, M. (2002). Tahıl ve Ürünlerinde Analitik Kalite Kontrolü ve Laboratuar Uygulama Kılavuzu (3. Baskı). Atatürk Üniversitesi Ziraat Fakültesi, Yayın No:335, Erzurum.

Erenler, S., Bilgin, O., Balkan, A. and İ. Başer (2022). Using the solvent retention capacity tests to determine the biscuit-making quality of soft bread wheat (*T. aestivum* L.) genotypes. *Journal of Tekirdag Agricultural Faculty,* 19(2): 296-304.

Ertugay, Z. (1982). Quality relationships between wheat, flour and bread. *Journal of Ataturk University Faculty of Agriculture* 13(1-2): 165-176. (In Turkish).

Feil, B. (1997). The inverse yield-protein relationship in cereals: Possibilities and limitations for genetically improving the grain protein yield. *Trends Agronomy,* 1: 103-119.

Gaines, C. S., Finney, P. F., Fleege, L. M. and Andrews, L. C. (1996). Predicting a hardness measurement using the single-kernel characterization system. *Cereal Chemistry,* 73: 278-283.

Godwin, I. D., Williams, S. B., Pandit, P. S. and Laidlaw, H. K. C. (1999). Multifunctional grains for the future: genetic engineering for enhanced and novel cereal quality. *In Vitro Cellular & Developmental Biology-Plant,* 45: 383-399.

Karaduman, Y. (2013). *Investigating of cookie quality characteristics in selected soft bread wheat lines.* (PhD. Thesis) Ankara University Graduate School of Natural and Applied Sciences, Ankara. (In Turkish).

Karaduman, Y. and Ercan, R. (2011). Yield and some grain characteristics of soft bread wheat lines selected for cookie-making in rainfed and irrigated conditions. *Journal of Field Crops Central Research Institute,* 20(2): 1-9.

Karaduman, Y., Akın, A., Belen, S., Sönmez, A. C., Dayıoğlu, R. and Bayramoğlu, H.O. (2021). Evaluation of soft winter wheat for soft-hard dough biscuit quality. *Journal of Cereal Science,* 102: 1-11.

Karaduman, Y., Akın, A., Belen, S., Sönmez, A. C., Dayıoğlu, R., Tunca, Z. Ş., Türkölmez, S., Sayaslan, A., Bayramoğlu, H. O., Aydın, N. and Demir, H. (2016). *Development of wheat genotypes with high biscuit quality.* Tübitak-1003 (214O050) Project Report. (In Turkish).

Karaduman, Y., Belen, S., Sönmez, A. C., Akın, A., Sayaslan, A., Dayıoğlu, R., Aydın, N. and Tunca, Z. Ş. (2018). Soft Wheat (*T.* aestivum) Development Studies Suitable for The Demands of The Biscuit Industry. *Türkiye Local Wheat Symposium*, 122-123, Bolu, Türkiye. (In Turkish).

Keçeli, A., Evlice, A. K., Pehliven, A., Şanal, T., Karaca, K., Külen, S., Subaşı, A. S. and Salantur, A. (2017). Investigation of the relationship between Zeleny sedimentation analysis and other quality parameters in bread wheat (*Triticum aestivum* L.). *KSÜ Journal of Agriculture and Nature* 20 (Special Issue): 292-296. (In Turkish).

Kelman, W.M. and Qualset, C.O. (1993). Responses of recombinant inbred lines of wheat to saline irrigation: Milling and baking qualities. *Crop Science,* 33:1223-1228.

Khatkar, B. S. and Schofield, D. (1997). Molecular and physicochemical basis of breadmaking properties of wheat gluten proteins: A critical appraisal. *Journal of Food Science and Technology,* 34:86-102.

Kitterman, J. S. and Barmore, M. A. (1969). A modified micro sedimentation test for screening early-generation wheat selections. *Cereal Chemistry,* 46: 273-280.

Kurt Polat, P. O. and Yagdı, K. (2017). Investigations on the relationships between some quality characteristics in a winter wheat population. *Turkish Journal of Field Crops,* 22(1): 108-113.

Kurt, P. Ö. and Yağdı, K. (2013). Investigation of quality traits performance of some advanced bread wheat (*Triticum aestivum* L.) lines under in Bursa conditions. *Journal of Tekirdag Agricultural Faculty,* 10(2): 34-43.

Morris, C. F., Campbell, K. G. and Kin, G. E. (2005). Kernel texture differences among US soft wheat cultivars. *Journal of the Science of Food and Agriculture,* 85: 1959-1965.

Özkaya, H. and Özkaya, B. (2005). Tahıl ve Ürünleri Analiz Yöntemleri. Gıda Teknolojisi Derneği Yayınları No: 31, Ankara.

Öztürk, S. and Özdağ, S. (1993). Bisküvi Teknolojisi ve Sorunları. *1. Un-Bulgur-Bisküvi Sempozyumu*. 21-22 Haziran, S. 27-29. Karaman, Türkiye.

Protic, R., Jovin, P., Protic, N., Jankovic, S. and Jovanovic, Z. (2007). Mass of 1,000 grains in several winter wheat genotypes, at different dates of sowing and rates of nitrogen fertilizer. *Romanian Agricultural Research*, 24: 39-42.

Şahin, M., Akçacık, A.G., Aydoğan, S., Ayrancı, R., Çeri, S., Bağcı, S.A., Akçura, M., Özer, E., Ekici, M. and Görgülü, M.N. (2012). *Biscuit wheat variety improvement project*. Bahri Dağdaş International Agricultural Research Institute (TAGEM) Project Report.

Simpson, G. M. (1968). Association between grain yield per plant and photosynthetic area above the flag leaf node in wheat. *Canadian Journal of Plant Science,* 48: 253.

Singh, M. and Khatkar, B.S. (2005). Structural and functional properties of wheat storage proteins: A review. *Journal of Food Science and Technology,* 42:455-471.

Souza, E. J., Sneller, C., Guttieri, M. J., Sturbaum, A., Griffey, C., Sorrells, M., Ohm, H. and Van Sanford, D. (2012). Basis for selecting soft wheat for end-use quality. *Crop Science,* 52(1): 21-31.

Steel, R. G. D. and Torrie, J. H. (1960). Principles and Procedures of Statistics. Mc-Graw-Hill Book Co. Inc. New York.

TUIK (2021). TUIK İstatistik Veritabanı http://tuikapp.tuik.gov.tr/bitkiselapp/bitkisel.zul (Accessed Date: 18.06. 2022).

Williams, P., El-Haramein, F. J., Nakkoul, H. and Rihawi, S. (1986). Crop Quality Evaluation Methods and Guidelines. ICARDA, Syria.

Zheng, B., Zhao, H., Zhou, Q., Cai, J., Wang, X., Cao, W., Dai, T. and Jiang, D. (2020). Relationships of protein composition, gluten structure and dough rheological properties with short biscuits quality of soft wheat varieties. *Agronomy Journal*, 112:1921-1930.

Zhou, Q., Li, X., Yang, J., Zhou, L., Cai, J., Wang, X., Dai, T., Cao, W. and Jiang, D. (2018). Spatial distribution patterns of protein and starch in wheat grain affect baking quality of bread and biscuit. *Journal of Cereal Science,* 79: 362-369.