Turkish Journal of Agriculture and Forestry

Volume 36 | Number 3 Article 5

1-1-2012

Differences in some physical and chemical properties of wheat grains from different parts within the spike

HÜSEYİN BOZ

KAMİL EMRE GERÇEKASLAN

MEHMET MURAT KARAOĞLU

HALİS GÜRBÜZ KOTANCILAR

Turk J Agric For
36 (2012): 309-316
© TÜBİTAK
doi:10.3906/tar-1102-41

Research Article

Differences in some physical and chemical properties of wheat grains from different parts within the spike

Hüseyin BOZ[1,*], Kamil Emre GERÇEKASLAN[2], Mehmet Murat KARAOĞLU[2], Halis Gürbüz KOTANCILAR[2]

[1]Food Technology Department, Narman Vocational High School, 25300 Narman, Erzurum - TURKEY

[2]Food Engineering Department, Faculty of Agriculture, Atatürk University, 25240 Erzurum - TURKEY

Received: 17.02.2011

Abstract: There is not enough information on the distribution of grain components from different areas within a spike of wheat. The aim of this study was to determine how grain position affects some physical and chemical properties of grains. Grain size, thousand-grain and hectoliter weight, Zeleny sedimentation, falling number, wheat color, grain hardness, wet and dry gluten contents, and protein and ash contents were determined in grains from different parts of the spike (bottom, middle, and top) in Karasu-90, Palandöken-97, Yıldırım, Bezostaya-1, and Doğu-88 wheat varieties. Grain position in the spike had a significant effect on some physical and chemical properties of grains. The protein content of grains increased from the top to the bottom of the spike. Grains from the middle portion of wheat spikes were larger than those from the top and bottom portions. The lowest dry gluten values were obtained from the top part while the highest values were determined in the bottom of the spike. In addition, significant differences were observed among grain positions within the spike based on hectoliter weights.

Key words: Grain position, physical and chemical properties, spike, wheat

Başak üzerinde farklı kısımlarda bulunan buğday tanelerinin bazı fiziksel ve kimyasal özelliklerindeki farklılıklar

Özet: Buğday başağı içerisinde farklı kısımlarda bulunan tanelerin bileşen dağılımı hakkında çok fazla bilgi mevcut değildir. Bu çalışma tanelerin bazı fiziksel ve kimyasal özelliklerini tane pozisyonunun nasıl etkilediğinin daha iyi anlaşılmasını amaçlamıştır. Bu amaçla beş farklı buğday çeşidinde (Karasu-90, Palandöken-97, Yıldırım, Bezostaya-1 ve Doğu-88) başağın farklı kısımlarından (alt, orta ve üst) elde edilen tanelerde irilik, bin dane ağırlığı, hektolitre ağırlığı, sertlik, protein, kül, düşme sayısı, Zeleny sedimentasyon, yaş ve kuru öz içerikleri belirlenmiştir. Başakta tane pozisyonunun tanelerin fiziksel ve kimyasal özelliklerini önemli ölçüde etkilediği belirlenmiştir. Buğday tanelerinin protein içeriği üst kısımdan alta doğru artış göstermiştir. Başağın orta kısmından elde edilen tanelerin alt ve üst kısımlardaki tanelerden daha büyük olduğu gözlemlenmiştir. En düşük kuru gluten içeriği başakların üst kısımlarında tespit edilmiştir. Bu çalışmada başağın farklı kısımlarından elde edilen tanelerin hektolitre ağırlıkları arasında da önemli farklılıklar belirlenmiştir.

Anahtar sözcükler: Buğday, başak, fiziksel ve kimyasal özellikler, tane pozisyonu

* E-mail: huseyinboz@atauni.edu.tr

Introduction

Wheat is an annual plant consisting of roots, a stem, leaves, and a head, also known as a spike. The spike is the part of the plant where grain is formed and is generally made up of a zigzag central axis that supports alternating spikelets. Spikelets develop at nodes in the spike, and the flowers and seeds develop in these spikelets (Magness et al. 1971). Grains from different spike positions are synthesized at different times, and they have different compositions (Huebner et al. 1990).

Little is known about component distribution within the spike of bread wheat (*Triticum aestivum* L.). Several researchers have analyzed grains at various locations along the wheat spike. After dividing the spike into 3 equal sections, Ali et al. (1969) found that the lowest third of the spike contained the highest protein content. Their study showed that protein content decreases toward the top of the spike. Significant differences in protein content among the top, middle, and bottom portions of the spike were verified by Miller (2003), as well. Calderini and Ortiz-Monasterio (2003) investigated the nutrient supply in individual grains throughout the spike and found that concentrations of Mg, Ca, K, P, and S decreased in the third and fourth florets. However, there has been no extensive and detailed research on this subject.

We investigated differences in some physical and chemical properties of grains obtained from different parts of the spike. The objective of this study was to determine how grain position affects protein content, ash distribution, grain size, wheat color, hectoliter and thousand-grain weight, falling number, Zeleny sedimentation, and grain hardness.

Materials and methods

In this study, 5 different wheat varieties were used (Karasu-90, Palandöken-97, Yıldırım, Bezostaya-1, and Doğu-88). Wheat spikes were gathered by hand from the same field. After harvesting, the wheat grain was cleaned manually to dispose of dust and other foreign materials. Each spike was then divided into 3 equal sections (bottom, middle, and top). Wheat grains were separated from the wheat spike and packed in air-tight plastic containers.

Analytical methods

The hectoliter and thousand-grain weights of each wheat variety were determined as described by Elgün et al. (1999). Moisture and ash contents were determined according to American Association of Cereal Chemists (AACC)-approved methods 44-15A and 08-01 (AACC 2000). Wet and dry gluten contents were determined according to International Association for Cereal Science and Technology standard method 137-1 (ICC 2000) using the Glutomatic 2200 system (Perten, Huddinge, Sweden). Falling and liquid number values and Zeleny sedimentation volumes were determined according to AACC method 56-81 (AACC 1983) and International Association of Cereal Chemistry standard method 115-116 (IACC 1972). Protein in wheat flour was determined by approved method 46-11A (AACC 2000). The factor N × 6.25 was used to convert nitrogen to protein. All results are given on a 14% moisture basis. Color intensity was determined using the Minolta Colorimeter CR-200 (Minolta Camera Co., Osaka, Japan) (Elgün et al. 1999). Data were presented as *L*, *a*, and *b* values of the Hunter color system. The *L* value represents lightness (values range from 0 to 100, dark to light), while the *a* and *b* values are chromatic components of (+) redness to (-) greenness and (+) yellowness to (-) blueness, respectively. All determinations were carried out in triplicate. Seed size classes (large, medium, and small) were obtained by passing common seed over 2.8-, 2.5-, and 2.2-mm sieves. Large seed was retained on the 2.8-mm sieve, medium-sized seed passed through the 2.8-mm sieve but was retained on the 2.5-mm sieve, and small seed passed through the 2.5-mm sieve but was retained on the 2.2-mm sieve.

Grain hardness

Grain hardness was evaluated by compression test using a TA-XT-plus texture analyzer (Stable Micro Systems, Godalming, UK). The following parameters were used: load cell = 30 kg, probe = aluminum cylinder with 10 mm diameter, test speed = 0.5 mm/s, and trigger force = 5.0 g. Grain hardness was defined as the maximum force needed to compress the disk to 40% of its height. Each hardness value was reported as the mean of 15 measurements.

Statistical analysis

All data were subjected to analysis of variance based on general linear models for measurement using SPSS. Grain location within the spike and the wheat components were tested for significance using analysis of variance (ANOVA) techniques. Means were compared using Duncan's multiple range test at the level of $P < 0.005$. All data are presented as mean ± standard error (SE).

Results

The ANOVA results for physical and chemical characteristics of wheat varieties and grains from different parts within the wheat spikes are given in Table 1. Of the main variance sources, the variety of wheat and grain position in the spike had a significant ($P < 0.01$) effect on hectoliter and thousand-grain weight, Zeleny sedimentation, wet and dry gluten contents, falling and liquid numbers, wheat color, grain hardness, ash, protein, and grain size. Wheat variety and grain position interaction significantly affected hectoliter weight ($P < 0.01$), Zeleny sedimentation ($P < 0.01$), dry gluten content ($P < 0.05$), falling and liquid numbers ($P < 0.01$), *L* color value ($P < 0.01$), grain hardness ($P < 0.01$), and grain size ($P < 0.01$).

Both wheat variety and grain position had a very significant ($P < 0.01$) effect on thousand-grain weight, wet gluten content, and ash and protein values (Table 2). The protein content of the wheat investigated in this study varied from 7.50% to 16.17%. The Doğu-88 and Karasu-90 varieties had the lowest protein content, whereas Yıldırım had the highest. This situation reflects on the wet gluten content; the highest wet gluten was seen in Yıldırım and Bezostaya-1. In general, thousand-grain weight was greater in the middle than in the bottom, while

Table 1. Analysis of variance for physical and chemical characteristics of wheat varieties and grains from different parts within wheat spikes.

	Source of variation						
	Wheat variety (A)	df	Grain position (B)	df	A × B	df	Error
Thousand-grain weight (g)	152.67**	4	61.72**	2	2.14	8	14
HectoHectolitre (kg/hL)	164.75**	4	125.45**	2	14.69**	8	14
Grain size classes (% grains)							
>2.8 mm	6025.22**	4	2249.22**	2	232.48**	8	14
2.8-2.5 mm	3870.72**	4	1287.03**	2	190.20**	8	14
2.5-2.2 mm	5154.58**	4	2223.45**	2	1907.90**	8	14
<2.2 mm	17.87**	4	6.66	2	11.87**	8	14
Grain hardness (N)	333.73**	4	51.11**	2	17.16**	8	14
Wheat color *L*	556.22**	4	8.96*	2	28.88**	8	14
Wheat color +*a*	2.70	4	0.01	2	2.00	8	14
Wheat color +*b*	65.15**	4	3.92	2	2.04	8	14
Wet gluten (%)	95.11**	4	22.41**	2	4.37	8	14
Dry gluten (%)	85.37**	4	24.81**	2	5.37*	8	14
Gluten index	44.52**	4	2.31	2	4.06	8	14
Zeleny sedimentation (cm^3)	13045.50**	4	61.00**	2	68.50**	8	14
Falling number (s)	1218.51**	4	23.19**	2	17.32**	8	14
LN	360.19**	4	33.28**	2	17.50**	8	14
Protein (%)	519.16**	4	47.13**	2	3.48	8	14
Ash (%)	299.18**	4	21.99**	2	3.51	8	14

*F: significant at 5% level, **F: significant at 1% level; LN: liquid number.

Table 2. The effect of wheat variety and grain position on thousand-grain weight and wet gluten, protein, and ash contents (mean ± SE)[a].

	n	Thousand-grain weight (g)	Wet gluten (%)	Protein (%)	Ash (%)
Part of the spike					
Bottom	10	38.24 ± 1.26b	39.97 ± 2.00a	13.26 ± 1.16a	1.81 ± 0.06a
Middle	10	39.32 ± 1.27a	39.87 ± 2.16a	12.33 ± 1.13b	1.77 ± 0.06b
Top	10	35.06 ± 1.56c	35.22 ± 2.64b	11.55 ± 0.99c	1.73 ± 0.05c
P		**	**	**	
Wheat varieties					
Palandöken-97	6	40.64 ± 0.69a	30.94 ± 1.05c	14.11 ± 0.52b	1.97 ± 0.03a
Yıldırım	6	37.92 ± 0.68b	45.79 ± 1.14a	16.17 ± 0.42a	1.78 ± 0.02c
Bezostaya-1	6	38.11 ± 0.90b	46.18 ± 0.70a	14.52 ± 0.32b	1.92 ± 0.01b
Karasu-90	6	29.93 ± 1.22c	36.18 ± 2.50b	9.60 ± 0.35c	1.44 ± 0.01e
Doğu-88	6	41.10 ± 0.92a	32.69 ± 1.09c	7.50 ± 0.12d	1.44 ± 0.01e
P		**	**	**	**

[a]Values are given as mean ± SE; means with different letters in the same column are statistically significant. *P < 0.05, **P < 0.01.

the lowest thousand-grain weight was determined in the top position.

The gluten index, wheat +*b* color values, and weight percentages of grains of <2.2 mm differed (P < 0.01) only between wheat varieties (Table 3). The weight percentages of grains of <2.2 mm varied from 0.12% (Doğu-88) to 0.63% (Karasu-90). The highest gluten index value was determined in Karasu-90, and it was the lowest in Doğu-88. Grains from the top portion had the highest +*b* color value in Bezostaya-1, Karasu-90, Palandöken-97, and Doğu-88. On the other hand, the grain position on the spike resulted in no significant differences in +*a* color values in any wheat varieties.

Weight percentages of grains of >2.8 mm were the highest in the middle portions of Palandöken-97 (80.61%), Yıldırım (70.50%), Bezostaya-1 (80.30%), Karasu-90 (44.22%), and Doğu-88 (84.23%) (Figure 1a). In general, weight percentages of grains of >2.8 mm decreased from the middle to the top of the spike. The weight percentages of grains of 2.8-2.5 mm in the top portion were higher than those in the bottom and middle portions, except in Karasu-90 (Figure 1b). On the other hand, the weight percentages of grains of 2.5-2.2 mm decreased from the bottom to the top of the spike, except in Karasu-90 (Figure 1c). It was determined that grains from the top portion of the spike were smaller in size than those from other portions.

An interesting observation regarding grain hardness is that there are significant differences in grain hardness among parts of the spike. In general, grain hardness values decreased from the bottom to the top portion (Figure 1d). The lowest grain hardness values were found in the top portions of spikes. An exception was Palandöken-97, which had its lowest grain hardness value in the bottom position.

The opposite trends were observed for *L* color value in Palandöken-97, Karasu-90, and Doğu-88 (Figure 2a). For instance, the *L* color value of grains from the middle portions was the lowest in Palandöken-97 and Karasu-90; it was the highest in Doğu-88. The *L* color value of Bezostaya-1 increased from the bottom to top, and it decreased from the bottom to top in Yıldırım. Generally, the hectoliter weight of different grain positions on the spike increased toward the top of the spike in all wheat varieties; however, the opposite effect was observed in Karasu-90 (Figure 2b).

The highest falling number values were found in the Bezostaya-1 variety at 1237, 1304, and 1220 s (bottom, middle, and top), respectively (Figure

Table 3. The effect of wheat variety on grain size, wheat +*b* color, and gluten index value (mean ± SE)[a].

Wheat varieties	n	Grain size classes (% grains) (<2.2 mm)	Wheat color +*b*	Gluten index
Palandöken-97	6	0.14 ± 0.07bc	23.81 ± 0.11a	64.28 ± 3.82c
Yıldırım	6	0.26 ± 0.08b	21.16 ± 0.27b	58.80 ± 0.68c
Bezostaya-1	6	0.08 ± 0.01c	17.82 ± 0.22d	69.96 ± 3.20b
Karasu-90	6	0.63 ± 0,23a	18.62 ± 0.51d	82.39 ± 3.32a
Doğu-88	6	0.12 ± 0.04bc	20.23 ± 0.51c	47.36 ± 1.75d
P		**	**	**

[a]Values are given as mean ± SE; means with different letters in the same column are statistically significant. *P < 0.05, **P < 0.01.

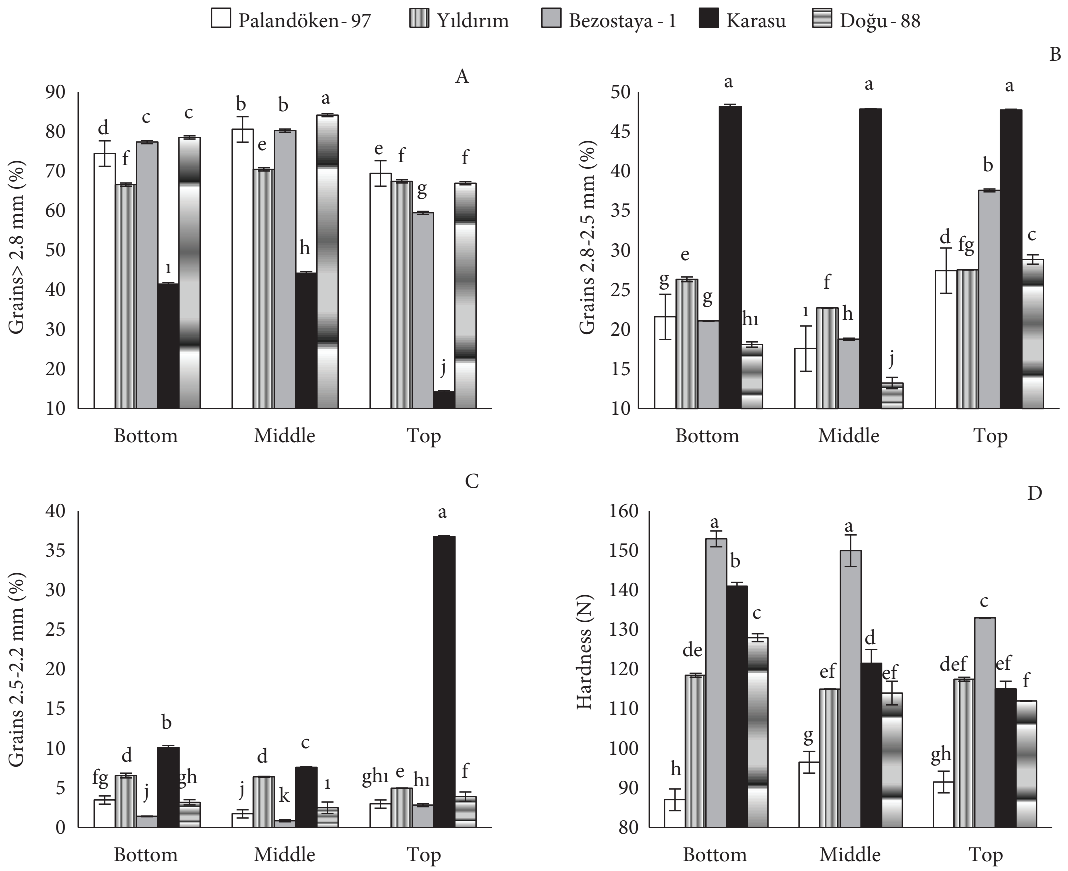

Figure 1. Grain size [weight percentages of grains of >2.8 mm (a); weight percentages of grains of >2.5 mm (b); weight percentages of grains of >2.2 mm (c)] and grain hardness (d) values of grains from different spike locations. Different letters indicate significantly (P < 0.05) different values for each parameter.

3a). The highest falling number values were in Palandöken-97, Yıldırım, and Doğu-88, while the lowest were in the top portions of the Bezostaya-1 and Karasu-90 varieties. Meanwhile, significant differences in the Zeleny sedimentation value among the wheat varieties were found according

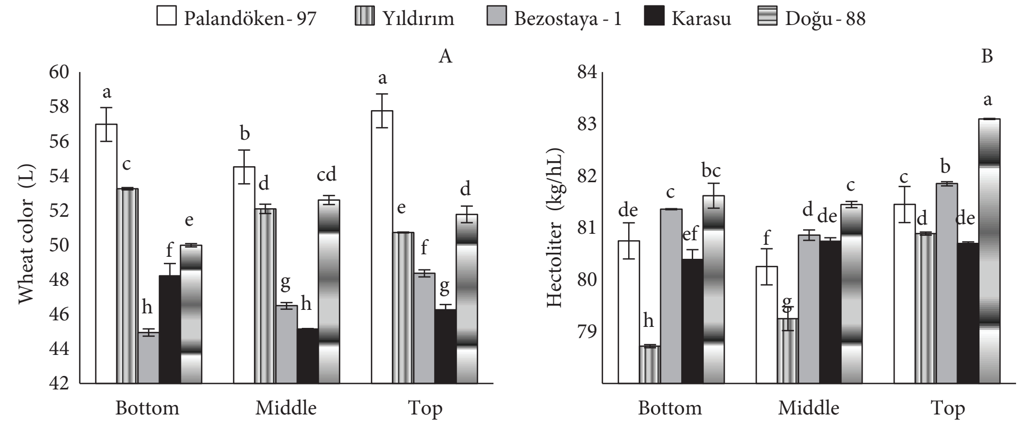

Figure 2. Wheat color L (a) and hectoliter weight (b) values of grains from different spike locations. Different letters indicate significantly (P < 0.05) different values for each parameter.

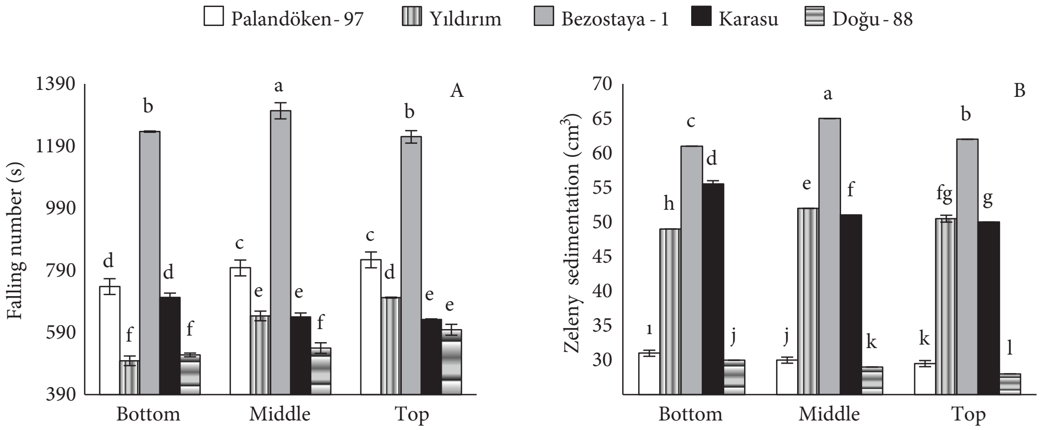

Figure 3. Falling number (a) and Zeleny sedimentation (b) values of grains from different spike locations. Different letters indicate significantly (P < 0.05) different values for each parameter.

to grain position on the spike (Figure 3b). In the Palandöken-97, Karasu-90, and Doğu-88 wheat varieties, the highest and lowest Zeleny sedimentation values were determined in the bottom and top portions of the spike, respectively. In the Yıldırım and Bezostaya-1 varieties, the highest Zeleny sedimentation values were obtained in the middle portions. Differences in dry gluten content among grain positions within the spike were observed, as well. The lowest dry gluten value was obtained in the top portion, while the highest wet and dry gluten values were found in the bottom of the spike (Figure 4).

Discussion

Wheat grain size changed with grain position within the spike. The smallest grain size was found in the top portion of the spike. These results related to grain size were supported by thousand-grain and hectoliter weights. The results for thousand-grain weight were also supported by the results for grain size, since the lowest thousand-grain weight and grain size results were obtained in the top portion of the spike. According to the grain size results, grains from the top portion of the spike were smaller than those from other portions. The first grains in flower will have the

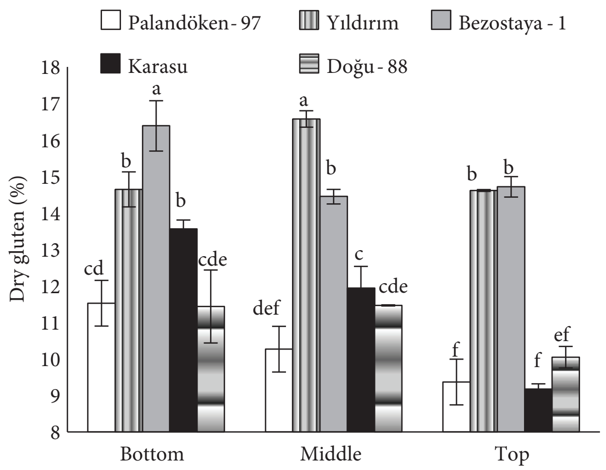

Figure 4. Dry gluten content of grains from different spike locations. Different letters indicate significantly ($P < 0.05$) different values.

longest development times; later grains may have less time to develop, which affects protein synthesis and accumulation (Huebner 1990). This also may affect grain size.

The quality of wheat is dependent on grain hardness, and grain texture is used to describe classes of wheat on the world market (Morris et al. 2005). Hard and high protein-containing wheat is of high quality and suitable for making bread (Snape et al. 2005). Grain hardness is related to the protein content of the grain since protein (especially gluten) is harder than starch. The increase in protein content results in increasing rigidity or hardness (D'Egidio 2001). Findings from this experiment showed that grain hardness is positively correlated to protein content in wheat. A positive relation between wheat protein and grain hardness was similarly determined by Slaughter et al. (1992). In general, in the present study, grain hardness decreased from the bottom to the top portion of the spike (Figure 1d).

Thousand-grain and hectoliter weights, which can be used to determine the potential flour yield in wheat grain, are accepted as the main quality factors by the milling industry (İlker et al. 2009; Mut et al. 2010). The hectoliter weight was higher in the top portions of spikes. The grain size decreased toward the top of the spike, which might be the result of an increase in hectoliter weight in the top of the spike.

The color of wheat, usually white or red, is related to pigments in the seed coat. The *L* color value is a measure of lightness (high *L* value) to darkness (low *L* value). The +*b* color value is a measure of yellowness; a higher number indicates more yellowness. Our results opposite trends for the *L* and +*b* color values. On the other hand, grain position on the spike showed no significant differences in +*a* color values in any wheat varieties. Zapotoczny and Majewska (2010) found a high correlation between the color of the seed coat and the color of the endosperm of wheat grains.

We observed differences in falling number values among grain positions within the spike (Figure 3a). Grain with a low falling number due to high alpha-amylase activity causes important economic losses for growers and significant processing and storage problems, which leads to poor quality end-products (Mares and Mrva 2008). Significant differences in the Zeleny sedimentation values were found according to grain position on the spike among the wheat varieties. The Zeleny test positively correlated with protein content; both protein and Zeleny sedimentation values were lower in the top portion of the spike. The Zeleny sedimentation test is used as a rapid means of estimating the baking quality of wheat flour. It relies on the relationship between flour baking strength and gluten hydration capacity, assumed as a function of gluten quantity and quality (Sozinov and Poperelya 1980).

The importance of protein content lies in the ability of gluten to produce dough with the desired rheological properties (Ktenioudaki et al. 2010). Viscoelasticity is one of the basic properties of gluten. Therefore, wheat gluten is very important in bakery products (Roccia 2009). There were differences in protein content among the top, middle, and bottom portions of the spike. The study showed that protein content had a decreasing trend toward the top in all varieties. Similar results for protein content in the spike were obtained by Bramble et al. (2002), who determined decreasing protein toward the top. Differences were observed between grain positions for wet and dry gluten content. Protein and especially gluten content are important indicators of bread quality. As the loaf volume increases, the protein content increases. It has been stated that protein content varies according to the position of grain within spikelets (Bramble et al. 2006).

In conclusion, our study showed quantitative differences among varieties depending on the grain position within the spike. Different wheat varieties have different quality characteristics; this situation is well known. However, there is very little information about how grain position within the spike affects quality characteristics. For this reason, grain position rather than wheat variety was considered. There was a significant difference in hectoliter weight, dry gluten content, Zeleny sedimentation, falling number, grain hardness, seed size, and wheat color values among grains located at different positions within the spikes of all 5 wheat varieties. The protein and ash contents of grains decreased from the bottom to the top of the spike. The wet and dry gluten contents were the lowest in the top portions of most wheat varieties. The lowest grain hardness values were generally found in the top portions of the spikes. The weight percentages of grains of >2.8 mm were highest in the middle portions.

References

Ali A, Atkins I, Rooney L, Porter K (1969) Kernel dimensions, weight, protein content and milling yield of grain from portions of the wheat spike. Crop Sci 9: 329-330.

American Association of Cereal Chemists (AACC) (1983) Approved Methods of the American Association of Cereal Chemists, 8th ed. Method 56-81. AACC, St Paul, MN, USA.

American Association of Cereal Chemists (AACC) (2000) Approved Methods of the American Association of Cereal Chemists, 10th ed. Methods 08-01, 44-15A, 46-11A. AACC, St Paul, MN, USA.

Bramble T, Dowell FE, Herrman TJ (2006) Single-kernel near-infrared protein prediction and the role of kernel weight in hard red winter wheat. Am Soc Agr Biol Eng 22: 945-949.

Bramble T, Herrman TJ, Loughin T, Dowell F (2002) Single kernel protein variance structure in commercial wheat fields in western Kansas. Crop Sci 42: 1488-1492.

Calderini D, Ortiz-Monasterio I (2003) Grain position affects grain macronutrient and micronutrient concentrations in wheat. Crop Sci 43: 141-151.

D'Egidio MG (2001) Composition and quality of durum wheat and pasta products. In: Durum Wheat, Semolina and Pasta Quality: Recent Achievements and New Trends (Eds. J Abecais, JC Autran, P Feillet). INRA, Paris, pp. 93-112.

Elgün A, Ertuğay Z, Certel M, Kotancılar HG (1999) Guide Book for Analytical Quality Control and Laboratory for Cereal and Cereal Products. Atatürk Univeristy Press, Erzurum, Turkey.

Huebner FR, Kaczkowski J, Bietz JA (1990) Quantitative variation of wheat proteins from grain at different stages of maturity and from different spike locations. Cereal Chem 67: 464-470.

İlker E, Altınbaş M, Tosun M (2009) Selection for test weight and kernel weight in high yielding wheat using a safety-first index. Turk J Agric For 33: 37-45.

International Association for Cereal Science and Technology (ICC) (2000) The Standard Methods of the ICC, 2000 ed. ICC Standard No. 137/1, Approved 1982 and Revised 1994. ICC, Vienna, Austria.

International Association of Cereal Chemistry (IACC) (1972) International Association of Cereal Chemistry Standard No. 115-116. IACC, St Paul, MN, USA.

Ktenioudaki A, Butler F, Gallagher E (2010) Rheological properties and baking quality of wheat varieties from various geographical regions. J Cereal Sci 51: 402-408.

Magness JR, Markle GM, Compton CC (1971) Food and Feed Crops of the United States: A Descriptive List Classified According to Potentials for Pesticide Residues. New Jersey Agricultural Experiment Station, New Brunswick, NJ, USA.

Mares D, Mrva K (2008) Late-maturity α-amylase: low falling number in wheat in the absence of preharvest sprouting. J Cereal Sci 4: 6-17.

Miller CL (2003) Variation in Single Kernel Hardness within the Wheat Spike. BS Thesis. Kansas State University, College of Agriculture, p. 32.

Morris CF, Campbell KG, Kin GE (2005) Kernel texture differences among US soft wheat cultivars. J Sci Food Agr 85: 1959-1965.

Mut Z, Aydin N, Bayramoglu HO, Ozcan H (2010) Stability of some quality traits in bread wheat (*Triticum aestivum*) genotypes. J Environ Biol 31: 489-495.

Roccia P, Ribotta PD, Perez GT, Leon AE (2009) Influence of soy protein on rheological properties and water retention capacity of wheat gluten. LWT-Food Sci Technol 42: 358-362.

Slaughter DC, Norris KH, Hruschka WR (1992) Quality and classification of hard red wheat. Cereal Chem 69: 428-432.

Snape J, Fish L, Leader D, Bradburne R, Turner A (2005) The impact of genomics and genetics on wheat quality improvement. Turk J Agr For 29: 97-103.

Sozinov AA, Poperelya FA (1980) Genetic classification of prolamines and its use for plant breeding. Ann Technol Agric 29: 229-245.

Zapotoczny P, Majewska K (2010) A comparative analysis of colour measurements of the seed coat and endosperm of wheat kernels performed by various techniques. Int J Food Prop 13: 75-89.