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Effects of wheat cultivar, cooking method, and bulgur type on the yield and colour properties of bulgur

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RESEARCH ARTICLE

Abstract

Making bulgur is an ancient process and bulgur may, in fact, be man's first processed food. Technological improvement is essential in order to achieve higher quality bulgur. The steam cooker is gaining popularity these days since it preserves the nutritional value of the food during the cooking. In the present study, coarse and fine bulgur types were produced from bread and durum wheat cultivars by using steam cooker and autoclave to determine the effects of cultivar, cooking method, and bulgur type on the yield and colour properties of bulgur. The less total bulgur yield was determined at durum wheat cultivars and autoclave cooking method because of the higher amount of bran removed. The percentage of the bulgur samples having a particle size ranging between 2.0 and 2.5 mm was the highest for both cooking methods. Durum wheat cultivars possessed harder and more breakable grain structure during the bulgur production, which caused 11.9% less coarse and 11.4% more fine bulgur yields. The kernels cooked in steam cooker also tended to break more during the debranning process which raised about 20% more fine bulgur yield. Bulgur produced from durum wheat cultivars possessed higher lightness (L) and yellowness (b), and lower redness (a) colour values. During the bulgur production, a decrease (11.6%) in 'L' colour value and an increase (164.6%) in 'a' colour value was determined from raw material to bulgur. The application of high temperature and pressure used for autoclave cooking caused darkening of bulgur colour. The coarse bulgur type had higher 'L' colour value and lower 'a' colour value. The steam cooker has been utilised for the first time in bulgur production as a cooking method, although it causes a higher amount of breakage of the kernels, the bulgur maintains the yellowish colour which is a desired trait.

Keywords: bulgur quality, cultivar, cooking method, bulgur type, yield, colour

1. Introduction

Bulgur, one of the first whole wheat-based foods in the world, has been produced in the Anatolia and the Middle East since the cultivation of wheat (Williams *et al.*, 1984). It was called by many different names such as cerealis, dagan, arisah, burghul, ala, daliya, birghil, plegouri and parboiled wheat by different cultures throughout history (Bayram, 2007; Haley and Pence, 1960).

Currently, Turkey is the largest bulgur producer and exporter of the world. The annual bulgur production was reported as about 451,429 tons in 2016 (TÜİK, 2016). However, this production is estimated to be more than 1 million ton including the homemade production (Bayram, 2007; Yousif *et al.*, 2018). Bulgur production and consumption are increased due to its low cost, long shelf-life, taste, ease of preparation, high nutritional and economic values (Yousif *et al.*, 2018). Turkey exported 257,298 tons bulgur to 94 countries in 2017 (TRADE MAP, 2017).

There is no universal method or system for producing bulgur. However, Karaman and Antep systems are the two most popular industrial bulgur production techniques in the world (Bayram and Öner, 2005; Yousif *et al.*, 2018). Further, there is a homemade bulgur production method (atmospheric pressure cooking and sun-drying in open air) which is being used extensively in villages of Turkey.

The main traditional bulgur production steps are as follows; cleaning, cooking, drying, tempering, debranning, cracking (milling), and size-classification (Özboy and Köksel, 2002; Savas and Basman, 2016; Yousif *et al.*, 2018). There are six types of bulgur according to particle size defined by Bulgur Communiqué (2016/49) (Turkish Food Codex, 2018) and Boiled and Pounded Wheat Standard (TS 2284) (Turkish Standards Institution, 2018). The first four of them are coarse (pilavlık) bulgur types while the last two of them are fine (köftelik) bulgur types.

The most critical steps are the cooking and drying stages in the bulgur production, which affects the important properties of wheat (Savas and Basman, 2016; Yousif *et al.*, 2018). Hence, different cooking (atmospheric, pressure, and microwave) and drying (solar, sun, sprouted bed, tray, ventilated oven, infrared, and microwave) methods were studied to examine the effects of these stages on the quality of the bulgur (Acer, 2004; Kahyaoglu *et al.*, 2010; Koca and Anıl, 1996; Savas and Basman, 2016; Yilmaz and Koca, 2017). Pressure cooking (autoclave) and cooking under atmospheric pressure (traditional method) are the most frequently used cooking methods. Bright yellow colour in bulgur is obtained by the traditional cooking method. However, with this method, the grains tend to get deformed which is not desired by the producers. Although, high temperature and pressure used in autoclave cooking method cause darkening of the bulgur colour, this cooking method is used widely in continuous systems (Koca and Anıl, 1996; Özboy, 1998). Traditionally, bulgur is sun-dried in open air, but it may cause quality degradation of the final product and contamination problem (Kahyaoglu *et al.*, 2010; Savas and Basman, 2016). In modern bulgur plants, hot air drying is often used due to increased capacity and sanitation benefits (Hayta, 2001; Kahyaoglu *et al.*, 2012).

Beside bulgur producing technique, the wheat species or cultivar used in bulgur production is one of the key factors affecting the quality of bulgur. Bulgur is a whole grain product which is commonly produced from durum wheat (*Triticum durum* Desf.). One of the most important quality criteria that distinguishes durum wheat from bread wheat is the high yellow pigment content that is existing at different levels in wheat species (Abdel-Aal *et al.*, 2002; Hidalgo *et al.*, 2017; Karwasra *et al.*, 2017). The bright yellow colour is the most important determinant of the bulgur quality which affects the consumer's choice in Turkey (Bayram, 2005). In order to meet the demands of the customers, the producers are trying to achieve yellowish colour in bulgur (Balci and Bayram, 2015). Bulgur yield, which is another quality parameter, is important for the producer and varies according to the variety/species (Özboy, 1998; Yılmaz, 2012), cooking (Savaş, 2010; Yılmaz, 2012), drying (Savaş, 2010; Yılmaz, 2012), and milling (Bayram and Öner, 2005) conditions.

Technological improvement for bulgur production is essential to increase the bulgur quality since the production and consumption of bulgur are increasing in developing and developed countries (Kahyaoglu *et al.*, 2010). Therefore, each step of bulgur production should be well-considered and meet with new technologies. The steam cooking is a relatively new technique and no reports have been found for the steam cooker as a cooking method in bulgur production. To our knowledge, the steam cooker for producing bulgur was used for the first time in the present study. Therefore, the aim of the study was to determine the effects of cultivar (seven durum wheat and two bread wheat), cooking method (steam cooker and autoclave), and bulgur type (coarse and fine) on the yield and colour properties of bulgur.

2. Materials and methods

Materials

The material of this study consisted of seven durum wheat cultivars (Altın 40/98, Ankara-98, Çeşit 1252, Eminbey, Kunduru-1149, Kızıltan-91, and Mirzabey-2000) and two bread wheat cultivars (Demir-2000 and Tosunbey). All cultivars were grown in two locations in Turkey (İkizce/Ankara and Altınova/Konya) and two consecutive growing seasons (2008-2009 and 2009-2010) under rainfed conditions.

Methods

Bulgur production

Bulgur samples were prepared from 36 wheat samples (combining 9 cultivars, 2 years, and 2 locations) with two different cooking methods (steam cooker and autoclave) and two bulgur types (coarse and fine). The samples were kept in a refrigerator at 4 °C until further analyses.

For all soaking, cooking, tempering, and debranning techniques, all treatments were determined by preliminary tests. Different soaking ratios were trialled for both cooking techniques: 1.0:1.0, 1.1:1.0, 1.2:1.0, 1.3:1.0 (w/v, wheat:water) for autoclave while 0.7:1.0, 0.8:1.0, 0.9:1.0, 1.0:1.0, 1.1:1.0 (w/v) for steam cooker. Optimum soaking ratio was found 1.0:1.0 (w/v) for both cooking techniques. For cooking time from 13, 15, and 17 min., 15 min. was found to be the optimum time for autoclave cooking technique while 90 min. was optimum for starch gelatinisation in steam cooker. From different tempering moistures (14 and 16%), tempering time (18 h and 30 min.), and debranning time (2, 4, 6 and 8 min.); 16% tempering moisture content, 30 min. tempering time, and 6 min. debranning time were observed to be the optimum for debranning process.

Cooking

A steam cooker (Tefal VC 7003, Rumilly, France) used in this study was utilised for the first time in bulgur production. One unit of cleaned wheat was cooked with 1 unit of tap water (100 °C) for 90 min until full starch gelatinisation. Autoclave cooking method was modified from Savas and Basman (2016). Both bread and durum wheat samples were soaked to increase the humidity about 45% in tap water (1:1 w/v, wheat:water ratio) at 60 °C for 3 h. Later, the soaked grain was cooked in the autoclave (OT 4060V; Nüve, Ankara, Turkey) under a steam pressure of 1.2 atm at 121 °C for 15 min. Cooked wheat samples were kept at room temperature for 30 min in order to vaporize surface moisture before drying.

Drying

After the cooking operation, cooked and cooled samples were placed over trays and dried in a ventilated oven (FN 055; Nüve) at 60 °C for about 18 h until the water content of about 9-11%.

Tempering, debranning, and cracking

Before the debranning operation, cooked and dried wheat samples were tempered in order to help the removing bran from the surface of the wheat kernel. The samples were tempered to 16% moisture content and rested for 30 min before debranning. In order to remove the bran of tempered wheat, a debranner (Poyraz Muhendislik, Konya, Turkey) was utilised by for 6 min. The debranned samples were cracked by using a hammer mill (Duru Değirmen Makinaları, Karaman, Turkey).

Analysis of bulgur samples

Amount of bran removed

The percentage of the bran removed during the debranning process was measured as the proportion of bran weight to the total wheat sample weight (Savas and Basman, 2016).

Sieve analysis and classification

After the milling operation, the cracked samples were sifted using a sieve shaker (Retsch AS 200, Haan, Germany) through 3.5, 3.0, 2.8, 2.5, 2.0, 1.6 and 0.5 mm square hole sieves for 5 min according to Bulgur Communiqué (2016/49) (Turkish Food Codex, 2018) and Boiled and Pounded Wheat Standard (TS 2284) (Turkish Standards Institution, 2018) to determine the particle size distribution. After determining the particle size distribution, samples were classified bulgur types as coarse (pilavlık, 3.5>×>2.0 mm), fine (köftelik, 2.0>×>0.5 mm), and total (3.5>×>0.5 mm) bulgur. The bulgur samples having the particle size less than 0.5 mm were separated as they were not classified as bulgur sample.

Milling for meal and semolina

The wheat samples were grinded to the meal (Perten 3100, Huddinge, Sweden) to determine moisture content as described by the AACCI Method 44-15A (AACCI, 2000). Then, the wheat samples were tempered and milled to semolina according to AACCI Method 26-41.01 (AACCI, 2000) by using the Buhler 70028 pneumatic laboratory mill (Uzwil, Milan, Italy).

Colour

Colour values (L, a, b) of the semolina and bulgur samples were measured by using HunterLab colorimeter (Gardner BYK Color view, Columbia, MD, USA), where 'L' is lightness (100)/darkness (0), 'a' is redness (+)/greenness (-), and 'b' is yellowness (+)/blueness (-). The colour measurements were performed on semolina and bulgur samples at laboratory temperature (22±2 °C).

Statistical analysis

All experiments were carried out in duplicates and mean values were noted. Analysis of variance (ANOVA) was performed using SAS computer package program, version 8.0 (SAS Institute, 1999). When significant differences ($P<0.05$) were detected, Duncan's test was applied to identify the differences among means.

3. Results and discussion

Amount of bran removed and sieve analysis

According to analysis of variance, amount of bran removed by debranning was significantly ($P<0.01$) affected by both cultivar and cooking method (Table 1). The amount of bran separated by debranning of the cultivars ranged from 11.65 to 14.14% and the average was determined as 12.51%. The amount of bran removed during the debranning stage was higher for cultivars Altın 40/98, Ankara-98, Eminbey, and Kızıltan-91 with 'a' letter grouping (Table 2). Further, the amount of bran removed during debranning was found mostly higher in the samples produced from durum wheat cultivars, which was similar to that found by Savas and Basman (2016).

When cooking methods were examined, more bran was separated in the autoclave (13.64%) compared to steam cooker (11.37%) (Table 2). This is the result of the increase in broken kernel amount during the debranning stage of the steam cooker method, which negatively affected the amount of bran removed. However, Savas and Basman (2016) reported that the amount of bran removed during

Table 1. Analysis of variance for amount of bran removed by debranning and coarse, fine and total bulgur yields.[1]

Source of variance	DF	Amount of bran removed	Bulgur yield		
			Coarse	Fine	Total
Cooking method (CM)	1	184.69**	738.84**	1,753.03**	215.82**
Replication	14	2.06	10.38*	16.14**	3.64*
Cultivar (C)	8	14.09**	111.44**	69.75**	13.90**
CM × C	8	1.74	24.71**	34.09**	1.83
Error	112	1.91	4.99	5.56	1.85
Corrected total	143				
Coefficient of variation (%)		11.05	4.6	6.23	1.58

[1] * and ** = significant at the 0.05 and 0.01 probability levels, respectively.

Table 2. Amount of bran removed by debranning and coarse, fine and total bulgur yields of cultivars and cooking methods.[1]

Cultivar[2]	Amount of bran removed (%)	Bulgur yields (%)		
		Coarse	Fine	Total
Altın 40/98	14.14±1.35 a	45.52±2.52 c	38.87±2.84 a	84.39±1.35 d
Ankara-98	13.34±1.41 a	46.65±1.42 c	38.48±2.09 a	85.14±1.35 cd
Çesit 1252	11.65±1.80 b	47.26±2.76 bc	39.62±2.04 a	86.88±1.89 ab
Eminbey	13.32±0.97 a	47.31±2.08 bc	38.10±2.69 a	85.41±1.15 cd
Kunduru-1149	11.94±1.61 b	48.90±2.12 b	37.61±2.35 a	86.51±1.47 ac
Kızıltan-91	12.94±1.50 ab	46.51±2.53 c	39.02±2.86 a	85.54±1.66 bd
Mirzabey-2000	11.90±1.11 b	46.54±1.70 c	39.96±1.95 a	86.50±1.20 ac
Demir-2000	11.66±1.24 b	52.97±3.51 a	34.07±3.35 b	87.04±1.36 a
Tosunbey	11.67±1.04 b	52.15±1.84 a	34.68±2.37 b	86.83±1.14 ab
Min.-Max. values	11.65-14.14	45.52-52.97	34.07-39.96	84.39-87.04
Mean values	12.51	48.20	37.82	86.03
Mean values for cooking methods[2]				
Autoclave	13.64±1.47 a	50.47±2.23 a	34.33±2.42 b	84.80±1.49 b
Steam cooker	11.37±1.21 b	45.94±2.31 b	41.31±2.59 a	87.25±1.30 a

[1] Data are means±SE.
[2] Means with the same letter within a column are not significantly different (*P*<0.01).

the debranning step was lower for the wheat samples cooked in autoclave compared to atmospheric pressure. In another comprehensive study, the more bran was removed from the samples cooked by atmospheric pressure as compared to autoclave and infrared cooking methods during the debranning step (Certel, 1990). Different genotypes and cooking methods were possibly the reason for the different results reported.

The results of particle size distribution for cooking methods were given in Tables S1 and S2. When the results of sieve analysis belong to bulgur samples were examined, the percentage of the bulgur samples having the particle size ranging from 2.0 to 2.5 mm was the highest for both cooking methods within two years, changing between 35.4-50.3% and 35.7-45.8% for autoclave and steam cooking methods, respectively. The percentages of this fraction on average were higher for the sample cooked in autoclave than steam cooker for both years. In general, the values belong to the coarse fractions (3.5>×>2.0) were higher in the autoclave cooking method whereas those belonging to the fine fractions (2.0>×>0.5) were higher in the steam cooking method. These results are in agreement with the previous researches which reported that the percentage of the bulgur samples with sizes 2.0 mm and 2.5 mm was the highest (Melik, 2014; Savas and Basman, 2016). Similar to our results, Savas and Basman (2016) reported that the samples cooked in autoclave generally had higher particle size compared to the samples cooked under atmospheric pressure.

Coarse, fine, and total bulgur yields

Results from the present study demonstrated that coarse and fine bulgur yields were significantly influenced (P<0.01) by cultivar (C), cooking method (CM), and their (CM × C) interaction while total bulgur yield was affected (P<0.01) by cultivar and cooking method (Table 1). Similarly, a significant effect of cultivar on coarse, fine or total bulgur yields was reported by several researchers (Anıl, 1994; Koca and Anıl, 1996; Yılmaz, 2012). The coarse, fine, and total bulgur yields of the cultivars varied between 45.52-52.97, 34.07-39.96 and 84.39-87.04%, respectively, with a mean of 48.20, 37.82 and 86.03% (Table 2). In the present study, lower coarse and higher fine bulgur yields were determined compared previously reported studies (Aydın *et al.*, 1993; Certel, 1990; Yılmaz, 2012). This might be the result of different genotypes, cooking methods, tempering, debranning and cracking conditions, and sieve hole sizes used in other studies.

Two bread wheat cultivars (Demir-2000 and Tosunbey) had the highest coarse bulgur yields while the lowest fine bulgur yields, compared to durum wheat cultivars (Table 2). These results were parallel with the findings of Aydın *et al.* (1993) who reported that increasing coarse bulgur yield caused a decrease in fine bulgur yield. Among the cultivars used, durum wheat cultivars gain harder kernel structure during the bulgur production process. Therefore, the amount of smaller particle size was increased at debranning and cracking steps due to breakage, which caused higher fine bulgur yield on durum wheat cultivars. Similar results were reported by several researchers (Certel, 1990; Koca and Anıl, 1996).

The highest total bulgur yield was obtained only from cv. Demir-2000. When statistically evaluated, it took place at 'a' letter grouping with cultivars Tosunbey, Çeşit 1252, Kunduru-1149, and Mirzabey-2000. Aforementioned five cultivars had higher total bulgur yields caused by the lower amount of bran removed during the debranning process (Table 2). Similar to our results, Koca and Anıl (1996) reported that the coarse and total bulgur yields were found higher on bread wheat cultivars.

Comparing the cooking methods, higher coarse bulgur yield (50.47%) was obtained from autoclave while higher fine (41.31%) and total (87.25%) bulgur yields were determined at steam cooker (Table 2). The amount of broken kernel during the debranning step in the steam cooking method was higher compared to autoclave cooking method, which increased the amount of smaller particle size and fine bulgur yield in the steam cooking method. The results in this study agree with those found by Certel (1990) who reported that the highest coarse bulgur yield was obtained from autoclave cooking while the lowest was gained at traditional (atmospheric pressure) cooking among the three cooking methods (autoclave, traditional, and infrared). In another comprehensive study comparing these three cooking methods, significant differences (P<0.05) were found between the cooking methods and the highest bulgur yield was found at autoclave cooking method (Bilgiçli, 2009). However, in a study carried out by Yılmaz (2012), cooking methods haven't affected the coarse and fine bulgur yields except for the total bulgur yield. In the same study, the highest total bulgur yield was obtained from the traditional cooking method compared to the autoclave and the infrared cooking methods.

Cooking method and cultivar interaction (CM × C) graphs belong to coarse and fine bulgur yields were given in Figure 1 and 2. When Figure 1 was examined, the highest coarse bulgur yield was obtained from cv. Demir-2000 using

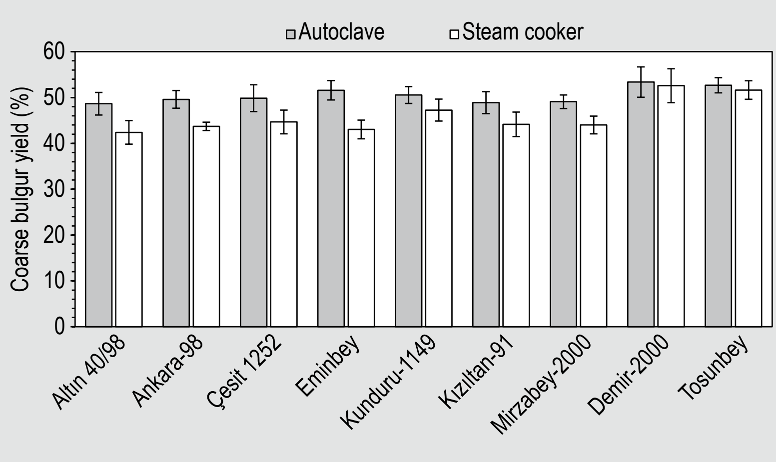

Figure 1. Interaction graph between cooking method and cultivar (CM × C) on coarse bulgur yield.

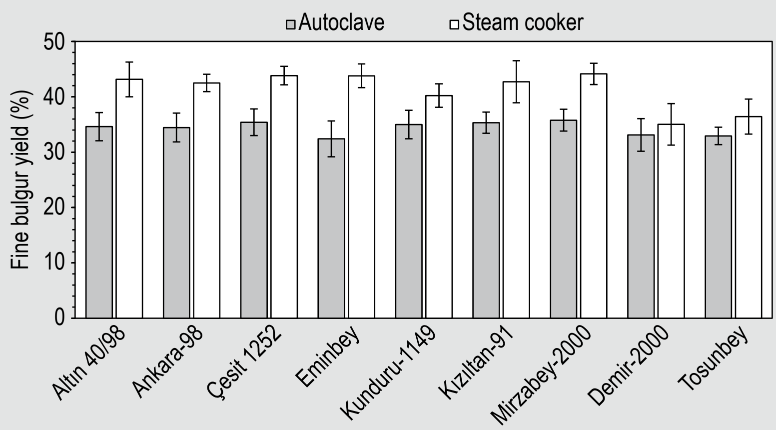

Figure 2. Interaction graph between cooking method and cultivar (CM × C) on fine bulgur yield.

autoclave cooking method while the lowest was found at cv. Altın 40/98 produced by the steam cooker. Higher coarse bulgur yields were obtained from autoclave cooking method for all cultivars involved in the study, compared to steam cooker method. On contrary, fine bulgur yields of cultivars produced by steam cooker were higher than the ones produced by autoclave. The highest and the lowest values were identified on cv. Mirzabey-2000 (steam cooker) and cv. Eminbey (autoclave), respectively (Figure 2). However, gaps between cooking methods for coarse and fine bulgur yields were larger for all cultivars except for bread wheat cultivars (Demir-2000 and Tosunbey) (Figure 1 and 2). These results are not in agreement with previous results where CM × C was statistically significant (P<0.01) on total bulgur yield, not significant for coarse and fine bulgur yields (Anıl, 1994).

Colour

Colour in bulgur is an important quality factor and bulgur should maintain the amber yellow colour during the process. The difference in bulgur colour is under the influence of the wheat cultivar, the processing technique and especially the storage (Özboy and Köksel, 1998). ANOVA results and colour values of the bulgur samples produced by nine cultivars and two cooking methods were shown in Table 3 and 4, respectively.

The effect of cultivar on bulgur L, a, b colour values in the present study was found to be significant at 1% level (Table 3). The highest bulgur 'L' and 'a' colour values were gained from cv. Çeşit 1252 (80.6) and cv. Demir-2000 (3.05), respectively, both of which statistically were included in 'a' letter grouping. The highest bulgur 'b' colour value

Table 3. Analysis of variance for bulgur L, a, b colour values.

Source of variance	DF	Bulgur colour values[1]		
		L	a	b
Cooking Method (CM)	1	63.10**	1.060**	2.753**
Bulgur Type (BT)	1	12.55**	0.391*	0.045
CM × BT	1	0.93	0.042	0.247
Replication (CM × BT)	28	2.71*	0.282**	1.100**
Cultivar (C)	8	147.47**	5.291**	91.781**
CM × C	8	16.11**	0.668**	1.999**
BT × C	8	0.21	0.008	0.026
CM × BT × C	8	0.21	0.008	0.024
Error	224	1.69	0.075	0.378
Corrected total	287			
Coefficient of variation (%)	–	1.66	13.1	3.59

[1] * and ** = significant at the 0.05 and 0.01 probability levels, respectively.

Table 4. L, a, b colour values of cultivars, cooking methods and bulgur types.[1]

Cultivar[2]	L		a		b	
	Semolina	Bulgur	Semolina	Bulgur	Semolina	Bulgur
Altın 40/98	88.0±0.35 d**	79.3±1.00 b**	0.83±0.27 ac**	1.85±0.27 d**	18.9±0.27d**	17.8±0.63 b**
Ankara-98	87.6±0.27 e	78.9±1.43 b	0.93±0.18 a	1.97±0.29 cd	16.8±0.18 f	17.5±0.40 b
Çesit 1252	88.3±0.35 c	80.6±1.45 a	0.78±0.26 ac	1.63±0.32 e	17.0±0.26 e	16.6±0.55 c
Eminbey	88.0±0.34 d	78.4±1.30 bc	0.89±0.25 ab	2.09±0.33 c	19.2±0.25 c	18.6±0.32 a
Kunduru-1149	87.7±0.33 e	78.0±1.49 c	0.93±0.24 a	2.12±0.29 bc	19.7±0.24 b	18.5±0.39 a
Kızıltan-91	87.9±0.38 d	79.1±0.78 b	0.75±0.29 ad	1.86±0.33 d	20.0±0.29 a	18.4±1.03 a
Mirzabey-2000	88.5±0.50 b	79.3±1.11 b	0.59±0.41 d	1.96±0.36 cd	19.2±0.41 c	17.8±1.02 b
Demir-2000	90.8±0.33 a	73.0±0.56 d	0.68±0.24 cd	3.05±0.22 a	11.1±0.24 h	13.3±0.31 e
Tosunbey	90.6±0.39 a	78.0±2.01 c	0.71±0.30 bd	2.29±0.29 b	11.8±0.30 g	15.8±0.35 d
Min.-Max. values	87.6-90.8	73.0-80.6	0.59-0.93	1.63-3.05	11.1-20.0	13.3-18.6
Mean values	88.6	78.3	0.79	2.09	17.1	17.1
Mean values for cooking methods[2]						
Autoclave		77.8±1.47 b**		2.15±0.35 a**		17.1±0.37 b**
Steam cooker		78.8±1.01 a		2.03±0.25 b		17.3±0.74 a
Mean values for bulgur types[2]						
Coarse		78.5±1.22 a**		2.05±0.30 b*		17.1±0.58
Fine		78.1±1.25 b		2.13±0.30 a		17.2±0.54

[1] Data are means±SE.
[2] Means with the same letter within a column are not significantly different: * = *P*<0.05; ** = *P*<0.01.

was determined at cv. Eminbey (18.6). It was in the same statistical group with cv. Kızıltan-91 and cv. Kunduru-1149. On the other hand, the lowest bulgur 'b' colour value was obtained only from cv. Demir-2000. The other bread wheat cultivar Tosunbey had also lower bulgur 'b' colour value compared to durum wheat cultivars. Previous studies have reported that there were significant differences between cultivars for bulgur L, a, b colour values (Melik, 2014; Yılmaz, 2012).

During the bulgur production, the colour was influenced by the processes from raw material to final product. The L, a, b colour values of raw material determined at semolina varied between 87.6-90.8, 0.59-0.93, and 11.1-20.0, respectively, and the mean values were 88.6, 0.79, and 17.1. Comparing the L, a, b colour values of semolina and bulgur samples, the decrease in the 'L' colour value was determined from raw material to bulgur. Especially, bulgur samples had almost 2.6 times higher 'a' colour value than semolina samples. Although the range of 'b' colour value was larger at semolina than bulgur, the same mean value was determined for both semolina and bulgur (Table 4). This negative alteration from semolina to bulgur at L, a, b colour values may have formed the result of the Maillard reaction because of the heat treatment applied at cooking and drying bulgur production steps (Özboy and Köksel, 1998).

Bulgur L, a, b colour values were clearly (*P*<0.01) affected by cooking methods (Table 3). The bulgur samples prepared by steam cooker had higher 'L' and 'b' colour values while those produced by autoclave got higher 'a' colour values (Table 4). The results in this study are in agreement with those found by a number of researchers who reported that the application of high temperature and pressure used for autoclave cooking caused darkening (lowering 'L' value) of bulgur colour (Certel, 1990; Savas and Basman, 2016; Yılmaz, 2012). However, Acer (2004) reported that cooking methods were insignificant at bulgur 'L' and 'a' colour values except for the 'b' colour value. Also, higher 'b' colour values were obtained from traditional method compared to microwave method in the same study.

Significant differences between bulgur types were found for 'L' colour value (*P*<0.01) and 'a' colour value (*P*<0.05) while those were not determined for 'b' colour value (*P*>0.05) (Table 3). L, a, b colour values were determined as 78.5, 2.05, and 17.1 for the coarse bulgur type and 78.1, 2.13, and 17.2 for the fine bulgur type. When bulgur types were examined in terms of colour, the coarse bulgur type had higher 'L' colour value and lower 'a' colour value while the fine bulgur type possessed lower 'L' colour value and higher 'a' colour value (Table 4). Although it had been stated in the literature (Hayta *et al.*, 2003; İnceer, 2011; Ünüvar, 2009; Yıldırım *et al.*, 2006) that the 'L' colour value was increased (bleaching) due to the decrease of the particle size, the higher 'L' colour value was obtained from the coarse bulgur type in the present study. Bran contamination to fine bulgur type may have caused lower 'L' colour value and higher 'a' colour value (Table 4).

Bulgur L, a, b colour values were significantly influenced ($P<0.01$) by cooking method and cultivar interaction (CM × C) (Table 3). Interaction graphs belong to bulgur L, a, b colour values were given in Figure 3-5. According to CM × C interaction graph for 'L' colour value, the highest and lowest bulgur 'L' colour values were obtained from Çeşit 1252 and Demir-2000 cultivars produced by autoclave cooking method, respectively. The bulgur samples produced by steam cooker had the higher 'L' colour values except for Çeşit 1252, Kunduru-1149, and Mirzabey-2000 cultivars (Figure 3). The reaction of the cultivars to cooking methods in terms of 'a' colour value was different that both the highest (cv. Demir-2000) and the lowest (cv. Çeşit 1252) 'a' colour values were obtained from autoclave cooking method (Figure 4). The highest bulgur 'b' colour value was determined at cv. Eminbey prepared by steam cooking method while the lowest was found at cv. Demir-2000 produced by autoclave cooking method. In general, lower bulgur 'b' colour values were obtained from bread wheat cultivars in the present study (Figure 5).

4. Conclusions

In the present study, two types bulgur samples were produced by using two different cooking method (steam cooking and autoclave) from seven durum wheat cultivars (Altın 40/98, Ankara-98, Çeşit 1252, Eminbey, Kunduru-1149, Kızıltan-91, Mirzabey-2000) and two bread wheat cultivars (Tosunbey and Demir-2000), grown in two locations and two growing seasons.

The genotype and cooking method caused differences in amount of bran removed, coarse, fine, and total bulgur yields. The amount of bran removed during the debranning stage was higher in the bulgur samples produced by both

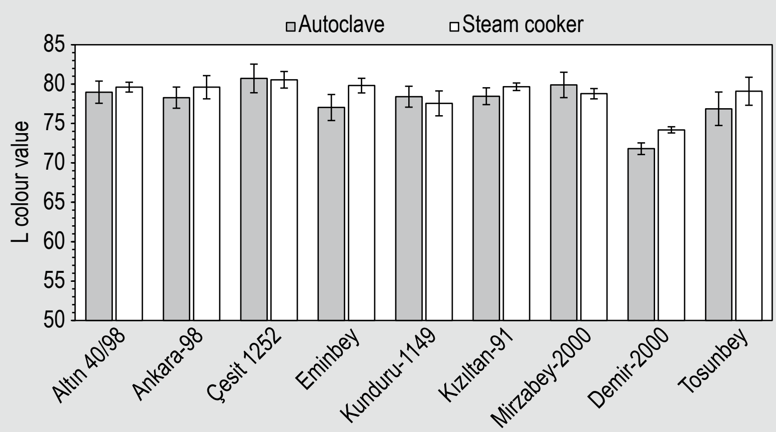

Figure 3. Interaction graph between cooking method and cultivar (CM × C) on bulgur 'L' colour value.

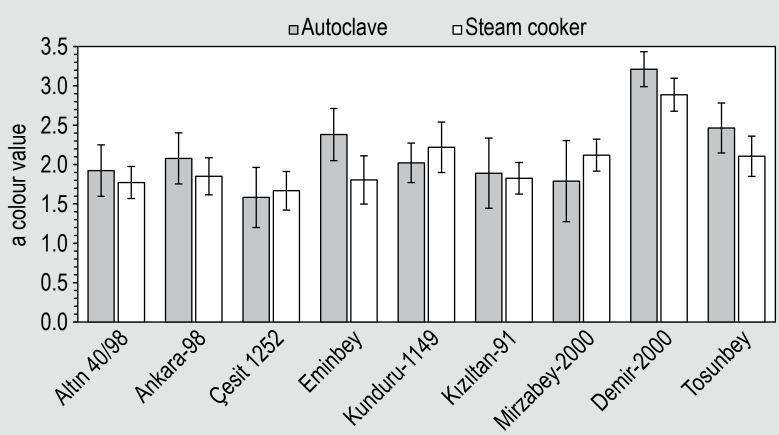

Figure 4. Interaction graph between cooking method and cultivar (CM × C) on bulgur 'a' colour value.

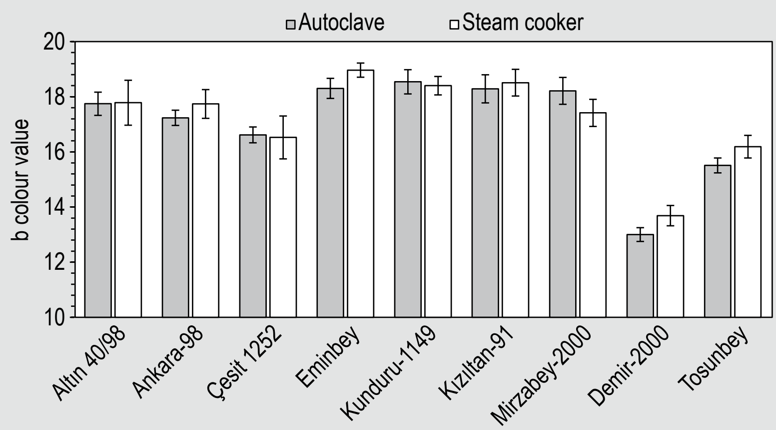

Figure 5. Interaction graph between cooking method and cultivar (CM × C) on bulgur 'b' colour value.

durum wheat cultivars and autoclave cooking method, which caused less total bulgur yield. Durum wheat cultivars possessed harder and breakable grain texture during the bulgur production, which caused higher fine bulgur yield compared to bread wheat cultivars.

The higher coarse bulgur yield was obtained from autoclave while the higher fine and total bulgur yields were achieved by steam cooker. The kernel cooked in steam cooker tended to break more during the debranning step, which caused smaller particle size and higher fine bulgur yield in the steam cooking method. The percentage of the bulgur samples having the particle size ranging between 2.0 and 2.5 mm was the highest for both cooking methods.

The bulgur colour was influenced by cultivar, cooking method, and bulgur type. Bulgur samples produced from durum wheat had desirable bulgur colour comparing to those produced from bread wheat cultivars. During the bulgur production, a decrease in lightness and an increase in redness was determined from raw material to bulgur. The application of high temperature and pressure used for autoclave cooking caused darkening of bulgur colour. While coarse bulgur type had higher lightness, it showed lower redness.

Although the steam cooker did not show promising results in terms of kernel breakage, the bulgur produced with steam cooker method maintained a good colour. It is very early to have definitive conclusions for this cooking method since this study is the first to utilise steam cooker. Further analysis is needed to have a better understanding of the effect of this cooking method. As a conclusion it can be said that; the results of this study are valuable to have a better understanding of the effects of the cultivar and cooking method on the final product. Also, it will be beneficial to researchers for further studies in this area.

Conflict of interest

The authors declare no competing financial interest.

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Supplementary material

Supplementary material can be found online at https://doi.org/10.3920/QAS2018.1431.

Table S1. Sieve analysis results of cracked bulgur samples cooked in autoclave (%).

Table S2. Sieve analysis results of cracked bulgur samples cooked in steam cooker (%).

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