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Investigation of Bioactive Compounds and Antioxidant Capacities of Various Cereal Products

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Abstract: In this study, some nutritional properties and bioactive components of 34 cereal products, including rice, corn, bulgur, pasta, biscuits, cakes, crackers, breads, bakery products and breakfast products, which are frequently consumed in daily life, have been examined. For this purpose, bioactive components such as total polyphenol content (TPC), total carotenoid content (TCC) and antioxidant capacity (DPPH and FRAP methods) were analyzed together with dry matter, protein, fat and ash analyzes. Significant differences were found between products and product groups with respect to bioactive components and antioxidant activities. TPC of the products were ranged between 301.16±4.91 (Baldo rice) - 1307.48±71.65 (corn bread) µg GAE/g DM. TCC of the products were ranged between 0.11±0.02 (Baldo rice) - 22.22±1.05 (yellow corn) µg LE/g DM. The lowest antioxidant activity results were found in Baldo rice samples 1.46±0.20 % İnh./mg DM (DPPH) and 1.14±0.19 Fe^{+2} µmol/g DM (FRAP) while the highest were in corn bread 11.17±0.39 % İnh./mg DM (DPPH) and in yellow corn 63.27±1.53 Fe^{+2} µmol/g DM (FRAP). In general, bioactive compounds and antoxidant activities of products containing whole grain, bran, fruit and cocoa were found higher than others in the same product group. In conclusion, consumption of corn and corn products are recommended thanks to high bioactive compounds content and so to promote healthier nutrition.

Keywords: Antioxidant, carotenoid, cereal, nutritional, phenolic

Çeşitli Tahıl Ürünlerinin Biyoaktif Bileşenleri ve Antioksidan Kapasitelerinin Araştırılması

Öz: Çalışmada, günlük yaşamda sıkça tüketilen pirinç, mısır, bulgur, makarna, bisküvi, kek, kraker, ekmek, fırın ürünleri ve kahvaltılık ürünlerden oluşan 34 adet tahıl ürününün bazı besinsel özellikleri ve biyoaktif bileşenleri incelenmiştir. Bu amaçla, kuru madde, protein, yağ ve kül analizleri ile birlikte toplam polifenol içeriği (TPC), toplam karotenoid içeriği (TCC) ve antioksidan kapasitesi (DPPH ve FRAP yöntemleri) gibi biyoaktif bileşenler analiz edilmiştir. Ürün ve ürün grupları arasında biyoaktif bileşenler ve antioksidan aktiviteleri açısından önemli farklılıklar bulunmuştur. Ürünlerin toplam polifenol içeriği 301,16±4,91 (Baldo pirinç) - 1307,48±71,65 (mısır ekmeği) µg GAE/g KM arasında değişmiştir. Ürünlerin toplam karotenoid içeriği 0,11±0,02 (Baldo pirinç) - 22,22±1,05 (sarı mısır) µg LE/g KM arasında değişmiştir. En düşük antoksidan aktivite sonuçları Baldo pirinç örneklerinde % 1,46±0,20 % İnh./mg KM (DPPH) ve 1,14±0,19 Fe^{+2} µmol/g KM (FRAP) iken en yüksek aktivite mısır ekmeği 11,17±0,39 % İnh./mg KM (DPPH) ve sarı mısır 63,27±1,53 Fe^{+2} µmol/g KM (FRAP) örneklerinde tespit edilmiştir. Genel olarak, tam tahıl, kepek, meyve ve kakao içeren ürünlerin biyoaktif bileşenleri ve antoksidan aktiviteleri aynı ürün grubundaki diğer örneklerden yüksek bulunmuştur. Sonuç olarak, yüksek biyoaktif bileşik içeriği sayesinde daha sağlıklı beslenmeyi teşvik etmek için mısır ve mısır ürünlerinin tüketimi önerilmektedir.

Anahtar Kelimeler: Antioksidan, besinsel, fenolik, karotenoid, tahıl

1. Introduction

Interest to healthy nutrition has been increasing in recent years by scientists, society and producers. Cereals and their products, which have high varieties and consumption levels compared to other food groups have an important place in nutrition. About 60% of our daily energy is provided from cereals. Being a major energy source, relatively cheap, easily accessible, satisfying characteristic, neutral taste and aroma are the reasons for the high consumption of the cereals. According to FAO statistics, wheat is the second most produced cereal (749 million tonnes) all over the world, after maize (1 billion tonnes) in 2016 (FAOSTAT, 2018) and wheat products like breads, biscuits, bakeries, cakes are the most consumed cereal products among others. Cereal and cereal products that have such a crucial role in our nutrition undoubtedly have important influences on human health. Cereals are known as an energy source, based on starch. Additionally, cereals are a good source of protein (about 7-20%) but have relatively low quality due to limitations in the amounts of essential amino acids like lysine (Shewry, 2007). Except corn, cereals known as low-fat foods. The ash content of cereals is about 1-3% with the layer of bran. With a rising trend, consumers are becoming more interested in the relationship between diet and disease, and there is a shifted interest from animal to vegetal food. Some phytochemicals found in plants have been reported to have a positive effect on health and on to prevent some diseases (Sidhu et al., 2007). It is known that the bioactive compounds are not homogeneously spread in the grain, the grain parts have different antioxidant capacities, the germ and the bran are higher than the endosperm and whole grain and the bran has the highest antioxidant capacity (Fares et al., 2010; Gelinas and McKinnon, 2006). Therefore, whole grains and whole grain products are suggested to be an important part of the diet. Whole grains are important sources of nutrients including resistant starch, dietary fiber, trace minerals, some vitamins and compounds like phytoestrogens and antioxidants, which are related to disease prevention (Slavin et al., 1997).

Reactive oxygen species and free radicals may initiate or exacerbate cellular and molecular damage which are resulted as some diseases. Oxygen radicals and some reactive derivatives of oxygen are called together as reactive oxygen species (ROS) (Yu et al., 2002). To maintain human health, a balance is necessary between the formation and termination of ROS. High level of ROS and free radicals in cells can damage proteins, nucleic acids, membrane lipids which has resulted as age-related health problems (Adom and Liu, 2002; Yu et al., 2002). To protect the body from the destructive effect of free radicals, to reduce the risks of diseases, dietary antioxidants may be helpful (Zujko and Witkowska, 2011).

Significant levels of antioxidants have been detected in cereals and cereal products. Phenolic acids, flavonoids, carotenoids, tocopherols / tocotrienols, lignans and phytosterols / phytostanols are the group of bioactive compounds which are found in cereals (Yilmaz et al., 2015).

Antioxidants in cereals exist as free form and as bound form which is covalently linked to macromolecules (Holtekjolen et al., 2008).

Cereal-based diet which has high dietary fiber and antioxidants helps to protect the body against chronic diseases such as heart disease, stroke and some cancers (Ragaee et al., 2006; Sidhu et al., 2007; Slavin et al., 1997; Yu et al., 2002). Also, it helps to reduce cholesterol and blood sugar level (Okarter and Liu, 2010; Sidhu et al., 2007).

Phenolics are compounds with one or more aromatic rings and one or more hydroxyl groups. Phenolic acids, flavonoids, alkylresorcinols are the major compound groups in phenolics (Okarter and Liu, 2010). Phenolic compounds concentrations of the whole grains are influenced by grain types, varieties, and the fraction of the grain. Flavonoids and phenolic acids are the most common phenolic compounds in whole grains (Liu, 2007).

Carotenoids are natural pigments of fruits, vegetables and whole grains. Carotenoids are classified into two groups; carotenes (α- and β-carotene, etc.) and their oxygenated derivatives xanthophylls (lutein, zeaxanthin and β-cryptoxanthin, etc.) (Kean et al., 2008; Liu, 2007; Okarter and Liu, 2010). Carotenoids are the main compounds responsible for the yellow colour of cereals and have also received substantial attention because of both their role as provitamins and antioxidants (Liu, 2007; Pham and Hatcher, 2011). Xanthophylls are the major carotenoids in wheat, lutein is the most abundant (Hidalgo et al., 2006; Werner and Bohm, 2011).

In this study, it was aimed to determine some chemical properties and bioactive compounds like polyphenols and carotenoids and antioxidant potential of the most consumed 34 cereal products including rice, corn, bulgur, pasta, biscuits, cakes, crackers, breads, bakery products and breakfast products in Turkey. The differences between samples according to ingredients and the production methods also wanted to be revealed. Most of the studies on this topic in the literature have been made on a small number of product groups. It is not often that many product groups are analyzed and compared in the same way in a single study. This situation reduces the comparability of studies due to differences in parameters such as method and calibration.

2. Materials and Methods

2.1. Materials

The samples used in the study consist of 34 products collected in 10 groups. These groups are; rice, corn, pasta, bulgur, biscuits, cakes, crackers, breads, bakery products and breakfast products.

All products were supplied from Samsun/ Turkey. Breads and bakery products were supplied in triplicate from the local bakery at 3 different days. Corn samples were taken from the local bazaar but from 3 different sellers. The other branded products were supplied from the national markets, for every product, one brand was selected but samples were taken with 3 replicates with different lot numbers. Groups are given in Table 1.

Table 1. Product groups
Çizelge 1. *Ürün grupları*

Bakery Products	Biscuit	Bread	Breakfast Products	Bulgur
Pastry (Poğaça)	Petit beurre	Turkish Francala	Oatmeal	Coarse (>1.6 mm)
Sesame bagel (Simit)	Double baked petit beurre	Whole wheat	Muesli	Fine (>0.5 mm)
Grissini	Baby	With bran	Corn flake	
Whole wheat grissini	With oat	Corn bread	Rice flake	
	With bran			
	With grape			
Cake	**Corn**	**Cracker**	**Pasta**	**Rice**
Plain	Yellow	Bar cracker	Regular	Baldo
Fruity	White	With sesame	With egg	Osmancık
With Cocoa		With black cumin	With bran	
			With vegetables	

2.2. Methods

2.2.1. Sample preparation for analysis Samples were milled with a grinder (MC 23200; Siemens, Germany) until to <1 mm diameter for homogenization. Then, all samples were kept in polypropylene bags at 4 °C without sunlight.

2.2.2. Composition analysis

Dry Matter analysis of the samples was performed according to AACCI 44-15.02 method (AACCI, 2000) with the help of oven (FN-500, Nuve, Turkey) at a modified temperature 105 °C. Protein content of the samples was determined with the Kjeldahl method described by AACCI 46-30.01 (AACCI, 2000), based on to the determination of nitrogen content of the samples with the help of digestion and distillation system (BÜCHI Labortechnik AG, Switzerland). Nitrogen content was determined with the titration of the distilled samples with 0.1 N HCI and then protein content was calculated with conversation factor using 5.7. Crude Fat content of the samples was measured with a soxhlet distillation system, using petroleum ether for extraction with the method AACCI 30-25.01 (AACCI, 2000). Ash content analysis was done using the AACCI 08-01.01 method with some modifications (AACCI, 2000). Samples were incinerated with 1-2 ml of ethanol and then kept in a furnace at 900 °C until the grey ash obtained.

2.2.3. Total polyphenol content (TPC)

The Folin-Ciocalteu colorimetric method Singleton and Rossi (1965) was modified by using UV-visible spectrophotometer to determine total phenolics. 3 g of samples were mixed with 25 mL of 80% methanol. After that, the samples were vortexed for 1 min, mixed with orbital shaker in 4°C for 12 hr. Samples were centrifuged at 10,000 rpm for 15 min. 20 µL of supernatant, 1.58 mL of pure water and 100 µL of Folin-Ciocalteu reagent were mixed and incubated for 5 minutes, then 300 µL of saturated Na_2CO_3 was added and mixture was kept 2 hours in the dark avoiding from oxygen and sunlight. Absorbance was recorded at 760 nm and TPC of each sample was calculated by means of gallic acid calibration curve and expressed as µg of the gallic acid equivalents (GAE) per g of the sample on dry matter (DM).

2.2.4. Total carotenoid content (TCC)

AACCI 14-50.01 method was modified and used for determination of total carotenoids (AACCI, 2000). 2 g of ground sample was mixed with 10 mL water saturated butanol (WSB) in tubes. The mixture was covered with folio to protect from sunlight and vortexed for 1 min. Then, mixtures were shaken with orbital rotator at 4°C for 18 h in the dark. The samples were filtered with Whatman No. 1 filter paper and taken to the cuvettes. The absorbance of the extracts was recorded at 449 nm, which is the best-suited wavelength for the dominant pigment, lutein, in wheat and its products. WSB was used for blank measurement. Calculations were done with the coefficient of lutein in WSB extract which was given by Sims and Lepage (1968).

2.2.5. Antioxidant activity analysis

Antioxidant activity of the samples is evaluated by two assays; 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capacity and Ferric-reducing antioxidant power (FRAP) analysis. 80% methanolic extracts which were obtained for TPC analysis was also used for antioxidant assays.

2.2.6. DPPH radical scavenging analysis

The DPPH assay was followed according to the method given by Yilmaz and Koca (2017). Briefly, 1mL of freshly prepared DPPH solution was added to 50 µL of the sample extract. The mixtures were kept in the dark for 30 min at room temperature. Absorbance at 517 nm was recorded with a UV–visible spectrophotometer. Blank was measured only with 80% methanol and DPPH solution. The percentage of the inhibition was calculated with blank and samples absorbance which was given in Equation 1. The results were given as DPPH (%) scavenging capacity of mg DM of samples. Inhibition (%)= $[(A_{blank}-A_{sample})/A_{blank}]$ x 100 (Eq. 1)

2.2.7. Ferric reducing antioxidant power (FRAP) analysis

The FRAP assay was carried out with the method given in Koca et al. (2018) with slight modifications. FRAP reagent was prepared daily with sodium acetate buffer (300 mM, pH 3.6), 10 mM TPTZ solution (40 mM HCl as solvent) and 20 mM $FeCl_3$ solution at 10:1:1 ratio, respectively. 100 µL of sample was added to 3mL of the FRAP reagent. The mixture was incubated at 37 °C for 60 min and then absorbance was measured at 593 nm. Acetate buffer was used as a blank. FeSO4 was used to prepare calibration curve and the results were expressed as µmole Fe^{+2} equivalent /g DM of the samples.

2.2.8. Statistical analysis

Data are reported as mean±standard deviation of analysis results in triplicate. Bioactive compounds and antioxidant capacity analysis results were subjected to statistical evaluation. Two-way analysis of variance (ANOVA) and Duncan’s multiple range test was performed using SPSS 21 software (SPSS, Inc. Armonk, NY, USA) at $p<0.05$ significance level. Factors for variance analysis were decided as; comparison of the products within the group (1) and comparison of the groups to each other (2).

3. Results and Discussion

3.1. Composition analysis

Dry matter, ash, protein and fat content of the samples are given in Table 2. DM content of the products is varied depend on the production method and the final characteristics of the products.

Table 2. Chemical properties of the samples
Çizelge 2. *Örneklerin kimyasal özellikleri*

	Sample	DM (%)	Ash (%)	Protein (%)	Fat (%)
Biscuit	Baby	98,01±0,09 c	1,09±0,01 c	5,06±0,10 d	15,29±0,34 c
	With bran	98,52±0,06 b	1,22±0,03 b	10,79±0,37 a	9,08±0,29 e
	With grape	96,26±0,16 e	1,14±0,02 bc	6,62±0,07 c	17,40±0,15 b
	With oat	97,08±0,07 d	1,62±0,03 a	7,52±0,21 b	20,32±0,15 a
	Petit beurre	97,29±0,14 d	1,02±0,06 d	7,54±0,22 b	10,63±0,34 d
	DB Petit beurre	98,76±0,01 a	1,00±0,01 d	7,78±0,11 b	10,78±0,23 d
Cake	Plain	79,95±0,09 b	1,01±0,01 c	4,99±0,07 a	20,87±0,14 a
	Fruity	82,48±0,23 a	1,26±0,02 b	4,42±0,05 b	17,00±0,11 b
	With Cocoa	80,43±0,09 b	1,32±0,02 a	5,06±0,11 a	20,63±0,32 a
Cracker	Bar	98,27±0,03 a	4,13±0,14 a	7,54±0,24 b	8,89±0,18 c
	With sesame	97,86±0,20 b	2,85±0,07 b	10,37±0,31 a	18,74±0,34 a
	With BC	97,77±0,14 b	2,23±0,09 c	10,43±0,24 a	12,61±0,16 b
Bread	Turkish francala	66,52±1,05 b	0,78±0,09 c	8,19±0,05 c	1,12±0,07 d
	With bran	69,05±0,26 a	1,29±0,16 a	8,89±0,10 b	1,47±0,20 c
	Whole wheat	69,17±0,77 a	1,17±0,11 b	9,37±0,04 a	1,54±0,03 c
	Corn bread	65,10±0,69 b	1,31±0,09 a	5,69±0,19 d	3,70±0,04 a
Bakery Products	Pastry	76,88±0,75 c	0,67±0,11 d	6,99±0,09 d	15,68±0,27 a
	Sesame bagel	81,30±0,88 b	1,05±0,04 c	8,21±0,15 c	6,84±0,14 b
	Grissini	97,62±0,25 a	1,47±0,09 b	10,12±0,08 a	4,64±0,11 c
	WW grissini	98,96±0,25 a	1,92±0,05 a	9,51±0,17 b	3,56±0,25 d
Pasta	Regular	91,31±0,13 c	0,71±0,11 c	11,07±0,10 b	0,93±0,07 c
	With egg	92,56±0,23 b	0,94±0,01 b	11,95±0,08 a	2,96±0,08 a
	With bran	93,01±0,20 a	1,08±0,01 a	10,50±0,29 c	0,73±0,07 d
	With vegetables	92,89±0,12 ab	0,90±0,04 b	10,92±0,09 b	1,14±0,03 b
Bulgur	Coarse	87,88±0,11 b	1,25±0,02 a	8,84±0,16	2,27±0,16 a
	Fine	89,04±0,06 a	1,18±0,02 b	8,83±0,18	1,87±0,08 b
Corn	White	87,76±0,18 a	1,21±0,03	6,72±0,11 a	4,67±0,10
	Yellow	86,04±0,12 b	1,22±0,08	6,12±0,21 b	4,75±0,11
Rice	Osmancık	85,78±0,27 a	0,57±0,04	6,17±0,16	0,77±0,06 b
	Baldo	86,64±0,10 b	0,49±0,03	6,56±0,22	1,45±0,11 a
Breakfast Products	Corn flake	96,82±0,17 a	1,85±0,06 a	6,01±0,08 c	0,92±0,04 c
	Rice flake	97,00±0,23 a	0,57±0,04 c	6,08±0,12 c	0,39±0,04 d
	Oatmeal	89,67±0,12 b	1,92±0,07 a	11,58±0,18 a	6,12±0,27 a
	Muesli	89,11±0,55 b	1,67±0,03 b	8,68±0,20 b	4,26±0,11 b

BC: Black cumin; DB: Double baked; DM: Dry matter; WW: Whole wheat. Different small letters in the same column indicate significant differences in product groups ($p \leq 0.05$)

Except for cakes, breads and bakery products like pastry (poğaça) and bagel with sesame (simit), all the other samples have lower moisture content than 14%, which is the critical level for cereals and cereal products about microbiological risks. The above products are considered microbiologically risky and shelf life of them are a few days in room conditions.

Double baked petit beurre biscuit had higher DM content (98.76±0.01 %) than petit beurre biscuit (97.29±0.14 %) as a result of a longer baking process ($p<0.05$). It has been determined that the products containing the ingredients known to have a high moisture content such as fruits (grape etc.) have lower amount of dry matter. Biscuit with grape had statistically lowest DM content than other biscuits ($p<0.05$). Similar findings were observed in cake samples, fruity cake had the lowest DM content among cake samples.

Ash content of the rice samples and rice flakes are the lowest among products. Polishing before the use and consumption of rice is the reason for low ash and also mineral content of these samples. It is well known that outer layers and especially bran layer of the cereals are the main source of minerals which is completely or partially removed after polishing and refining process (Ragaee et al., 2006; Sidhu et al., 2007; Slavin et al., 1997).

Crackers were found to have more ash content than all samples because of high salt content, especially bar cracker was the highest ($p<0.05$). Crackers were followed by whole wheat grissini, breakfast cereals like oatmeal, muesli and corn flake, which are generally produced from whole cereals. Whole grains and bran added products have been found to have higher ash content than other products in their group. Biscuit with oat and with bran was found to have higher ash content than other biscuit samples ($p<0.05$). Similar findings were also observed in whole wheat bread and bread with bran samples among bread samples ($p<0.05$). It was also determined that whole wheat grissini had higher ash content than normal grissini, and pasta with bran had higher ash content than regular pasta ($p<0.05$).

When all samples were compared together, cake samples and baby biscuit was found to have lower protein content than others. Pasta samples were the higher product group with respect to protein content. The main reason for these differences is the wheat species which are used for production. *Triticum compactum,* which is known as the softest and the lowest protein content species, is the main ingredient of the products like cakes and biscuits. The main ingredient of pasta is *Triticum durum,* are well known as hard and high protein species (Fustier et al., 2009; Pareyt and Delcour, 2008). Noticeably, biscuit with bran was found to have the highest protein among biscuit samples ($p<0.05$) and one of the highest value among all samples. It is thought that wheat variety with higher protein content and quality may be preferred in order to prevent the breakdown of biscuits easily due to the use of bran in biscuit production. The addition of high protein ingredients, such as sesame or black cumin, has been shown to have a significant effect on the protein content of crackers ($p<0.05$). Corn bread had lower protein content than other bread samples ($p<0.05$). The lower protein content of corn (6-10%) than bread wheat (10-12%) is thought to be the main reason of this difference. Similar findings were reported by Al-Kanhal et al. (1999). As expected, it was determined that oatmeal has the highest protein content among breakfast cereals ($p<0.05$), due to higher protein amount of oat, than rice and corn.

The fat content of the samples is directly related with the formulation of the product. Products like biscuits, cakes, crackers and pastry are known as high-fat foods thanks to addition a significant amount of fat to the formulations. It can be observed from results in Table 2 that these products had higher fat content than other product groups. The lowest fat content (<1%) were found in; regular pasta, pasta with bran, Osmancık rice, corn flake and rice flake.

3.2. Bioactive compounds

Total polyphenol and carotenoid contents, as well as the antioxidant capacity (DPPH and FRAP) results of the samples, are presented in Table 3.

3.2.1. Total polyphenol content

Phenolic compounds are considered as a major group that contribute to the antioxidant activities of the cereals (Yu et al., 2002). When the TPC results were examined, it was statistically determined that the double baked petit beurre (DBPB) and grape biscuit had the highest TPC results among the biscuit samples. The lowest TPC content was determined in the baby biscuit. Among cakes, cocoa cake has the highest TPC content ($p<0.05$). Rupasinghe et al. (2008) reported that the TPC of muffin samples was about 2300 μg GAE/g DM, which is about 4 times higher than plain cake samples. On the contrary, TPC of control muffins was reported about 300 μg GAE/g DM by Rosales-Soto et al. (2012), which is about half of plain cake samples of this study.

Table 3. Bioactive compounds and antioxidant activity of the samples
Çizelge 3. *Örneklerin biyoaktif bileşenleri ve antioksidan aktiviteleri*

	Sample	**TPC µg GAE/g DM**	**TCC µg LE/g DM**	**DPPH % İnh./mg DM**	**FRAP Fe^{+2} µmol/g DM**
Biscuits	Baby	522,13±13,88 d	3,20±0,18 e	2,95±0,15 c	13,41±1,03 e
	With bran	620,52±20,04 c	4,25±0,20 d	3,20±0,07 c	17,34±1,08 d
	With grape	777,86±28,40 a	5,04±0,24 bc	6,68±0,25 a	32,71±1,74 a
	With oat	597,85±40,70 c	4,80±0,36 cd	4,63±0,17 b	26,27±1,96 b
	Petit beurre	691,11±23,13 b	5,26±0,36 bc	5,11±0,31 b	12,26±0,29 e
	DB Petit beurre	756,43±34,80 a	7,26±0,41 a	7,11±0,36 a	20,32±1,42 c
	Mean	**638,14±103,74 E**	**5,04±1,20 F**	**4,85±1,50 E**	**20,24±6,79 D**
Cake	Plain	604,36±23,99 b	4,70±0,34 b	3,13±0,25 c	15,75±0,86 b
	Fruity	651,06±22,47 b	6,19±0,72 a	4,47±0,37 b	15,86±1,39 b
	With cocoa	1010,84±27,98 a	6,86±0,37 a	10,95±0,34 a	36,60±2,19 a
	Mean	**755,42±183,31 B**	**5,92±1,04 E**	**6,18±3,43 C**	**22,74±9,93 BC**
Cracker	Bar	708,99±63,06 a	10,71±0,96 a	7,05±0,44 a	23,45±2,62 a
	With sesame	609,07±12,55 b	8,02±0,24 b	5,73±0,39 a	15,49±1,20 b
	With BC	705,47±22,32 a	4,97±0,49 c	4,02±0,80 b	10,19±0,92 c
	Mean	**674,51±60,7 DE**	**7,90±2,43 C**	**5,60±1,37 D**	**16,38±5,73 E**
Bread	TF	601,06±31,54 c	2,88±0,13 c	3,04±0,15 c	8,79±0,37 c
	With bran	802,85±57,23 b	4,79±0,42 b	4,99±0,83 b	23,04±4,29 b
	Whole wheat	726,12±46,55 b	5,19±0,26 b	5,13±0,28 b	13,92±0,68 c
	Corn bread	1307,48±71,65 a	18,83±1,38 a	11,17±0,39 a	41,45±1,38 a
	Mean	**859,38±273,88 A**	**7,92±6,40 C**	**6,08±3,09 C**	**21,80±12,65 C**
Bakery Products	Pastry	633,87±35,78 c	3,05±0,12 bc	3,92±0,22 c	5,94±0,94 b
	Sesame bagel	820,39±21,49 a	5,02±0,30 a	3,64±0,04 c	7,93±0,57 b
	Grissini	730,08±27,29 b	2,81±0,18 c	7,22±0,39 b	27,19±1,99 a
	W.W grissini	850,54±56,42 a	3,56±0,24 b	8,47±0,36 a	26,98±2,02 a
	Mean	**758,72±92,62 B**	**3,61±0,88 G**	**5,81±2,10 CD**	**17,01±10,21 E**
Pasta	Regular	736,39±64,53	4,52±0,10 c	2,11±0,33	6,21±0,66 c
	With egg	722,72±37,14	6,13±0,16 b	1,89±0,10	7,80±0,75 bc
	With bran	655,06±30,44	6,80±034 b	1,84±0,17	13,23±1,24 a
	With vegetable	751,90±36,62	18,23±0,61 a	2,11±0,33	8,32±0,46 b
	Mean	**719,02±55,0 BC**	**8,92±5,45 B**	**1,99±0,23 G**	**8,89±2,75 F**
Bulgur	Coarse	541,89±10,07 a	2,79±0,54 a	2,78±0,06	2,81±0,40
	Fine	468,53±19,10 b	1,76±0,20 b	2,67±0,27	3,29±0,64
	Mean	**505,21±39,73 F**	**2,27±0,66 H**	**2,73±0,20 F**	**3,05±0,59 G**
Corn	White	815,79±75,01	0,77±0,14 b	8,00±0,11	49,11±1,26 b
	Yellow	948,20±53,16	22,22±1,05 a	8,22±0,05	63,27±1,53 a
	Mean	**882,00±92,79 A**	**11,50±10,75 A**	**8,11±0,14 A**	**56,19±7,22 A**
Rice	Osmancık	334,54±17,17 a	0,12±0,03	1,98±0,23	2,34±0,67 a
	Baldo	301,16±4,91 b	0,11±0,02	1,46±0,20	1,14±0,19 b
	Mean	**317,85±20,93 G**	**0,12±0,03 I**	**1,72±0,34 G**	**1,74±0,78 G**
Breakfast Products	Corn flake	884,69±55,51 a	12,16±1,46 a	6,24±0,32 c	18,71±1,10 c
	Rice flake	642,47±35,23 b	2,71±0,20 d	7,91±0,14 b	26,70±1,31 b
	Oatmeal	517,52±28,85 c	6,83±0,53 b	4,77±0,32 d	16,14±0,40 d
	Muesli	789,65±69,32 a	4,74±0,42 c	8,86±0,25 a	32,64±0,42 a
	Mean	**708,6±148,7 CD**	**6,61±3,61 D**	**6,95±1,59 B**	**23,55±6,60 B**

BC: Black cumin; DB: Double baked; DM: Dry matter; GAE: Gallic acid equivalent; LE: Lutein equivalent; TF: Turkish Francala; WW: Whole wheat. Different small letters in the same column indicate significant differences in product groups ($p \leq 0.05$) and different capital letters in the same column indicate significant differences between product groups ($p \leq 0.05$).

Formulation of product and extraction diversity may be the main reasons for these differences. The amount of TPC of sesame cracker was found lower than other crackers ($p<0.05$). Millar et al. (2017) determined that the TPC of wheat crackers (31 min cooked) about

1082.6 µg GAE/g DM, which is higher than cracker samples in this study (674.51±60.7 avr.). Among the bread samples, the highest TPC was found in corn bread, while the lowest value was found in Turkish francala bread ($p<0.05$). Polyphenol contents were found to be higher ($p<0.05$) as expected for whole wheat flour and with bran breads, which are known to be richer raw materials in terms of bioactive components (Kaur et al., 2014). Holtekjolen et al. (2008) were studied the soluble TPC of bread sample which was produced with wheat/whole wheat flour mixture (60:40%), They reported the soluble TPC of bread sample about 962 µg GAE/g DM, which is higher than all wheat based breads of this study. It was found that whole wheat grissini and sesame bagel had higher TPC than grissini and pastry among bakery products ($p<0.05$). Remarkably, there was no statistical difference was recorded between the TPC results of pasta samples ($p>0.05$) despite the phenolic-rich ingredients like bran and vegetables. TPC of 5 different brand's regular and whole wheat pasta samples were determined between 718-927 µg/g ferulic acid equivalent (FAE) and 773-1529 µg/g FAE, respectively by Hirawan et al. (2010). These findings are in parallel of regular pasta sample (736.39±64.53 µg GAE/g DM, but significantly low than pasta with bran sample (655.06±30.44 µg GAE/g DM). Coarse bulgur has higher TPC results than fine bulgur ($p<0.05$). It is thought that the coarse bulgur might contain more pericarp than fine bulgur and that could be the reason of this difference. Nevertheless, bulgur samples had lower TPC than literature data (Ertas, 2017; Tacer Caba et al., 2012; Yilmaz and Koca, 2017). Among corn samples, yellow corn had higher polyphenol content than white corn, but this difference was not found at a significant level ($p>0.05$). 3 accessions of yellow and white corns were analyzed by Trehan et al. (2018). They reported that the TPC of accessions were ranged between 1170-1640 µg GAE/g for yellow corn and 903-1332 µg GAE/g for white corn. These results are lower than the findings of this study. Accession difference could be the main reason for this difference. Osmancık rice had higher TPC than Baldo rice and among breakfast cereals, muesli and corn flakes had higher phenolic content ($p<0.05$). Free TPC content of 7 white rice accessions were determined about 100-400 µg GAE/g by Pang et al. (2018). These findings are in line with Baldo and Osmancık rice samples.

In the same product group, it is seen that the most effective parameter on the amount of phenolic substance is the compounds which are used in the production. When the product groups were compared with each other, it was determined that corn samples and bread samples had the highest average and rice samples had the lowest TPC. It is observed that the raw material is also determinative in the results among the product groups, but the factors such as the production method, the applied heat treatment and the duration are also seen to have a significant effect. Abdel-Aal and Rabalski (2013) studied the effect of baking on phenolic acids in wholegrain bakery products like breads, cakes and muffins and they reported that the effect of baking seems to dependent on the type of product, recipe and baking conditions. They also reported that there is a reduction in phenolic acid content in all products with the effect of baking but an increase in the bioavailability of these phenolics.

3.2.2. Total carotenoid content

Generally, carotenoid content of the samples depends on cereal type, accession, refining level of cereal and addition of high carotenoid ingredients. It was determined that DBPB had the highest TCC, while baby biscuit had the lowest, among biscuit samples ($p<0.05$). Cocoa and fruity cake had higher TCC than the plain cake ($p<0.05$). Bar cracker was the highest and black cumin cracker was the lowest samples among the crackers with respect to TCC ($p<0.05$). TCC of bread samples showed great differences due to raw material properties of the bread type. The highest TCC was determined in corn bread ($p<0.05$). TCC of corn bread (18.83±1.38 µg LE/g DM) was found about 6 times higher than Turkish francala (2.88±0.13 µg LE/g DM). It was observed that the carotenoid contents of the samples decreased with the increase of refining levels of wheat flour used in bread production. TCC of whole wheat bread and bread with bran were higher than Turkish francala ($p<0.05$), which is produced from refined wheat flour. The highest TCC was observed in sesame bagel, while the lowest content was in pastry and grissini among bakery products ($p<0.05$). Among the pasta samples, it was determined that vegetables, known to have a high content of pigments, had a higher TCC than the other samples, followed by whole wheat and egg pasta ($p<0.05$). Pasta with vegetable was found to have 4 times higher TCC than regular pasta.

Hidalgo et al. (2010) found that the total carotenoid content (inc. α-β carotene, β-cryptoxanthin, lutein and zeaxanthin) of bread wheat based water biscuit, pasta and bread samples were below 1 mg/kg DM. These results are lower than biscuit, pasta and bread samples of this study. On the contrary, in the same study, researchers determined the total carotenoid content of the water biscuit, pasta and bread samples, which were produced from einkorn wheat (*Triticum monococcum*), were about 8, 5 and 9 mg/kg DM, respectively. Determination method differences (HPLC vs spectrophotometer), wheat accession and formulation diversity were the main reasons for non-compliant results.

For bulgur samples, coarse bulgur (2.79±0.54 μg LE/g DM) had higher TCC than fine bulgur (1.76±0.20 μg LE/g DM) ($p<0.05$). Yilmaz and Koca (2017) determined that the total yellow pigment of durum wheat bulgur, produced by 6 different methods was around 3-4 μg LE/g DM.

It is understood that the most important parameter affecting the TCC is the color of the raw materials, thus, the pigment content. Corn samples are the best examples for the effect of raw material color on the TCC content. The TCC value of white corn is 0.77±0.14 μg/g Lutein equivalent (LE) DM, while it is 22.22±1.05 μg LE/g DM for yellow corn, which is the highest among all samples. Rice samples were very low in TCC results (0.11-0.12 μg LE/g DM) as expected because of natural color and no statistical difference was observed between the samples ($p>0.05$). Metabolite profiles of rice cultivars were studied by Biswas et al. (2018). They stated that there was no all-E-lutein as carotenoid in white rice samples, but it was determined in red and black rice samples. As expected, in the breakfast products, corn flake was found the highest and rice flake was found the lowest TCC content ($p<0.05$). It has been reported that corn has more carotenoid content than wheat and rice (Abdel-Aal et al., 2007).

The average TCC results of the product groups were compared statistically. It is observed that the highest value was determined in corn samples, followed by pasta samples produced from *T. durum* wheat, which is known as a richer source of lutein than other wheat species ($p<0.05$) (Pham and Hatcher, 2011). The lowest TCC average was determined in rice samples ($p<0.05$), that were known as poor by carotenoids (Melini and Acquistucci, 2017). As well as carotenoid content of cereal or products, stability of carotenoids after thermal treatments like baking mainly depends on the severity of the thermal treatments. It was expressed that at lower temperatures (60-100°C) most of the carotenoids are stable but above 100°C, total carotenoid contents are decreased (Maiani et al., 2009). Except for corn and rice samples, all other product groups in this study were subjected a heat treatment and yellow corn had higher TCC (22.22±1.05 μg LE/g DM) than all other products, including heat treated corn flakes 12.16±1.46 μg LE/g DM) and corn bread 18.83±1.38 μg LE/g DM).

3.2.3. DPPH scavenging capacity

Performing antioxidant capacity determination with two or more analysis methods is necessary for a more accurate assessment of the capacity. While examining the results, DPPH scavenging capacity shows ~~a~~ great parallelism with TPC results. As determined in TPC results, it was determined that grape and DBPB biscuits have the highest inhibition power ($p<0.05$). The lowest inhibition was found in baby biscuits and whole wheat biscuits ($p<0.05$). Cocoa cake has the highest inhibition power among cake samples ($p<0.05$), 2 times higher than fruity cake and 3 times higher than plain cake. It was determined that bar and sesame crackers had higher reducing power than black cumin cracker ($p<0.05$). Bread sample's inhibition power was obtained in parallel with TPC and TCC results. Corn bread had the highest, while turkish francala bread had the lowest inhibition power ($p<0.05$). Whole wheat grissini was found to be the highest bakery product in terms of DPPH scavenging capacity, while pastry and sesame bagel were the lowest ($p<0.05$). There was no statistically significant difference between the reducing powers of pasta samples as in TPC results ($p>0.05$). Similarly, Hirawan et al. (2010) could not found important differences between DPPH scavenging capacity of regular and whole wheat pasta samples of different brands. There was also no significant difference in the DPPH scavenging power results of bulgur, maize and rice samples ($p>0.05$). It was determined that muesli has the highest inhibition power in breakfast products and oatmeal has the lowest result as in TPC results ($p<0.05$).

When the antioxidant capacity results of some products in various studies are examined; DPPH scavenging capacity was determined as 2.21 %/mg in plain cookie (biscuit) (Bhat et al., 2018), 1.59 %/mg in wheat bran muffin (cake) (Li et al., 2007), 1.75 %/mg in white rice and 8.75 %/mg in brown rice samples (Choi et al., 2007). DPPH scavenging results of biscuit and cake samples were found higher than these studies, while Osmancik and Baldo (white) rice samples were found similar to white rice but significantly lower than brown rice samples of that study.

To compare the DPPH scavenging capacity of the product groups, it was determined that the highest value were in corn samples, followed by the breakfast products. Rice and pasta samples were recorded as the lowest value ($p<0.05$).

3.2.4. Ferric reducing antioxidant power

For determining antioxidant capacity, FRAP assay was chosen due to its simplicity and durability (Holtekjolen et al., 2008). According to FRAP results of biscuits, it was found that grape biscuits have the highest antioxidant capacity while baby and petit beurre biscuits have the lowest antioxidant capacity among biscuit samples ($p<0.05$). Many studies reported an antioxidant activity increase after heat treatments like baking, because of Maillard reaction products (Capuano et al., 2009; Carciochi et al., 2016; Nanditha and Prabhasankar, 2009). Similar results were observed for petit beurre and double baked petit beurre samples. With the effect of longer baking time, DBPB samples DPPH and FRAP results showed an important increase. Cocoa cakes were determined as the highest antioxidant capacity among cakes samples ($p<0.05$). Bar crackers had the highest and black cumin crackers had the lowest FRAP values among cracker samples ($p<0.05$). Among bread samples, it was seen that corn bread have the highest and turkish francala bread have the lowest FRAP value ($p<0.05$). Whole wheat grissini and grissini was found to be the highest bakery products in terms of FRAP value, while pastry and sesame bagel were the lowest ($p<0.05$). The highest FRAP results in pasta samples were found in pasta with bran and the lowest value was found in regular pasta. There was no significant difference between bulgur samples in terms of FRAP value ($p>0.05$). It has been determined that yellow corn has a higher FRAP result than white corn. Among the rice samples, Osmancık rice was found to have higher FRAP value ($p<0.05$). It was determined that muesli has the highest FRAP result and oatmeal has the lowest result among breakfast products ($p<0.05$). Comparing the products group with each other, it was observed that corn samples have the highest FRAP average, rice and bulgur samples have the lowest average ($p<0.05$). Both for DPPH and FRAP results, the addition of antioxidant-rich ingredients like bran, grape and oat had a positive effect on antioxidant capacity. It was reported that using wholemeal flour, instead of type 550 wheat flour increased the FRAP results of biscuits from 2.24 to 3.88 mmol Trolox equivalent/kg (Haase et al., 2012). Hidalgo et al. (2016) stated that the increase of antioxidant capacity with the effect of baking does not related with the increase in natural antioxidants like phenolics, carotenoids or tocols, this is a consequence of heat damage.

Considering the bioactive component and antioxidant capacity results together, some important similarities are remarkable. It is seen that corn samples have the highest value among product groups in all analyzes, whereas rice samples have the lowest results. In the product groups, it can be seen that corn-containing products have higher values than the other products in the same group. This suggests that corn has a higher bioactive component content and therefore has a higher antioxidant capacity (Adom and Liu, 2002). The low bioactive component and antioxidant capacity of the rice and rice-containing samples were also consistent with the literature (Adom and Liu, 2002; Butsat and Siriamornpun, 2010). It is also seen that products containing bran and whole grain generally have higher results. Additionally, it is observed that fruits and cocoa added products have a higher antioxidant capacity than the others in their group.

4. Conclusions

According to the results of 10 cereal-based product groups, dry matter, ash, protein and fat content of all samples were in the range of expectations and literature results, except low protein content of bulgur samples. All product groups except rice samples were found to contain an important amount of bioactive components. Additionally, significant differences were determined between the bioactive components and antioxidant activities of the product groups. Product type and production method, as well as the raw material properties used in the product, have a direct effect on these differences. For example, yellow corn and corn containing products can be preferred for higher carotenoid intake and antioxidant activity. It has been concluded that those who want to consume bioactive components and antioxidant activity rich cereals should prefer the products with high capacity raw materials such as bran, germ, fruit, cocoa as well as whole grain products.

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