RESEARCH ARTICLE

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The effect of boiling and baking process on total phenolic compounds and antioxidant capacity of Osmanoğlu and Sarıaşlama chestnuts grow in Bursa

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Abstract

Chestnut is a fruit with high carbohydrate content, low-oil ratio and protein content, including minerals, vitamins, amino acids and phenolic compounds which can have antioxidant properties. It has been determined that the amount and composition of phenolic components could change in according to environmental and growing conditions, and the variety of chestnuts having impact on protein content. This study was conducted to investigate the possible effects of boiling and baking on some physical and chemical properties, antioxidant activity and total phenolic content of Osmanoğlu and Sarıaşlama chestnut varieties grown in Bursa. According to the results of the present study, some physical and biochemical properties of raw chestnut were determined as humidity 48.78–56.57 %, ash 1.11–1.27 g 100 g^{-1}, water activity 0.705–0.844, pH 7.03–7.29, color L* 60.52±2,64; a* 0.13±0,18; b* 12.39±1.57. The total phenolic compounds content was 129.17±6.23 mg GAE (gallic acid equailent) kg^{-1} in raw chestnuts, 180.97±18.25 mg GAE kg^{-1} in boiled chestnuts, and 149.86±7.95 mg GAE kg^{-1} in baked chestnuts. Also, the antioxidant capacity found like 0.42±0.01 µmol AAE (ascorbic acid equivalent) g^{-1} for raw chestnuts, 0.31±0.03 µmol AAE g^{-1} for boiled chestnuts, and 0.40±0.01 µmol AAE g^{-1} of baked chestnuts. It was determined that while the application of the boiling process caused a significant decrease in the antioxidant activity of chestnuts, the application of the baking process did not cause any meaningful change on the antioxidant capacity of the chestnuts. It was determined that there was a significant increase in the total phenolic compounds content with the boiling and baking process compared to raw chestnuts.

Keywords: Chesnut, Total phenolic compounds content, Antioxidant capacity

INTRODUCTION

Chestnut was a general name given to trees of the genus *Castanea* and has the edible seeds of these trees. Although it can be grown in all over the world except in Antarctica, most production in the world is made in China and Bolivia (Atasoy and Altıngöz, 2011). Turkiye ranks third in this ranking, with 62,904 tons in 2017 (Faostat, 2018). The main chestnut varieties grown in Turkiye were Osmanoğlu, Sarıaşlama, Hacı İbiş, Hacıömer and Mahmutmolla.

Chestnut has been an important source of carbohydrates and proteins in human nutrition since ancient times (Jaynes, 1979; Payne et al., 1983) and these proportions change according to the type, variety and ecological conditions in which chestnuts grows (Payne et al., 1983). Chestnuts are rich in carbohydrates and low in oil (1.5-2%) and protein (2.5-3%), unlike other hard-shelled fruits. Chestnut, which is a nutritious and high-calorie food, is rich in vitamins B1, B2

and C. Regarding its mineral content, chestnut is also a source of K, Mg, Fe, Mn and Cu (Borges et al., 2008). They are an excellent source of dietary fiber; It provides 8.1 g (approximately 21% Reference Daily Intake) fiber per 100 g. Dietary Fiber helps to lower blood cholesterol levels by limiting excessive cholesterol absorption in the intestines (URL– 4, 2017). Compared to other hard-shelled fruits, it contains the lower oil and higher carbohydrate (Turkomp, 2022). Although the sugar content is equal to the 10% of carbohydrate composition, the remaining part is starch and dietary fiber, which causes it to be a fruit with a low glycemic index.

Chestnut, which is rich in carbohydrates, is a healthy food due to its cholesterol-free, low glycemic index, little calories, rich in protein and vitamin C (Ribeiro et al., 2019). The oil and high fiber content of chestnuts make them a healthy food and a well energy source. Recently, chestnut consumption has been increasing daily with the health benefits of chestnuts, changes in dietary habits and gluten-free nutrition approaches (Wani et. al., 2017). The protein content of chestnut contains essential amino acids tryptophan, lysine, and methionine (Wani et. al., 2017). The amino acid profile of chestnut is dominated by L-aspartic acid, followed by L-glutamic acid, Leucine, L-alanine and Arginine (Borges et al., 2008). Furthermore, chestnut contains important components that have a positive effect on health; these are antioxidant compounds such as L-ascorbic acid, vitamin E, carotenoids, and polyphenols (especially gallic and ellagic acids) (Barreira et al., 2009; de Vasconcelos et al., 2010, De Vasconcelos et al., 2007; De Vasconcelos et al., 2009; Gonçalves et al., 2010; Neriet al., 2010; Barros et al., 2011).

Chestnut fruits (Ribeiro et al., 2007) and leaves (Calliste et al., 2005) have been shown to contain phenolic compounds (Barreira et al., 2008). Phenolic compounds are secondary metabolites found in fruits, vegetables, and grains. They influenced the color, taste and aroma of fruits and vegetables (Wollgast and Anklam, 2000; Havsteen, 2002;). The antioxidant activities of phenolic compounds are related to a number of different mechanisms, such as free radical scavenging, hydrogen donation, $^1O_2$ quenching, metal ion chelation, and acting as a substrate for $O_2^{\cdot -}$ and $OH^{\cdot}$ radicals. A direct relationship was found between the antioxidant capacity of plants and their total phenolic content (Robards et al., 1999; Barreira et al., 2008). Natural antioxidants, phenolic acids and their derivatives present in the diet or prepared synthetically have been shown to have chemopreventive (preventing the harmful effects of chemicals) properties (Fang, Yang and Wu, 2002; Barreira et al., 2008).

Like almonds, hazelnuts, walnuts and pistachios, chestnuts are in the group of hard-shelled fruits. Tree-grown fruits such as hazelnuts, chestnuts, walnuts and pecans have high antioxidant content (Blomhoff et al., 2006; Barros et al., 2011). In recent years, chestnut has also attracted attention in the health, pharmaceutical and material sectors, apart from food products. The use of chestnuts to develop gluten-free products, for high cholesterol, diabetes and celiac patients is becoming widespread. Studies on the antioxidant functions of chestnuts and its effects on diet-induced obesity have been increasing. The variety of chestnuts in the market has led to increase in the use and consumption of chestnut. However, consumers prefer fresh chestnuts because they think it is healthier. In addition, chestnut flours are used in the formulations of products made for celiac patients. (Li et al., 2022; Liu et al., 2020; Niazi et al., 2018). Fresh chestnuts are generally consumed after boiling, baking, or roasting processes. The aim of this study to investigate the effects of heat treatments applied by boiling and baking chestnuts on antioxidant activities in chestnuts. Thus, the effect on the nutritive properties of chestnuts during industrial processing can be optimized.

MATERIALS AND METHODS

The type of chestnut used in this study is *Castanea sativa* Mill. It was obtained from Kurşunlu village of Karacabey district of Bursa province and from Cumalıkazık, Yiğitali and Kirazlı villages of Bursa center in October 2015. Chestnut varities used in this study were Osmanoğlu and Sarıaşlama. After the inner and outer shells of the raw chestnuts were cleaned, they were cut into small pieces using a shredder. The prepared samples were used for physical analysis and antioxidant analyses. For boiled chestnuts, 200 g chestnuts were boiled in 1000 ml water for 30 min. For the chestnuts baked in the oven were drawn as (+) using a knife and then baked in the oven at 180˚C for 30 min. Then it was separated from its inner and outer shells and then was made homogeneous by crushing.

Physicochemical Analysis

The water activity of raw chestnut samples was measured from the prepared homogenate at 25˚C with a water activity analyzer (Novasina, LabMaster). For determination the total dry matter, 4 g of the raw chestnut samples were weighted from the homogenate then the weighted sample were taken into petri dishes. The weights were taken by keeping them in a vacuum oven at 70ºC (200 mmHg) for 24 hours and calculated as % dry matter. For pH determination, suspension was prepared by taking 5 g of homogeneous sample and diluting it with 25 ml of distilled water. The resulting suspension was mixed at 20 min intervals and measured with a pH meter (Thermo Scientific, Orion3Star, Singapore) at 20ºC. For ash determination, 4 g of the homogenate was taken (prepaid) and weighed in a porcelain crucible. Then, 95% ethanol was poured into the crucibles and burned until charred. The charred sample was burned in the muffle furnace at 550ºC until there were no black spots.

Color measurement; Chestnut fruit flesh color was

determined by measuring the peeled chestnuts with a colorimeter (Konica Minolta, CR-400, Japan) in the Hunter (L*, a*, b*) color measurement system at room temperature. Flesh color of chestnut fruit was measured in terms of L*, a*, and b*. L* stands for brightness/darkness, a* stands for redness (+)/greenness (-), and b* stands for yellowness (+)/blueness (-).

Determination of total phenolic content (TPC)

The total phenolic content in extracts of raw, boiled and baked chestnuts was determined according to the Singleton et al. (1999) method with some modifications. The Folin-Ciocalteu method is based on the absorbance measurement according to the color intensity formed by the reagent that gives the method its name (Huang et al., 2005). A calibration curve was drawn by using gallic acid solutions. 1 mL of chestnut fruit extract were taken and placed in balloon bottles. 45 mL of distilled water, 1 mL of 2N Folin-Ciocalteu reagent and 3 mL of 3% Na_2CO_3 solution were added after 3 min. After 2 hours, the absorbance of the mixture was read in the spectrometer at 720 nm. The results of the samples were calculated as mg GAE kg^{-1} wet weight.

Determination of total antioxidant activity

The antioxidant activity of raw, boiled and baked chestnuts was determined according to the DPPH (2,2-Diphenyl-1-picrylhydrazyl) antioxidant activity method. 0.1 ml of diluted extract was taken, and 3.9 ml of DPPH solution ($6x10^{-5}$ M) was added. After the mixture was kept at dark for 30 min, absorbance values of the samples were read at 515 nm and antioxidant activity values in the samples were calculated according to the calibration graph drawn with ascorbic acid. The results were given as µmol AAE g^{-1} wet weight (Coklar and Akbulut, 2016).

Statistical analysis

Statistical analyzes were performed using the SPSS 20.0 package program. The significance of differences between the physicochemical properties of chestnut fruit cultivars were determined by using an independent two-sample t-test (0.01 ve 0.05 confidence interval). The effects of boiling and baking processes on chestnuts on the total antioxidant activity and total phenolic content were determined using a one-way MANOVA Duncan multiple comparison method at a 95% confidence interval.

RESULTS AND DISCUSSION

In terms of nutritional physiology, preserving vitamins and minerals in foods depends on processing and storage conditions. During processing and storage, the physical and chemical state of water affects the quality of food. Similarly, chestnut varieties should also be considered when the quality properties of them were evaluated. Water activity is known as the ratio of the vapor pressure of water in food to the vapor pressure of pure water at the same temperature. Water activity has an important role in the deterioration of foods rather than the amount of water chestnuts contain (Erdal 2013). In our study, the water activity value was found to be 0.705–0.844. In terms of water activity (aw) values, the average value of water activity of the Sarıaşlama variety was higher than the Osmanoğlu variety ($p<0.01$). Erdal (2013), the quality of chestnut fruit before and after harvest, found water activity between 0.952 and 0.963 in peeled chestnuts. Erdal (2013) determined that storage conditions (temperature, humidity and time) have an affect on water activity values. Erdal (2013) worked with chestnuts obtained from the Nazilli region of Aydın province but the samples we used were obtained from Bursa province. Thus these differences may be due to the difference in the growing environment of chestnuts.

Total dry matter content may vary depending on the type and variety of chestnut and the conditions during storage. In our study, the total dry matter content was determined as 48.82±1.19% in the chestnut fruit of the Sarıaşlama variety and 46.96±1.17% in the Osmanoğlu variety. Moisture content was determined as 51.1% in the Sarıaşlama variety and 53.04% in Osmanoğlu. There was no statistical difference between Sarıaşlama and Osmanoğlu cultivars in terms of total dry matter ($p>0.01$). The moisture content was found by Yıldız et al., (2009), Otles and Selek, (2012), Fatih et al., (2013), Mert and Ertürk, (2017) 54.84%, 26.14–44.99%, 52.6-56.9%, 46.52-59.47% as, respectively. Neri et al., (2010) determined between 42.27-52.89% of the moisture content of chestnut fruits in Italy. In addition, the total dry matter amount values found in our study are consistent with the results determined in previous studies.

The term pH is used to describe the degree of acidity or, in other words, the strength of acidity. The factor affecting pH is the active hydrogen ion concentration. The pH value was 7.18 of Sarıaşlama cultivar and 7.26 in Osmanoğlu cultivar and the difference was determined to be statistically significant ($p<0.01$). In our study, it was observed that the pH of raw chestnuts varied between 7.03 and 7.29.

Ash refers to the sum of the mineral substances in the food, and the amount of mineral substance varies from food to food. In our study, the amount of ash was found to be 1.11±0.14% in the chestnuts of the Sarıaşlama variety and 1.27±0.15% in the chestnuts of the Osmanoğlu variety. There was no statistical difference between Sarıaşlama and Osmanoğlu cultivars in terms of ash ratio ($p>0.01$). Ertürk et al., (2006) found the amount of ash 1.02-3.22 g 100 g^{-1} in their study. In the study conducted in the Erfelek region of Sinop province, the ash amount of chestnut was determined as 1.40-4.92 g 100 g^{-1} (Üstün et al., 1999). Yıldız et al., (2009) found the amount of ash 1.078 g 100 g^{-1}. In the study conducted with chestnuts grown in the Marmara region, they stated

that the amount of ash varied between 2.09 g 100 g^{-1} and 4.39 g 100 g^{-1} and the average was 3.00 g 100 g^{-1} (Mert and Ertürk, 2017). The amount of ash we determined in our study is similar to other studies.

Table 1. Some physicochemical properties of Sarıaşılama and Osmanoğlu raw chestnut cultivars

	Sarıaşlama	Osmanoğlu
Water activity	0.784±0.02**	0.728±0.01
Total dry matter (%)	48.82±1.19	46.96±1.17
pH	7.18±0.05	7.26±0.04**
ash (%)	1.11 ±0.14	1.27±0.15
L*	61.02±3.37	60.01±2.50
a*	-0.05±0.02	0.29±0.02
b*	12.94±1.90	11.84±1.20

** The difference is statistically significant ($p<0.01$).

Color is a visual property that occurs depending on the spectral distribution of light. The main reasons why color gains importance in foods are taking a role in the pleasing of food in terms of consumer preferences; The change in the color of the food gives an idea about the ripening and the deterioration with the change in taste and texture. In our study, the average color values of raw chestnuts were L* 60.52±2.64; a* 0.13±0.18; b* 12.39±1.57. Erdal, (2013) found L^*96.07, a^*-3.89, b^*7.44. Similarly, Algül et.al., (2016) determined L^*89.93, a^*-2.18, b^*5.20 in their research. In our study, between the sarıaşlama and osmanoğlu cultivars in terms of color parameters (L, a*, b*) were not found statistical difference ($p>0.05$). Color values were L* 61.02±3.37, a*-0.05±0.02, b* 12.94±1.90 in Sarıaşlama cultivar, L* 60.01±2.50, a* 0.29±0.02, b* 11.84±1.20 in osmanoğlu cultivar.

Abe et al., (2010) expressed the antioxidant activity of chestnut as 6.2 µmol Trolox equivalent g^{-1} d.m. using the DPPH method. Otles and Selek, (2012), determined the total antioxidant capacity of raw chestnuts according to the FRAP method as 9.08-14.15 mM $FeSO_4$ g^{-1} d.m. were found to vary within the range. The fact that the obtained data is lower than the values found in the literature due to the chestnut cultivars used in the present study and the differences in growing conditions.

In the study examining the total vitamin C content of chestnuts (ascorbic acid + dehydroascorbic acid) and antioxidant activity in raw and cooked chestnuts, the antioxidant content of roasted and boiled chestnuts decreased by 51% and 88%, respectively (Barros et al., 2011). Li et al., (2016) investigated the effects of different cooking methods on the content of important nutrients and volatiles in Chinese chestnuts. They reported that the compounds such as reducing sugar, sucrose, organic acids and total flavonoids of boiled, roasted and fried chestnuts were significantly lower than raw chestnut varieties after cooking ($p<0.05$). The total polyphenol content (2.24 mg/g) in raw chestnut remained unchanged after roasting (2.26 mg/g) but it decreased after boiling (2.03 mg/g) and frying (2.08 mg/g). Total flavonoid content (2.62 mg/g) also decreased after boiling (2.12 mg/g), roasting (2.25 mg/g) and frying (2.13 mg/g) processes (Li et al., 2016). Barros et al., (2011) and Li et al., (2016) determined that the antioxidant value of raw chestnuts was higher and heat treatment caused a decrease in the antioxidant value of chestnuts but Gonçalves et al., (2010) determined that the antioxidant value of roasted and boiled chestnuts is higher than that of raw chestnuts. Gonçalves et al., (2010) investigated

Table 2. Changes in the amount of TPC and DPPH in the boiling and baking process of chestnut varieties.

	Sarıaşlama		Osmanoğlu	
	DPPH µmol AAE g^{-1}	TPC mg GAE kg^{-1}	DPPH µmol AAE g^{-1}	TPC mg GAE kg^{-1}
Raw	0.41±0.01 c	121.06±7.45 a	0.42±0.01 b	137.28±5.00 a
Baked	0.23 ±0.04 a	175.11±13.39 b	0.30±0.02 a	186.83±23.10 b
Boiled	0.38±0.01 b	144.11±10.46 ab	0.42±0.01 b	155.61±5.43 ab

Different letters in each column indicate statistical difference ($p<0.05$)

The antioxidant activity values of chestnut samples are shown in Table 2. While it was determined as 0.41±0.01 µmol AAE g^{-1} of raw chestnut in Sarıaşlama variety, antioxidant activity values decreased with baking and boiling processes ($p<0.05$). When the antioxidant activity was examined after the cooking processes with raw chestnut in the Osmanoglu type, there was no significant change in the antioxidant activity with the boiling process ($p>0.05$), but a decrease occurred in the baking process ($p<0.05$). Neri et al., (2010) determined the antioxidant activity of chestnut by ABTS method as 4.77-8.15 µmol Trolox equivalent g^{-1} d.m. found to be in the range.

the metabolic composition of chestnut (*Castanea sativa* Mill.) during cooking. As a result of this research, they concluded that roasted chestnuts have higher gallic acid and total phenolic content, and boiled chestnuts have higher gallic and ellagic acids compared to raw chestnuts. Contrary to what is known, studies conducted in recent years have also shown that new antioxidant compounds can be formed with heat treatment and increase the number of phenolic compounds. It is also observed that antioxidant and phenolic components increase with the inactivation of enzymes that inhibit antioxidant activity and the liberation of some phenolic compounds by heat treatment (Pinelo et al., 2005).

Total phenolic content of boiled chestnut in Sarıaşlama cultivar was similar to that of baked chestnut, but higher than raw chestnut. Total phenolic content of boiled chestnut in Osmanoğlu cultivar was similar to that of baked chestnut, but higher than raw chestnut ($p<0.05$). The total amount of phenolic substance was found to be 121.06±7.45 mmol gallic acid equivalent/g sample in raw chestnut (Table-2). Total phenolic content of raw and baked chestnuts was similar and higher than boiled chestnuts in both cultivars ($p<0.05$). When the researches were examined, it was seen that different results were recorded depending on many factors such as fruit variety, the season in which the fruit is harvested, the fraction of the fruit, and the climatic conditions in which it is grown (Coklar and Akbulut, 2016).

Neri et al., (2010) determined the total phenolic content of raw chestnuts as 1120,6 mg GAE/kg dm. In another study conducted on chestnuts collected from 12 different locations in Turkey, the amount of TPC was 500–3200 mg GAE kg^{-1} dm. (Otles and Selek, 2012). Suárez et al., (2012) determined in their study that the TPC amount of chestnuts obtained from 20 different locations in Spain varied from 196-431 mg GAE kg^{-1} dm. and the average was 284 mg GAE kg^{-1} d.m. In another study, Chang et al. (2020) determined the phenolic content of five types of chestnut produced in China between 243,5-586 mg GAE kg^{-1} dm. in different cultivars. As seen in previous studies, the amount of TPC in chestnut varies according to the place where it is grown and the type of chestnut.

CONCLUSION

As a result of the research, according to the studies on chestnut fruits, physicochemical analyzes are generally compatible. It is thought that the differences in some parameters were caused by the type and variety of chestnut and the ecological conditions in which it is grown. In antioxidant analysis, the total amount of phenolic substances in raw chestnuts was higher than others. The difference may be due to genetic and environmental factors. While the boiling process caused a significant decrease in antioxidant capacity according to the DPPH method, the baking process did not cause any change. It was observed that there was a significant increase in the total phenolic content with the boiling and baking process.

As a result, this study, some physicochemical and antioxidant properties of two different chestnut species grown in the Bursa region were determined and the effects of boiling and baking on chestnuts' antioxidant properties and phenolic substance content of chestnut were investigated. Chestnut, which is not widely consumed raw, is generally used in confectionery, bakery, and pastry products. Chestnuts used commercially in confectionery and pastry products are first boiled. The boiling process is important in this respect. In addition, chestnuts are also consumed by baking. In our study, in which we examined the antioxidant substance content and total phenolic substance changes when chestnuts were treated with these two most consumed cooking techniques, it can be concluded that the best method is the baking method.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. In addition, all the authors verify that the Text, Figures, and Tables are original and have not been published.

Ethical approval

Ethics committee approval is not required.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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