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The effect of roasting in microwave and oven on selected constituents, antioxidant activity, fatty acids, phenolic compounds and mineral contents of Chestnut (*Cestanea sativa* Milles) kernels

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ABSTRACT

In this study, the effect of roasting in microwave and oven on selected constituents, bioactive properties, fatty acid compositions, polyphenol and mineral contents of Chestnuts (*Cestanea sativa* Milles) grown in Bursa in Turkey was investigated. The oil contents of Chestnut fruits are defined between 0.85 (control) and 3.30% (microwave). While antioxidant results of Chestnut roasted change between 68.07 (microwave) and 70.03% (oven), total phenolic amounts of Chestnut extracts roasted varied between 74.65 (control) and 129.10 mgGAE/100 g (oven). Gallic acid and 3,4-dihydroxy benzoic acid contents of Chestnut roasted were recorded between 9.55 (control) and 21.79 mg/100 g (microwave) to 2.93 (control) and 11.47 mg/100 g (microwave), respectively. Oleic and linoleic acid contens of unroasted and roasted chestnut oils were reported between 35.40 (microwave) and 38.91% (oven) to 39.02 (control) and 43.22% (microwave), respectively. The Ca and K amounts of unroasted and roasted Chestnut samples changed betweeen 770.40 (oven) and 1156.30 mg/kg (microwave) to 7436.01 (control) and 7947.72 mg/kg (microwave), respectively. In general, while oven roasting is recommended for bioactive components of Chestnuts, microwave roasting is recommended for phenolic components and minerals.

1. Introduction

Chestnut (*Castanea sativa* Mill; family Fagaceae) is one perennial plant, and widespread cultivation is carried out in the wild or cultural base in Turkey. Although the Chestnut trees are used in the production of wood and tanning materials, their fruits have an important economic value (Gonçalves et al., 2010). The most consumed chestnut type in Turkey is *Castanea sativa* Mill and Chestnut fruits are ripen in October/November in Turkey (Ertürk et al., 2006). Due to the increase in Chestnut consumption especially in Europe, Australia, New Zealand and the United States of America, international interest in Chestnuts has increased (Gold et al., 2005). They are consumed as mostly roasted, boiled and fried (Goulão et al., 2001; Ribeiro et al., 2007). It has been reported that Chestnuts have become increasingly important in human nutrition due to their nutritional composition and potential beneficial health effects (Pazianas et al., 2005). It has a great importance in human nutrition due to the nutritional composition of Chestnuts (Sabaté et al., 2000; Pazianas et al., 2005). Chestnut is considered a good source of energy along with high fiber content. In addition, Chestnuts, which have high amounts of vitamin C, also do not contain cholesterol (Gold et al., 2005). Chestnut contains 20–32% sugar, 50–70% starch, 4–10% dietary fiber, 2–7% protein and 2–4% lipid (Vaughan & Geissler, 1997a; Chenlo et al., 2007). It has been confirmed by various researchers that chestnuts are rich in K and P (Vaughan & Geissler, 1997b; De Vasconcelos et al., 2010). It was reported by Borges et al. (2008) that it is a good source for Fe, Mn and Cu. One of the important factors affecting the organoleptic properties of fruits and vegetables is the structure and concentration of organic acids (Vaughan & Geissler, 1997c). It was reported that organic acids with antioxidant properties would have protective properties against various diseases due to their antioxidant potential (McCharty &

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Table 1
Some bioactive properties of unroasted and roasted chestnuts.

Heat treatment	Moisture content (%)			Antioxidant activity (%)			Total phenolic content (mg/100 g)			Oil content (%)		
Control	49.39	±	1.39*a	69.45	±	0.00b	74.65	±	0.01c	0.85	±	0.25c
Microvawe (W)	2.41	±	0.48b**	68.07	±	0.00c	101.46	±	0.03b	3.30	±	0.40a
Oven (°C)	2.07	±	0.10c	70.03	±	0.00a	129.10	±	0.04a	3.10	±	0.10b

*mean ± standarddeviation; **Values in each column with different letters are significantly different ($p < 0.05$)

Table 2
Phenolic compounds of unroasted and roasted chestnuts (mg/100g).

Phenolics	Control			Microwave (W)			Oven (°C)		
Gallic Acid	9.55	±	0.23*c	21.79	±	1.05a	19.15	±	1.70b
3,4-Dihydroxybenzoic acid	2.93	±	0.92c**	11.47	±	0.26a	10.04	±	1.11b
(+)-Catechin	5.44	±	0.41c	17.75	±	0.73a	16.75	±	1.74b
1,2-Dihydroxybenzene	4.89	±	0.01c	15.43	±	1.24a	11.51	±	0.88b
Syringic acid	3.32	±	0.52b	4.02	±	0.67a	2.08	±	0.56c
Caffeic acid	4.02	±	0.30a	2.74	±	0.27b	2.22	±	0.32c
Rutin trihydrate	0.81	±	0.72b	2.33	±	0.26a	0.46	±	0.11c
p-Coumaric acid	0.13	±	0.09b	0.15	±	0.07a	0.11	±	0.03c
trans-Ferulic acid	1.13	±	0.85c	1.71	±	0.20a	1.31	±	0.19b
Apigenin -7 -glucoside	1.59	±	0.32a	1.04	±	0.06b	0.88	±	0.06c
Resveratrol	0.28	±	0.26a	0.28	±	0.21a	0.15	±	0.08b
Quercetin	2.08	±	0.78a	1.64	±	0.90b	0.44	±	0.41c
trans-Cinnamic acid	0.13	±	0.10a	0.03	±	0.03c	0.08	±	0.05b
Naringenin	0.63	±	0.15a	0.39	±	0.16b	0.14	±	0.00c
Kaempferol	0.92	±	0.82a	0.11	±	0.00c	0.55	±	0.45b
Isorhamnetin	0.44	±	0.16a	0.38	±	0.25b	0.13	±	0.10c

*mean±standarddeviation; **Values in each row with different letters are significantly different ($p<0.05$)

Meredity, 1988; Senter et al., 1994; Künsch et al., 1999; Silva et al. (2004). Moreover, the amount of reducing sugar increased with the applied process while the crude fat content did not change (Shin et al., 1981; Künsch et al., 1999). In the previous study, roasting, boiling and frying had a significant effect on the reduction of total organic acid content (Ribeiro et al., 2007). It has been reported that roasting causes little change in the composition of Chestnuts (Künsch et al., 2001; Ribeiro et al., 2007). Also, heat treatment such as roasting improves the digestibility and shelf life of Chestnuts. Microwave process finds great applications in a variety of food processing areas such as drying, pasteurizing, sterilizing, thawing, tempering and cooking food. In addition, the changes in the fatty acid composition of Chestnuts during roasting at 182 °C were investigated and it was observed that the ratio of unsaturated fatty acids to saturated fatty acids decreased (Morini & Maga, 1995). Various studies have been conducted to investigate the effect of vegetable oils on the quality such as color, flavor, fatty acid profile and bioactive compounds using microwave and traditional heating methods (Albi et al., 1997; Cerretani et al., 2009). However, since most of the studies have focused on the composition of raw fruits, information on possible changes in the composition of phytochemical after using different heating procedures is relatively limited. The goal of this study was to determine the effect of roasting in microwave and oven on selected constituents, bioactive properties, fatty acid compositions, polyphenol and mineral contents of Chestnuts (*Cestanea sativa* Milles) grown in Bursa in Turkey.

2. Material and methods

2.1. Material

Maturate wild Chestnut fruits (about 20 kg peeled Chestnuts) were provided from Chestnut trees growing in Bursa province in Turkey in October 2021. For analysis, the chestnuts were transported in cloth bags to the laboratory, and the crushed, unripe fruits inside were removed by hand. After all these processes, the moisture content of the Chestnut samples was determined immediately. The remaining samples were kept at room temperature for the duration of analysis. The outer and inner shell of samples were removed before roasting process.

2.2. Methods

2.2.1. Roasting process

Chestnut samples were roasted in an oven at 120 °C for 1 h; in a microwave system at 900 W for 15 min. Both fresh and roasted samples were milled to 0.5 mesh thickness in a laboratory scale mill for analysis (Künsch et al., 2001).

2.2.2. Moisture content

The moisture amounts of ground Chestnut fruits were established in an oven set at 105 °C degrees (Nüve FN055 Ankara, Turkey) up to constant weight (AOAC, 1990).

2.2.3. Extraction process

Samples were extracted according to Gonçalves et al. (2010). Ground samples (4 g) were added to 10 mL of methanol:water (70:30, v/v). The mixture was kept in water-bath for 30 min at 70 °C and mixed using a vortex apparatus for 5 min, followed by centrifugation at 6000 rpm for 20 min. Then the supernatant was collected and filtered through a 0.45 μm membrane filter.

2.2.4. Total phenolic content

The Folin-Ciocalteu chemical was applied to measure the total phenol contents of Chestnut fruit extracts (Yoo et al., 2004) with some modifications. 1 mL Folin-Ciocalteu was added on extract, and mix was stirred for five minutes. Then, 10 mL Na_2CO_3 solution were added and mixed. The final volume was completed to 25 mL with distilled water. After it was kept for 1 h, total phenolic contents of samples were measured at 750 nm wave length in a spectrophotometer (Shimadzu--Japan). The results were described as mg gallic acid equivalent (GAE)/100 g.

2.2.5. Antioxidant activity

The method of Lee et al. (1998) was applied to assess the DPPH (1.1-diphenyl-2-picrylhydrazyl) free radical scavenging activity of

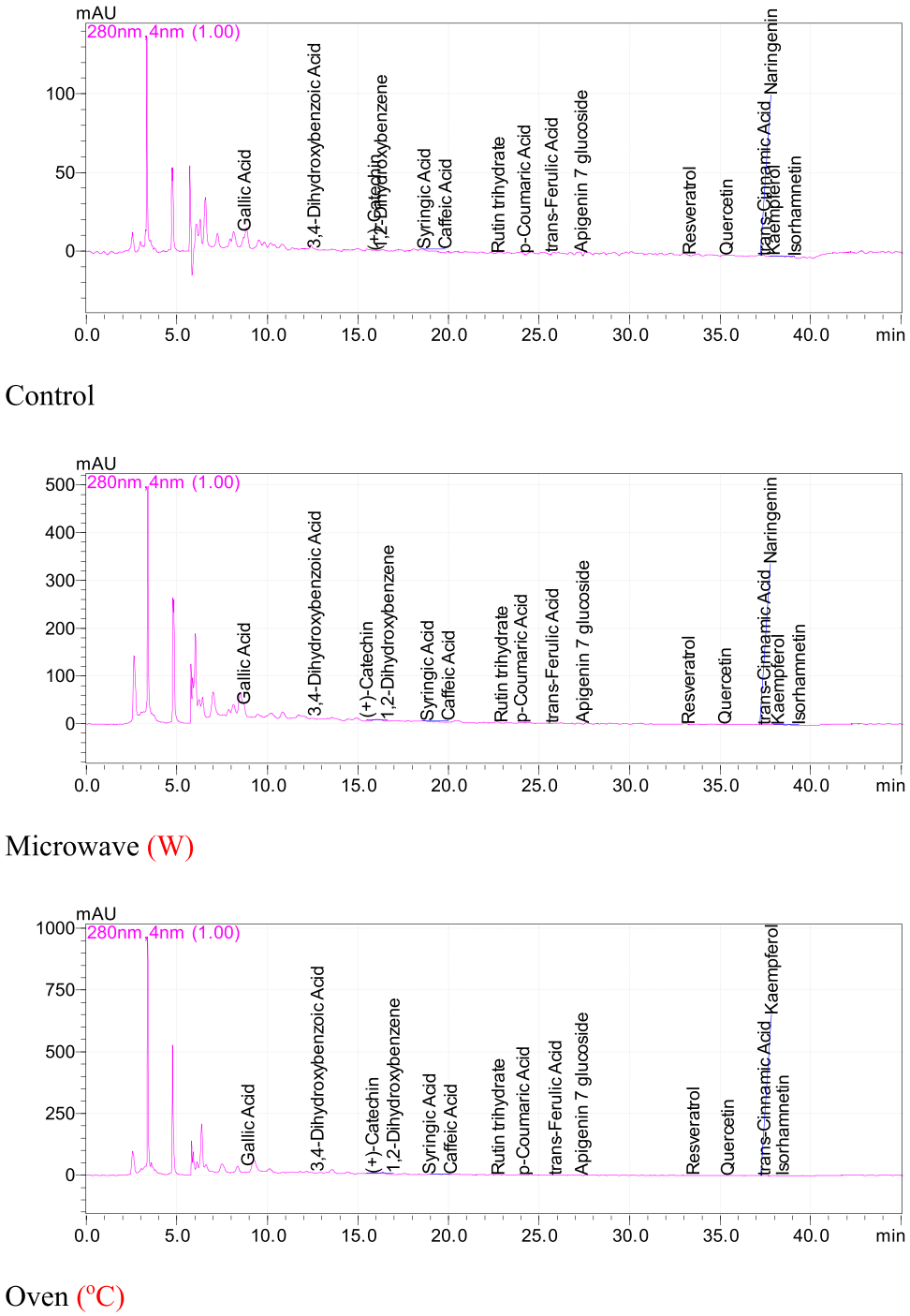

Fig 1. Phenolic chromatograms for unroasted and roasted Chestnut.

Chestnut fruit extracts. After mixing 0.2 mL extract with 2 mL of DPPH in methanol and 30 min incubation in the dark at room, the absorbance was measured at 517 nm and percenatge inhbition was calculated as described previously. Antioxidant activity (%) was calculated using following relation:

$$Inhibition(\%) = \left[\frac{\Delta AControl\ 517 - \Delta AExtract517}{\Delta AControl\ 517}\right] \times 100$$

2.2.6. Determination of phenolic compounds

A Shimadzu-HPLC equipped with a PDA detector and an Inertsil ODS-3 (5 μm; 4.6×250 mm) column was applied for the qualification and quantification of phenolic constituents of Chestnut fruits. The mobile phase was composed of 0.05% acetic acid (A) and acetonitrile (B) and 20 μl of the extract was injected and run at 1 mL/min at 30 °C for a total running time of 60 min. The peaks were measured at 280 and 330 nm using a PDA detector (Khang et al., 2016).

2.2.7. Oil content

The oil amounts of Chestnut fruits belong to each color type were established according to AOAC (1990) method. The total oil contents of the Chestnut fruits were extracted with petroleum ether in Soxhlet apparatus for 5 h, and then the solvent was evaporated at 50 °C by rotary evaporator.

Table 3
Fatty acid composition of the oils extracted from unroasted and roasted chestnut (%).

Fatty acids	Control			Microwave (W)			Oven (°C)		
Myristic	0.12	±	0.00*a	0.12	±	0.01a	0.09	±	0.00b
Palmitic	16.22	±	0.13a**	15.71	±	0.77b	15.22	±	0.02c
Stearic	1.46	±	0.34b	0.94	±	0.15c	1.59	±	0.00a
Oleic	36.47	±	0.88b	35.40	±	0.69c	38.91	±	0.10a
Elaidic	1.42	±	0.16a	1.13	±	0.03c	1.29	±	0.01b
Linoleic	39.02	±	0.78b	43.22	±	0.05a	39.06	±	0.07c
Arachidic	0.38	±	0.05a	0.15	±	0.13c	0.37	±	0.00b
Linolenic	4.18	±	0.56a	3.10	±	0.04c	3.16	±	0.03b
Behenic	0.22	±	0.02a	0.14	±	0.05c	0.21	±	0.00b
Arachidonic	0.14	±	0.03a	0.07	±	0.01c	0.09	±	0.00b

*mean±standarddeviation; **Values in each row with different letters are significantly different ($p<0.05$)

2.2.8. Fatty acid composition

The fatty acid methyl esters (FAMEs) of extracted Chestnut oils were prepared as described in standard method (ISO-5509, 1978). FAMEs were determined using a gas chromatography (Shimadzu GC-2010) consisting of flame-ionization detector (FID) and capillary column. The carrier gas and total flow rate were nitrogen with 1.51 mL/min flow rate and 80 mL/min. In addition, split rate was also 1/40. The temperature of injection block and detector was 260ºC and column temperature was programmed 120ºC for 5 min and increased 240ºC at 4ºC/min and held 25 min at 240ºC (AOAC, 1990).

2.2.9. Determination of mineral contents

About 0.5 g dried and ground Chestnut fruit was put into a burning cup and added pure 15 mL pure HNO_3. The sample was incinerated in a MARS 5 Microwave Oven at 200 °C and solution was diluted to the specify volume with water. Then, mineral content of samples were determined with an ICP-AES (Skujins,1989).

2.3. Statistical analyses

All treatments were done three times and data of triplicate analyses were averaged and subjected to analysis of variance. Results were described as mean±standard deviation (MSTAT C) of Chestnut samples and roasting times (Püskülcü & İkiz, 1989).

3. Result and discussion

3.1. The chemical and bioactive properties of Chestnut roasted in oven and microwave

The chemical and bioactive properties of Chestnut roasted in oven (120 °C/1 h) and microwave (900 W/15 min) systems are illustrated in Table 1. The moisture contents of Chestnut changed between 2.07% (oven) and 49.39% (control) while oil contents of Chestnut are determined between 0.85% (control) and 3.30% (microwave). In addition, while antioxidant activity values of Chestnut extracts roasted in microwave and oven change between 68.07% (microwave) and 70.03% (oven), total phenol contents of Chestnut extracts roasted in microwave and oven varied between 74.65 mgGAE/100 g (control) and 129.10 mgGAE/100 g (oven). Gonçalves et al. (2010) determined 46.8% and 54.2% drymatter, 3.2% and 3.08% oil, 16.2 mg/g and 19.3 mg/g total phenol in raw and roasted Chestnut fruits, respectively. The antioxidant activity and total phenolic compounds of chestnuts exposed to heat treatment in the oven show an advantageous situation compared to those roasted in the microwave. However, microwave roasting is more prominent in terms of fat content. Abe et al. (2010) determined 50% moisture and 5.8% lipid, 92.0 mg/100 g total phenol and 6.2 μmol Trolox/g in raw Chestnut fruit. The oil amounts of the Chestnut kernels changed between 0.49 and 2.01 g/100 g (Ertürk et al., 2006). In other studies on Chestnuts, oil content of varieties belonging to *C. sativa* Mill Chestnut species was found between 0.66 and 5.59 g /100 g (Üstün et al., 1999; Demiate et al., 2001; Sundriyal & Sundriyal, 2001). As seen in Table 1, while the moisture contents of Chestnut during roasting decreased, oil contents of Chestnut increased. The increase in the fat content of roasted Chestnut samples in both roasting systems may be due to the decrease in moisture content and the increase in dry matter content. Also, the antioxidant activity and total phenol contentr of Chestnut roasted in oven increased pasrtially compared to control and microwave.

3.2. The phenolic compounds of unroasted and roasted-Chestnut

The phenolic compounds of unroasted (control) and roasted Chestnut in oven and microwave systems are shown in Table 2. While gallic acid amounts of Chestnut roasted in microwave and oven change between 9.55 (control) and 21.79 mg/100 g (microwave), 3,4-dihydroxy benzoic acid contents of Chestnut were identified between 2.93 (control) and 11.47 mg/100 g (microwave). Also, (+)- catechin contents of unroasted and roasted Chestnut samples were determined between 5.44 (control) and 17.75 mg/100 g (microwave) (Fig. 1). While 1,2-dihydroxybenzene amounts of roasted and roasted Chestnut samples change between 4.89 (control) and 15.43 mg/100 g (microwave). The syringic acid contents of unroasted and roasted Chestnut samples changed between 2.08 (oven) and 4.02 mg/100 g (microwave) while caffeic acid amounts of Chestnut samples roasted in microwave and oven are determined between 2.22 (oven) and 4.02 mg/100 g (control). In addition, while *trans*-ferulic asid content of Chestnut sample, roasted in microwave and oven system are determined between 1.13 (control) and 1.71 mg/100 g (migroweve), apigenin-7-glucoside contants of unroasted and roasted Chestnut samples varied between 0.88 (oven) and 1.51 mg/100 g (control). The quercetin contents of unroasted and roasted Chestnut fruits changed between 0.44 (oven) and 2.08 mg/100 g (control). The highest rutin-trihydrate, *p*-coumaric acid, resveratrol, *trans*-cinnamic acid, naringenin, kaempferol and isorhamnetin amounts of Chestnut samples were determined as 2.33 (microwave), 0.15 (migrowave), 0.28 (control and microwave), 0.13 (control), 0.63 (control), 0.92 (control) and 0.44 mg/100 g (control), respectively. There were observed statistically significant differences among contents of phenolic constitutents of unroasted and roasted Chestnut samples ($p < 0.05$). As seen in Table 2, phenolic constituents of Chestnut roasted in microwave (except *trans*-cinnamic acid, kaempferol, caffeic acid, apigenin-7-glucoside, quercetin) were found high when compound to results of control and Chestnut roasted in oven. In addition, phenolic constituents of Chestnut samples roasted in microwave and oven system were determined than that of result of control group (except cafeic acid, apigenin-7-glucoside, quercetin, *trans*- cinnamic acid, naringenin, kampferol and isorhamnetin at the trace amounts) the high phenolic components of the Chestnut roasted in the microwave and oven are probably due to maillard reaction products produced during roasting. In general, phenolic components of chestnuts roasted in microwave were determined in higher amounts than those roasted in the oven and raw. This shows that microwave roasting is advantageous in terms of heat

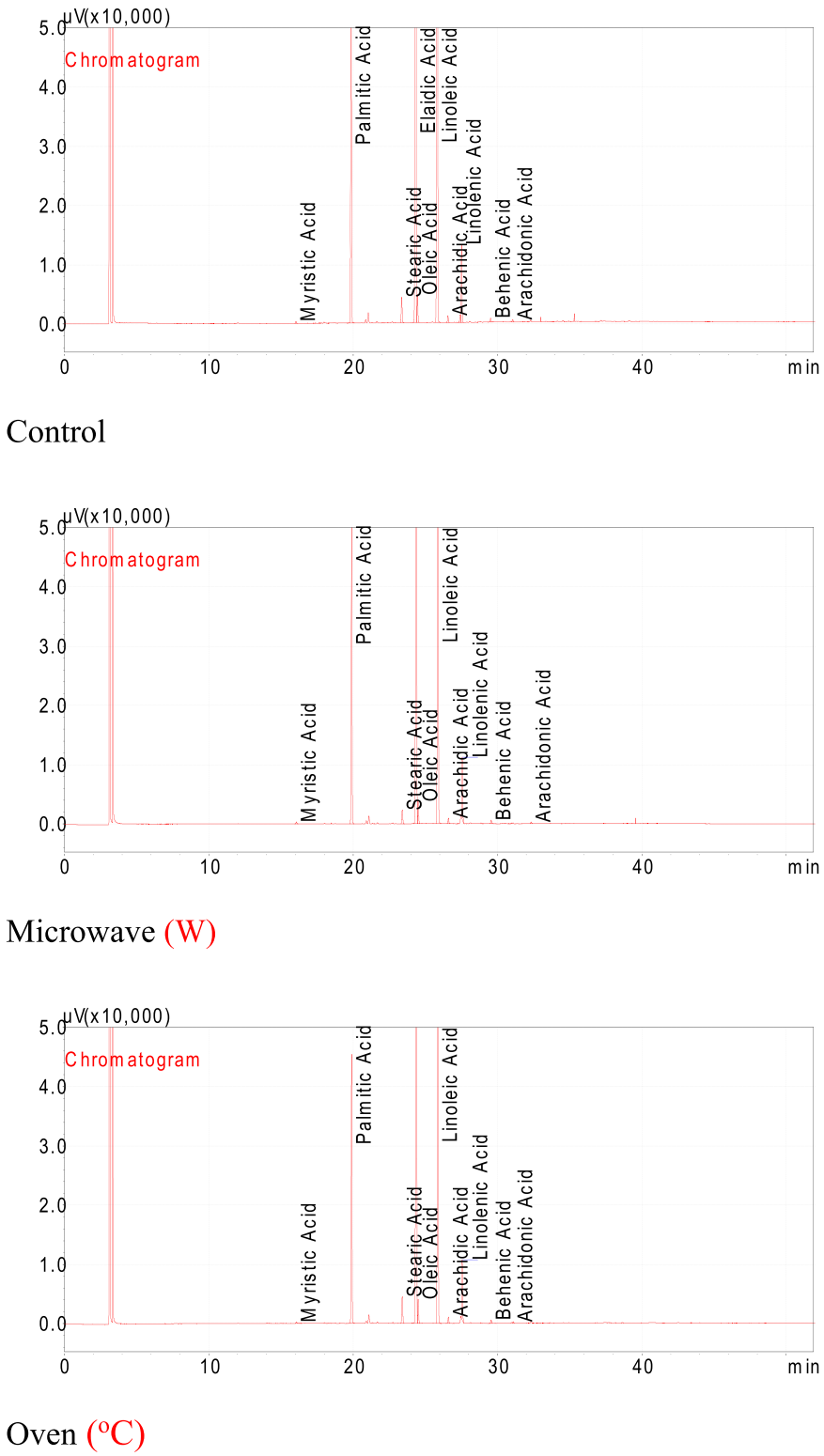

Fig 2. Fatty acid composition chromatograms for unroasted and roasted chectnut oils.

resistance of phenolic compounds.

3.3. *The fatty acids of oils extracted from unroasted and roasted Chestnut*

The fatty acids of unroasted and roasted Chestnut oil are presented in Table 3. Palmitic, elaidik and linoleic acids were the major fatty acids of unroasted and roasted Chestnut oils (Fig. 2). While palmitic acid contents of unroasted and roasted Chestnut oils are determined between 15.22% (oven) and 16.22% (control), oleic acid contens of unroasted and roasted Chestnut oils varied between 35.40%(microwave) and 38.91%(oven). In addition, linoleic acid contents of Chestnut oil samples were determined between 39.02% (control) and 43.22% (microwave). While linoleic acid contents of unroasted and roasted Chestnut oils are found between 3.10% (microwave) and 4.18%(control). Also, stearic

Table 4
Mineral contents of unroasted and roasted chestnuts (mg/kg).

Minerals	Control	Microwave (W)	Oven (°C)
B	9.59±0.75*c	11.01±1.30a	9.74±0.22b
Ca	889.90±4.89b**	1156.30±116.99a	770.40±100.39c
Cr	3.89±0.16a	3.73±0.04b	3.63±0.41c
Cu	12.62±0.98c	12.82±2.11b	16.20±0.54a
Fe	78.60±1.08c	112.03±14.91a	94.15±0.69b
K	7436.01±504.15c	7947.72±89.51a	7625.62±211.21b
Mg	755.99±62.62b	763.39±13.13a	740.48±9.06c
Mn	35.89±2.43c	52.79±1.11b	57.28±1.08a
Na	329.00±25.14a	293.10±23.84b	246.41±11.92c
Ni	4.38±0.34a	3.06±0.37c	3.94±0.33b
P	1557.42±103.18a	1545.85±11.26b	1497.01±15.44c
Zn	13.86±3.84a	11.39±0.44b	9.44±0.34c

*mean±standarddeviation; **Values in row column with different letters are significantly different ($p<0.05$)

acid contenti of Chestnut oil samples varied between 0.94% (microwave) and 1.59% (oven) while elaidic acid contents of Chestnut oil sapmles change between 1.13%(microwave) and 1.42% (control). Myristic, arachidic, behenic and arachidonic acid contents of Chestnut oils were found at trace amounts (<0.38%). There were observed significant variations among fatty acid composition of unroasted and roasted Chestnut oils ($p < 0.05$). Considering the palmitic and linoleic acid amounts of chestnut oils, microwave roasting seems to be advantageous, while oven roasting is preferred in terms of oleic acid. Künsch et al. (2001) reported that Chestnut (five varieties) oils contained 2.3–5.5% palmitic, 0.2–0.4% stearic, 2.9–11.0% oleic, 5.3–12.6% linoleic and 1.0–1.8% linoleic acids. In general, the fath acids of roasted Chestnut oil samples were paitially reduced compored to control (except alaidicin oven and linoleic in microwave). The differences in fatty acids of unroasted and roasted chestnut oils are probably due to the different drying mechanism of the roasting systems used in roasting.

3.4. The micro- and macro element quantities of unroasted and roasted-Chestnuts

The micro- and macro element amounts of unroasted and roasted Chestnut samples are illustrated in table 4. The abundant minerals in unroasted and roasted Chestnut samples were Ca, K, Mg, Na, P and Fe. The Ca contents of unroasted and roasted chectnut samples changed betweeen 770.40 mg/kg (oven) and 1156.30 mg/kg (microwave) while K contents of unroasted and roasted Chestnuts are determined between 7436.01 (control) and 7947.72 mg/kg (microwave). In attition, Mg contents of unroasted an droasted Chestnut samples varied between 740.48 mg/kg (oven) and 763.39 mg/kg (microwave) while Na contents of Chestnut samples change between 246.41 mg/kg (oven) and 329.00 mg/kg (control). Also, P contents of unroasted and roasted Chestnuts were found between 1497.01 mg/kg (oven) and 1557.42 mg/kg (control). As a microelements, while Fe contents of unroasted and roasted Chestnuts change between 78.60 (control) and 112.03 mg/kg (microwave), Mn amounts of Chestnut samples were measured between 35.89 (control) and 57.28 mg/kg (oven). While Cu contents of unroasted and roasted Chestnut samples are found between 12.62 (control) and 16.20 mg/kg (oven), Zn amounts of Chestnut samples varied between 9.44 (oven) and 13.86 mg/kg (control). The highest Cr and Ni (3.89 mg/kg and 4.38 mg/kg) were found in unroasted Chestnut sample, respectively. While B, Ca (except oven), Fe, K, Mg (except oven), Mn contents of roasted Chestnuts in microwave and oven system, increase compared to control, Na, Ni, P and Zn contents partially decreased. There were fluctuations in element contents of unroasted and roasted Chestnut samples. These fluctuations may be related to the evaporation rate of water depending on the roasting time in both different systems. There were observed statistically significant differences among mineral contents of unroasted and roasted Chestnut samples ($p<0.05$). Cooking significantly affected the mineral composition. Goncahes et al. (2012) that raw and roasted chestnut fruits contained 1.13 and 1.18 g/kg P, 9.36 and 9.05 g/kg K, 0.548 and 0.505 g/kg Ca, 0.539 and 0.521 g/kg Mg, 25.91 and 25.72 mg/kg Fe, 8.22 and 8.89 mg/kg Cu, 8.91 and 9.06 mg/kg Zn and 36.61 and 36.31 mg/kg Mn, respectively. While the dominant main element in the kernels was potassium (K), P, Ca and Mg contents were found at low levels. Among the trace elements, Mn is the highest, followed by Fe, Zn, and Cr in decreasing order. Roasting by microwave and oven increased the amount of B, Ca, Cu, Fe, K, Mn, and decrease the amount of Cr, Na,N, P and Zn. In case of roasting by microwave increased in Ca, Fe, K and Mg. In addition, roasting by oven decreased the amount of Ca, Cr, Mg, Na, P and Zn. Ca, Mg, Fe, Mn, Cu, Zn, P, Na and K amounts of the Chestnut cultivars changed between 43 and 230 mg/100 g, 70 and 160 mg/100 g, 0.4 and 5.7 mg/100 g, 0.7 and 5.5 mg/100 g, 0.6 and 3.8 mg/100 g,1.8 and 9.1 mg/100 g, 107.0 and 191.6 mg/100 g, 6.0 and 41.0 mg/100 g, and 761and 1271 mg/100 g, respectively (Ertürk et al., 2006). In other study, K, P, Mg, Fe, Mn and Cu were the most abundant elements in chestnuts (Borges et al. (2008). Cu and Mn, besides having many important body enzyme components, are also enzyme activators (Belitz et al., 2004). Mineral results showed some changes compared to results of previous studies. These differences can be porbably due to growing conditions, climatic factors, plant species, harvest time and some analytical conditions.

As a result, besides obtaining information about the bioactive properties, phenolic components, fatty acids and mineral contents of unheated chestnuts and roasted chestnut fruits, the changes in these properties of chestnut as a result of the applied heat treatment were revealed.

4. Conclusion

Heating applications lead to a significant decrease of the total organic acid contents of the Chestnut fruit. In general, while oven roasting is recommended for bioactive components of Chestnuts, microwave roasting is recommended for phenolic components and minerals. The antioxidant activity and total phenolic compounds of Chestnuts exposed to heat treatment in the oven show an advantageous situation compared to those roasted in the microwave. However, microwave roasting is more prominent in terms of fat content. In general, phenolic components of Chestnuts roasted in microwave were determined in higher amounts than those roasted in the oven and raw. This shows that microwave roasting is advantageous in terms of heat resistance of phenolic compounds. In general, the fatty acids of the oils extracted from Chestnut roasted were partially reduced compared to control (except alaidicin oven and linoleic in microwave). Considering the palmitic and linoleic acid amounts of Chestnut oils, microwave roasting seems to be advantageous, while oven roasting is preferred in terms of oleic acid. Roasting by microwave and oven increased the amount of B, Ca, Cu, Fe, K, Mn, and decrease the amount of Cr, Na,N, P and Zn. In case of roasting by microwave increased in Ca, Fe, K and Mg. In addition, roasting by oven decreased the amount of Ca, Cr, Mg, Na, P and Zn. These results may be useful for knowledge of dietary and other nutrients, phenolic components and nutrients that require prior knowledge of the nutrient composition of Chestnuts.

Declaration of Competing Interest

The authors declare that they have no known competing financial interestsor personal relationships that could have appeared to influence the work reported in this paper. All the authors declare no conflict of interest for the study titled '**The effect of roasting in microwave and oven on selected constituents, antioxidant activity, fatty acids, phenolic compounds and mineral contents of Chestnut (*Cestanea sativa* Milles) kernels ".** We, further declare that this manuscript has not been published previously and is not under consideration for publication elsewhere. Moreover, we declare that its publication is approved by all authors and tacitly or explicitly by the responsible authorities

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References

Abe, L.T., Franco Lajolo, F.M., & Genovese, M.I. (2010). Comparison of phenol content and antioxidant capacity of nuts. Ciência e Tecnologia de Alimentos Campinas, 30 (Supl.1), 254–259.

Albi, T., Lanzón, A., Guinda, A., Pérez-Camino, M. C., & León, M. (1997). Microwave and conventional heating effects on some physical and chemical parameters of edible fats. *Journal of Agricultural and Food Chemistry, 45*, 3000–3003. https://doi.org/10.1021/jf970168c

AOAC, (1990). Official Methods of Analysis, 15 th edn. Association of Official Analytical Chemists, Washington, DC.

Belitz, H. D., Grosch, W., & Schieberle, P. (2004). *Food chemistry* (third ed.). Berlin, Heidelberg, Ger: Springer-Verlag.

Borges, O., Gonçalves, B., Soeiro, J., Correia, P., & Silva, A. (2008). Nutritional quality of chestnut (Castanea sativa Mill.) cultivars from Portugal. *Food Chemistry, 106*, 976–984. https://doi.org/10.1016/j.foodchem.2007.07.011

Cerretani, L., Bendini, A., Rodeiguez-Estrada, M. T., Vittadini, E., & Chiavaro, E. (2009). Microwave heating of different commercial categories of olive oil: Part I. Effect on chemical oxidative stability indices and phenolic compounds. *Food Chemistry, 115*, 1381–1388.

Chenlo, F., Moreira, R., Pereira, G., & Silva, C. C. (2007). Evaluation of the rheological behaviour of chestnut (*Castanea sativa* mill) flour pastes as function of water content and temperature. *Electronic Journal of Environmental, Agricultural and Food Chemistry, 6*(2), 1794–802.

De Vasconcelos, M. C., Nunes, F., García- Viguera, C., Bennett, R., Rosa, E., & Cardoso, J. V. (2010). Industrial processing effects on chestnut fruits (*Castanea sativa* Mill.). 3. Minerals, free sugars, carotenoids and antioxidan vitamins. *International Journal of Food Science and Technology, 45*, 496–505. https://doi.org/10.1111/j.1365-2621.2009.02155.x

Demiate, I. M., Oetterer, M., & Wosiacki, G. (2001). Characterization of chestnut (*Castanea sativa*) starch for industrial utilization. *Brazilian Archives of Biology and Technology, 44*, 69–78. https://doi.org/10.1590/S1516-89132001000100010

Ertürk, Ü., Mert, C., & Soylu, A. (2006). Chemical composition of fruits of some important chestnut cultivars. *Brazilian Archives of Biology and Technology, 49*(2), 183–188.

Gold, M. A., Cernusca, M. M., & Godsey, L. (2005). Chestnut market analysis producers perspective. *University of Missouri Center for Agroforestry*, 34.

Gonçalves, B., Borges, O., Costa, H. S., Bennett, R., Santos, M., & Silva, A. P. (2010). Metabolite composition of chestnut (*Castanea sativa* Mill.) upon cooking: Proximate analysis, fibre, organic acids and phenolics. *Food Chemistry, 122*, 154–160. https://doi.org/10.1016/j.foodchem.2010.02.032

Khang, D. T., Dung, T. N., Elzaawly, A. A., & Xuant, T. D. (2016). Phenolic profiles and antioxidant activity of germinated Legumes. *Foods, 5*, 1–10.

Künsch, U., Scharer, H., Patrian, B., Höhn, E., Conedera, M., Sassella, A., Jermini, M., & Jelmini, G. (2001). Effects of roasting on chemical composition and quality of different (Castanea sativa Mill) varieties. *Journal of the Science of Food and Agriculture, 81*, 1106–1112. https://doi.org/10.1002/jsfa.916

Künsch, U., Scharer, H., Patrian, B., Hurter, J., Conedera, M., Sassella, A., Jermini, M., & Jelmini, G. (1999). Quality assessment of chectnut fruits. *Acta Hortulture, 494*, 119–127. https://doi.org/10.17660/ActaHortic.1999.494.17

Lee, S.K., Mbwambo, Z.H., Chung, H.S., Luyengi, L., Games, E.J. C., & Mehta, R.G., (1998). Evaluation of the antioxidant potential of natural products. Combinational Chemistry and High Throughput Screening 1, 35–46.

Morini, G., & Maga, J. A. (1995). Changes in the fatty acid composition of roasted and boiled Chinese (*Castanea sativa*) and Italian. In G. Charalambous (Ed.), *C.sativa) chectnuts grown in the same location, in Food Flavors: Generation, Analysis and Process Influence* (pp. 563–568). Amsterdam: Elsevier Science.

Pazianas, M., Butcher, G. P., Subhani, J. M., Finch, P. J., Ang, L., Collins, C., Heaney, R. P., Zaidi, M., & Maxwell, J. D. (2005). Calcium absorption and bone mineral density in celiacs after long term treatment with gluten-free diet and adequate calcium intake. *Osteoporosis International, 16*, 56–63.

Püskülcü, H., & İkiz, F.. (1989). Introduction to Statistic. Bilgehan Press. p333. Bornova. İzmir,Turkey (1989). (in Turkish).

Ribeiro, B., Rangel, J., Valentao, P., Andrade, P. B., Pereira, J. A., Bolke, H., & Seabra, R. M. (2007). Organic acids in two Portuguese chestnut (*Castanea sativa* Miller) varieties. *Food Chemistry, 100*, 504–508. https://doi.org/10.1016/j.foodchem.2005.09.073

Sabaté, J., Radak, T., & Brown, J. Jr. (2000). The role of nuts in cardiovascular disease prevention. In R. Wildman (Ed.), Handbook of nutraceuticals and functional foods (pp. 261–267). London: CRC Press.

Shin, D. H., Oh, M. J., & Kim, S. Y. (1981). Effect of heat treatment on the chemical composition of flesh in chestnut processing. *Research Rep Agriculture Science and Technology, Chungnam University, 8*, 117–125.

Silva, B. M., Andrade, P. B., Valentão, P., Ferreres, F., Seabra, R. M., & Ferreira, M. A. (2004). Quince (*Cydonia oblonga* Miller) fruit (pulp, peel, and seed) and jam: antioxidant activity. *Journal of Agricultural and Food Chemistry, 52*, 4705–4712. https://doi.org/10.1021/jf040057v

Sundriyal, M., & Sundriyal, R. C. (2001). Wild edible plants of the sikim Himalaya: Nutritive values of selected species. *Economy Botany, 55*, 377–390. https://doi.org/10.1007/BF02866561

Üstün, N., Tosun, Y., & Serdar, Ü. (1999). Technological properties of chestnut varieties grown in Erfelek district of Sinop city. Acta Horticulture 494,107–110. DOI: 10.17660/ActaHortic.1999.494.15.

Vaughan, J.G., & Geissler, C.A.. (1997a). The new Oxford book of food plants (p. 30). New York: Oxford University Press.

Vaughan, J.G., & Geissler, C.A. (1997b). The new Oxford book of food plants (p. 216). New York: Oxford University Press.

Vaughan, J. G., & Geissler, C. A. (1997c). *The new Oxford book of food plants (p. xix)*. New York: Oxford University Press.

Yoo, K. M., Lee, K. W., Park, J. B., Lee, H. J., & Hwang, I. K. (2004). Variation in major antioxidants and total antioxidant activity of Yuzu (*Citrusjunos* SiebexTanaka) during maturation and between cultivars. *Journal of Agricultural Food Chemistry, 52*, 5907–5913. https://doi.org/10.1021/jf0498158