# Phenolic Profile of Meals Obtained from Defatted Hazelnut (*Corylus Avellana* L.) Varieties

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***Abstract*—In this study, the total phenolic contents (TPC) and phenolic profiles of defatted 17 hazelnuts were investigated. All samples were gathered in harvesting period from Black Sea Region (Ordu and Giresun prefecture) of Turkey. Methanolic extraction was used for taking the phenolics from the hazelnut varieties. The highest TPC was determined in Mincane (1093 ± 13.40 mg/100 g) and the lowest one belonged to Foşa (529 ± 16.19 mg/100 g) variety. Two-way ANOVA analyze showed that there was significant effect of the variety on phenolic profiles and TPC (P <0.01). Results revealed that all varieties have almost a similar phenoic profile. Catechin, catechol, chlorogenic and quercetin were found as major compounds in all varieties. This study also showed that defatted hazelnuts may be alternative method for the production of phenolics and the enrichment of foods or pharmaceutical products.**

***Index Terms*—hazelnut, HPLC, phenolic profile, TPC**

## I. Introduction

Hazelnut (*Corylus avellana L.)* is considered as an important natural additive for food industries such as confectionery, baking, ice cream and dairy, candy and chocolate to provide taste, flavor and aroma and to improve the nutritional value of food. Moreover, the hazelnut production surplus is used to produce oil. Remained defatted meal or cake is used for animal feed. Defatted meal is also used as source of food components for human nutrition except for fatty acids, oil soluble vitamins and some of phenolics. Therefore, defatted meal could be used for enrichment of foods as sources of amino acids (arginin, glutamic acid, aspartic acid etc), water-soluble vitamins (VitB2, VitB6 and niacin), dietary fiber, complex carbohydrates, trace elements and phenolics [1], [2]. Some researches revealed that edible nuts have a good source of phenolics with a high antioxidative potential especially with skins [3]-[8].

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Phenolic compounds are known secondary metabolites in plants and defined as substances processing an aromatic ring bearing one and more hydroxyl group, including their functional derivatives [9]. Phenolics in foods generally belong to phenolic acids, flavonoids, lignans, stilbenes, coumarins and tannins [9], [10]. Phenolic compounds are also responsible for taste as astringency, bitterness, and sourness, formation of off-flavor, colour as discoloration with enzymatic browning and reaction with a number of heavy metals, and haze formation in fruit and fruit product [11]-[13]. Another important reaction of polyphenols as tannins and *o*-dihydroxyphenols are the complex with protein affecting the protein quality of foods. This complex reduces protein absorption in digestive tract and decreases the availability of the lysine and cystine [11]. Detecting of adulterated food can benefit from phenolic profiles of foods [14]. Furthermore, analysis of phenolic compounds can permit taxonomic classification of the source of foods. In recent years, there is an upsurge of interest in phenolic compounds because they have protective effect against cancer, cardiovascular diseases. In addition, polyphenols have also been found to have antiulcer, anticarcinogenic, antioxidative, antimutagenic and antibacterial activities [8] -[17]. There is larger focus on natural source of polyphenols and extraction methods to use in new functional foods [16].

Number of published articles on the phenolic profile of defatted hazelnut varieties is very low. Senter et al. [18], analyzed the phenolic acid composition of some edible nuts that grown in the U.S. using GLC-MS. Yurttas et al. [4], have presented a general view of the main phenolic compounds and antioxidant activity in two hazelnut varieties, from Turkey (Tombul and Barcelona). Influences of roasting process on the phenolic composition of Tombul, Palaz and Foşa varieties in Turkey were determined by HPLC [5]. In another study, phenolic compounds of hazelnut leaves obtained from different cultivars, with the same ecological conditions



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identified by HPLC/DAD/MS/MS-ESI and quantitatively by HPLC/DAD [19]. Various investigators have studied the antioxidant activity of hazelnut and their by-products. The result of these studies demonstrated that hazelnut phenolics from dry or fresh nut (pellicle removed), skin, hard shell, kernel, green leafy cover and tree leaf could be considered as an inexpensive source of dietary antioxidants [7]-[20]. The antimicrobial activities of phenolics from the leaves of three hazel cultivars have been evaluated against different microorganisms [17]. In the study, Miraliakbari and Shahidi [21] investigated result of antioxidative components (including phenolic compounds) of tree nut oils by using a solvent stripping process. More recently the impact of different roasting conditions on both phenols extraction and antioxidant activity have been investigated, particularly considering the formation of Maillard products (melanoidins) during roasting [22].

The objective of our study is to determine the TPC and phenolic composition and to identify phenolics in defatted Turkish hazelnut varieties. Another aim of this study is to reveal the availability of defatted hazelnut varieties as enrichment materials in miscellaneous foods. Moreover, this study will show database in evaluation of the effect of hazelnuts on health.

## II. Materials and Methods

### A. Materials

Seventeen varieties of hazelnut (*Corylus avellana* L.) were gathered from different locations (Ordu and Giresun) in the Black Sea region of Turkey in the July 2002. 100 g of hazelnut sample for each cultivar (Acı, Cavcava, Cakıldak, Foşa, İncekara, Kalınkara, Kan, Karafındık, Kargalak, Kuş, Mincane, Palaz, Sivri, Tombul, Uzunmusa, Yassıbadem and Yuvarlakbadem) were taken randomly. Collected varieties were dried, unshelled, milled (as ≤ 0.2 mm thickness and whole kernel) and packed in polyethylene bags stored at -20 $^0$C until time of analysis. Phenolic standards were gallic acid (SIGMA, G-7384), protocatechuic acid (MERCK, 8.41533.0025), caffeic acid (SIGMA, C-0625), ferulic acid (SIGMA, F-3500), *o*-coumaric acid (SIGMA, C-4400), *p*-coumaric acid (SIGMA,C-9008), sinapic acid (FLUKA-85430), (+)-catechin (SIGMA, C-1251), catechol (WAKO, 034-13752), quercetin (SIGMA, Q-0125), rutin (WAKO, 189-00342), chlorogenic acid (SIGMA, C-3878), ellagic acid (FLUKA, 45140), vanillin (MERCK, 8.18718.0100) and syringic acid (ROTH, 5361). All solvents used for extraction and mobile phase were HPLC grade.

### B. Extraction Procedure of The Phenolic Fraction

30 g of grounded hazelnut samples were extracted by *n*-hexane using a Soxhlet apparatus for 6 h at 40 $^0$C. Hexane was removed by rotary evaporator under vacuum at 40 $^0$C. Then the residue *n*-hexane from hazelnut samples was removed in a drying oven at 40 $^0$C for 4 h. Weigh about 0.2 g defatted hazelnut meal nearest mg (0.001 g) were taken into polyethylene tube for methanolic extraction and added 2 ml MeOH 80% including 1% HCl. Mixture was centrifuged at 5,000 x g for 15 min. This extraction process was repeated two times. Supernatants were filtered through Whatman No. 1 paper and transferred into amber colored bottle.

### C. Analysis of Total Phenolic Content (TPC) in Extracts

The total concentrations of phenols in the extracts were determined according to the colorimetric Folin–Ciocalteu method by UV spectrophotometer (23). The total phenol concentration was calculated from the calibration curve, using gallic acid as a standard, and the results were expressed as mg of gallic acid equivalents (mg GAE) per 100 g sample (defatted meal). Linearity range of the calibration curve was 25 to 250 ng/mL (r = 0.9999).

### D. HPLC Analysis of Phenolic Compounds

Phenolic extracts were loaded on to a Sep-Pak $C_{18}$ cardige (Waters, Inc.) conditioned with MeOH to elute unwanted components (sugars and organic acids). Remaining components (phenolics) were eluted with MeOH (acidified) using for extraction. The mixture was then filtered through a nylon micropore filter (0.45 μm pores) and injected to HPLC. In this study, gradient elusion program was used for chromatographic phenols separation. Solvent system was MeOH (A) and acetic acid in deionized water (2.5%) (B). Programme was started with 5% MeOH (100%) and installing a gradient to obtain 35% A at 8 min, 40% A at 8.5 min, 56% A at 20 min, 60% A at 30 min, 65% A at 30.5 min, 80% A at 35 min. The flow rate of the mobile phase was 1 ml/min with a total run time of 45 min. Injection volume was 20 μl, and oven temperature was 25 $^0$C. Chromatograms were recorded at 280 nm. Spectral data from all peaks were accumulated in the range 200-600 nm. Phenolic compounds quantification was achieved by the absorbance recorded in the chromatograms relative to external standards. Chromatographic separation was carried out by HPLC (SHIMADZU), using a column (ACE 5C18-A11608, 250 x 4.6 mm, ID and 5 μ particle size) and a detector (Diode Array Detector, SPD-M10AVP-SHIMADZU), pumping system (LC-10ADVP-SHIMADZU), degassing system (DGU-14A-SHIMADZU), colon heater (CTO-10AS- SHIMADZU), control system (SCL-10AVP-SHIMADZU) and software program (Class-VP, 5.0).

### E. Statistical Analysis

The data were expressed as mean ± standard deviation of triplicate measurements for TPC and duplicate measurements for phenolic profiles. All data were evaluated in two-way ANOVA using MINITAB (Version 15.0, 2006 Minitab Inc., USA). Duncan's multiple range tests were used to determine significant differences between means using $P < 0.01$.

## III. Results and Discussion

According to variance analysis (two-way ANOVA), the effect of varieties on TPC were found as significant ($P < 0.01$). However, insignificant differences were observed among replications of TPC in similar varieties.

Results of TPC of defatted hazelnut varieties are shown in Table 1. The concentrations of identified TPC in the 17 defatted hazelnut cultivars were changed between 529 ±16.19 and 1093 ±13.40 mg/100 g as GAE. The mean TPC content of Mincane in 100 g defatted meal was about 2- fold higher than Foşa (Table I).

TABLE I. PHENOLIC PROFILES OF DEFATTED HAZELNUT VARIETIES.

| Hazelnut Varieties | TPC * (mg $100\ g^{-1}$ as GAE) | Phenolics (mg $kg^{-1}$)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Gallic | Protocatechuic | (+)-catechin | Catechol | Chlorogenic | Caffeic | Syringic | Vanillin | p-coumaric | Ferulic and/or Sinapic | Quercetin |
| Acı | 832.09 ±21.90$^{B}$ | 30.28 ±5.35$^{BC}$ | 26.89 ±2.09$^{CDEF}$ | 224.41 ±18.08$^{DEF}$ | 207.51 ±24.23$^{BCD}$ | 93.19 ±8.59$^{FG}$ | 7.37 ±1.25$^{CDE}$ | 18.56 ±2.13$^{CD}$ | 21.6 ±3.18$^{CDEF}$ | 8.9 ±1.2$^{EFG}$ | 78.8 ±12.62$^{CD}$ | 130 ±21.9$^{BCDEF}$ |
| Cavcava | 689.72 ±20.80$^{E}$ | 17.99 ±2.30$^{DEF}$ | 22.98 ±1.44$^{EFG}$ | 139.69 ±23.53$^{GH}$ | 365.73 ±17.66$^{A}$ | 116.90 ±9.19$^{EF}$ | 3.83 ±0.29$^{HI}$ | 12.42 ±0.97$^{EF}$ | 21.5 ±1.3$^{DEF}$ | 9.9 ±1.54$^{CF}$ | 83.7 ±3.59$^{CD}$ | 165.9 ±10.8$^{A}$ |
| Çakıldak | 613.82 ±10.65$^{F}$ | 28.36 ±3.80$^{BC}$ | 20.10 ±3.03$^{FG}$ | 205.66 ±39.16$^{EF}$ | 245.54 ±25.98$^{B}$ | 182.46 ±16.09$^{AB}$ | 5.5 ±0.75$^{EFGHI}$ | 19.71 ±1.71$^{C}$ | 26.95 ±5.18$^{BC}$ | 11.1 ±0.57$^{BCDEF}$ | 89.9 ±0.17$^{BCD}$ | 140 ±13.3$^{ABCD}$ |
| Foşa | 529.00 ±16.19$^{H}$ | 31.61 ±2.93$^{BC}$ | 33.09 ±5.07$^{BCD}$ | 237.58 ±3.34$^{CDEF}$ | 218.38 ±15.19$^{BC}$ | 89.69 ±1.86$^{GH}$ | 4.95 ±0.94$^{FGHI}$ | 13.78 ±0.1$^{EF}$ | 24.43 ±1.57$^{CD}$ | 12.4 ±1.56$^{BCD}$ | 98.3 ±2.04$^{ABC}$ | 141 ±10.5$^{ABCD}$ |
| İncekara | 760.62 ±8.41$^{CD}$ | 30.55 ±2.04$^{BC}$ | 39.13 ±0.93$^{B}$ | 268.77 ±33.93$^{BCD}$ | 178.11 ±12.56$^{CD}$ | 180.11 ±6.65$^{AB}$ | 7.21 ±0.14$^{CDEF}$ | 30.85 ±0.05$^{A}$ | 16.9 ±0.33$^{FGH}$ | 11.5 ±0.30$^{BCDE}$ | 83.5 ±2.56$^{CD}$ | 72.3 ±1.02$^{I}$ |
| Kalınkara | 691.89 ±14.30$^{E}$ | 26.23 ±0.55$^{BCD}$ | 35.36 ± 4.73$^{BC}$ | 258.47 ±35.33$^{CDE}$ | 251.57 ±3.67$^{B}$ | 144.23 ±21.01$^{CD}$ | 10.71 ±1.48$^{AB}$ | 26.10 ±3.51$^{B}$ | 11.87 ±0.88$^{HI}$ | 11.6 ±1.9$^{BCDE}$ | 60.1 ±19.7$^{E}$ | 125 ±11.6$^{DEFG}$ |
| Kan | 711.1 ±21.67$^{E}$ | 18.13 ±0.40$^{DEF}$ | 26.43 ±1.97$^{DEF}$ | 274.36 ±0.36$^{BCD}$ | 221.29 ±14.44$^{BC}$ | 148.02 ±3.73$^{CD}$ | 4.44 ±0.35$^{GHI}$ | 14.7 ±0.55$^{DE}$ | 9.17 ±0.20$^{I}$ | 9.88 ±0.1$^{CDEF}$ | 52.5 ±1.07$^{EF}$ | 135 ±3.26$^{BCDE}$ |
| Karafındık | 776.40 ±23.81$^{C}$ | 34.49 ±1.73$^{B}$ | 26.64 ±8.19$^{DEF}$ | 123.03 ±4.04$^{H}$ | 250.0 ±6.90$^{B}$ | 64.97 ±8.50$^{H}$ | 8.34 ±0.02$^{CD}$ | 12.1 ±2.33$^{EF}$ | 14.5 ±1.87$^{GHI}$ | 9.33 ±1.05$^{EF}$ | 34.4 ±4.03$^{F}$ | 101 ±9.9$^{GHI}$ |
| Kargalak | 796.0 ±19.59$^{BC}$ | 18.08 ±1.02$^{DEF}$ | 17.46 ±1.49$^{G}$ | 194.83 ±5.76$^{FG}$ | 163.50 ±1.24$^{DE}$ | 147.45 ±14.47$^{CD}$ | 3.87 ±0.93$^{HI}$ | 14.4 ±0.97$^{DE}$ | 13.6 ±0.45$^{GHI}$ | 8.43 ±0.33$^{F}$ | 80.1 ±6.27$^{CD}$ | 154 ±4.59$^{AB}$ |
| Kuş | 781.81 ±7.54$^{C}$ | 15.53 ±1.27$^{EF}$ | 20.96 ±1.84$^{FG}$ | 143.18 ±5.98$^{GH}$ | 245.75 ±25.71$^{B}$ | 203.62 ±11.57$^{A}$ | 3.23 ±0.07$^{I}$ | 9.62 ±1.03$^{F}$ | 14.2 ±0.54$^{GHI}$ | 11 ±0.3$^{BCDEF}$ | 87.1 ±2.86$^{BCD}$ | 151.4 ±3.88$^{ABC}$ |
| Mincane | 1093.0 ±13.40$^{A}$ | 14.59 ±1.85$^{F}$ | 20.56 ± 2.00$^{FG}$ | 316.41 ±14.07$^{B}$ | 215.64 2.22$^{BCD}$ | 95.95 ±2.47$^{EFG}$ | 6.2 ±0.85$^{DEFG}$ | 13.5 ±0.12$^{EF}$ | 32.55 ±1.96$^{B}$ | 6.35 ±0.23$^{G}$ | 87.7 ±3.82$^{BCD}$ | 155.8 ±9.52$^{AB}$ |
| Palaz | 765 ±21.5$^{CD}$ | 32.48 ±5.63$^{BC}$ | 51.29 ±3.90$^{A}$ | 147.3 ±6.69$^{GH}$ | 209.9 ±39.49$^{BCD}$ | 113.2 ±10.66$^{EFG}$ | 12.22 ±0.57$^{A}$ | 14.8 ±1.54$^{DE}$ | 38.9 ±3.54$^{A}$ | 12.9 ±0.42$^{BCD}$ | 78.2 ±2.34$^{D}$ | 120 ±9.98$^{DEFG}$ |
| Sivri | 584.3 ±23.71$^{FG}$ | 24.20 ±4.17$^{CDE}$ | 31.87 ±2.54$^{BCD}$ | 186.76 ±19.91$^{FG}$ | 259.0 ±8.71$^{B}$ | 154.05 2.80$^{CD}$ | 5.07 ±0.39$^{FGHI}$ | 12.7 ±3.67$^{EF}$ | 24.3 ±3.27$^{CDE}$ | 9.77 ±1.05$^{EF}$ | 104 ±10.3$^{AB}$ | 103.7 ±12.88$^{FGH}$ |
| Tombul | 726.5 ±23.13$^{DE}$ | 24.65 ±5.72$^{CD}$ | 59.08 ±2.47$^{A}$ | 142.95 ±18.56$^{GH}$ | 175.86 ±23.62$^{CD}$ | 149.58 ±11.31$^{CD}$ | 7.45 ±1.26$^{CDE}$ | 13.4 ±2.55$^{EF}$ | 19 ±2.35$^{DEF}$ | 8.78 ±0.84$^{EF}$ | 88.4 ±4.5$^{BCD}$ | 91.1 ±6.70$^{HI}$ |
| Uzunmusa | 608.2 ±21.40$^{F}$ | 28.88 ±0.85$^{BC}$ | 31.48 ±2.18$^{BCDE}$ | 282.14 ±34.22$^{BC}$ | 205.3 ±17.35$^{BCD}$ | 205.46 ±6.79$^{A}$ | 5.6 ±0.16$^{EFGH}$ | 21.9 ±1.86$^{C}$ | 24.6 ±2.1$^{CD}$ | 12.6 ±0.41$^{BCD}$ | 104 ±4.02$^{AB}$ | 112 ±6.5$^{EFGH}$ |
| Yassıbadem | 556.8 ±15.18$^{GH}$ | 43.37 ±5.19$^{A}$ | 37.88 ±4.37$^{B}$ | 223.28 ±21.27$^{DEF}$ | 121.88 ±30.43$^{E}$ | 169.03 ±9.15$^{BC}$ | 5.4 ±0.31$^{EFGHI}$ | 15.2 ±2.06$^{DE}$ | 18.0 ±3.6$^{EFGH}$ | 16.1 ±1.88$^{A}$ | 42.8 ±6.6$^{EF}$ | 152.8 ±2.57$^{AB}$ |
| Yuvarlakbadem | 798.1 ±20.33$^{BC}$ | 27.34 ±1.14$^{BC}$ | 19.93 ±2.32$^{FG}$ | 388.06 ±5.41$^{A}$ | 241.6 ±10.50$^{B}$ | 121.62 ±5.15$^{DE}$ | 9.32 ±1.72$^{BC}$ | 11.1 ±0.83$^{EF}$ | 12.9 ±0.78$^{GHI}$ | 9.26 ±0.57$^{EF}$ | 109 ±3.3$^{AB}$ | 143.1 ±4.2$^{ABCD}$ |

*= each value is the mean ± standard deviation of triplicate measurements, ** = each value is the mean ± standard deviation of duplicate measurements. Values within a column with differ superscript uppercase letters (A-I) differ significantly (P< 0.01)

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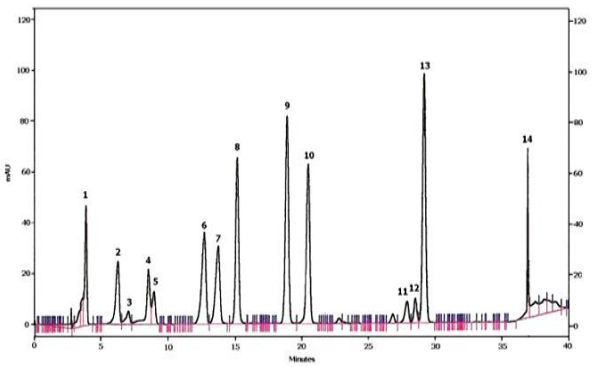
The mean content of TPC in natural hazelnuts (Tombul, Foşa and Palaz) ranged from 227 to 289 mg in 100 g fresh weight as GAE [6]. Kornsteiner et al. [6], reviewed that the mean content of TPC varied between 101 mg and 433 mg as GAE 100 g fresh weight. On the other hand, Arcan and Yemenicioğlu [20] reported the phenolic content in dry and fresh hazelnut between 256 and 425 mg as GAE 100 g. Our results for TPC are comparable with those results if dry extracts calculates according to the actual amount of hazelnuts. On the other hand, the change of phenolic profile in varieties was significant, whereas the replications of phenolic compounds for each cultivar did not show significant differences. Phenolic profile results in defatted hazelnut varieties were given in Table 1. Although the chromatogram contained over 40 peaks, the only 11 that matched with the 15 external standards were gallic acid, protocatechuic acid, caffeic acid, ferulic acid, *o*-coumaric acid, *p*-coumaric acid, sinapic acid, (+)-catechin, catechol, quercetin, rutin, chlorogenic acid, ellagic acid, vanillin and syringic acid which are fairly common phenolic acids. The peak profiles of defatted cultivar extracts had similar and characteristic chromatograms, besides, considerable differences were found among the levels of phenolics. According to the results, major phenolics were determined as (+)-catechin (123-388 mg/kg), catechol (121-365 mg/kg), chlorogenic acid (64-205 mg/kg) and quercetin (72-165 mg/kg) in defatted hazelnut varieties. Ferulic (and/or sinapic) (34-109 mg/kg), protocatechuic (17-59 mg/kg), gallic (14-43 mg/kg), vanillin (9-38 mg/kg), syringic (9-30 mg/kg), *p*-coumaric (6-16 mg/kg) and caffeic (3-12 mg/kg) followed them. The higher amount of phenolics in the varieties were found in Yassıbadem for gallic and *p*-coumaric, Tombul and Palaz for protocatechuic acid,

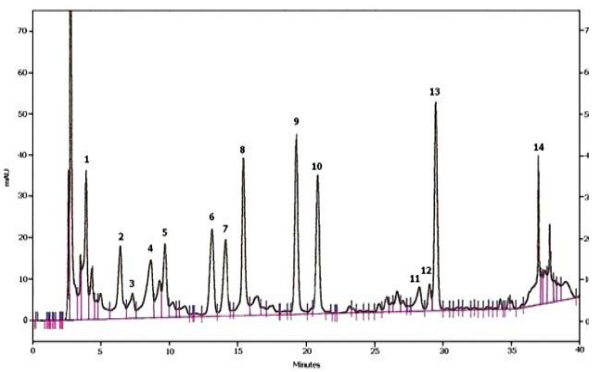
Yuvarlakbadem for (+)-catechin and ferulic or / and sinapic acid, Cavcava for catechol and quercetin, Uzunmusa and Kuş for chlorogenic, Incekara for syringic acid, Palaz for caffeic and vanillin (Table 1, Figure 1).

To identify the peaks by HPLC, we compared the retention time (Rt) of extract and standard peaks (Figure 1A, 1B). In a second trial, we injected in HPLC both standards and the mixture of extracts with standards (Figure 1C). Moreover, the spectrums of extract peaks were compared with mass spectrum of standards. The retention times (Rt) and mass spectrums for standard and extract peaks were similar. However, Rt values and peaks of ferulic and sinapic acid in chromatogram of standards mixture were overlapped against they have two different λmax values. Therefore, ferulic and sinapic acid was computed as the sum of each peaks and used as ferulic or / and sinapic acid in this study (Figure 1A, 1B; Table 2).

When the extract chromatograms detected at three distinct wavelengths as 250, 280 and 320 nm, size of peaks at the wavelength of 250 nm was enlarged (Figure 2). Moreover, flavan 3-ols, isoflavonoids and phenolic acids in the wavelength range 250-280 nm had maximum absorbance [12], [24]. This explains that, probably, unidentified peaks at first 15 min of extract chromatogram may be their polymers and ester forms of (+)-catechin or (-)-epicatechin. In addition, unidentified peaks at last 15 min may be isoflavonoids. Liggins et al. (25) reported the total isoflavones (daidzein and genistein) in hazelnut as 240 µg/kg wet weight. An important source of polyphenols is known to be present in brown hull or skins of seeds [16]. In this study, defatted hazelnuts with skin (natural) were used to determine phenolic profile.



**A**



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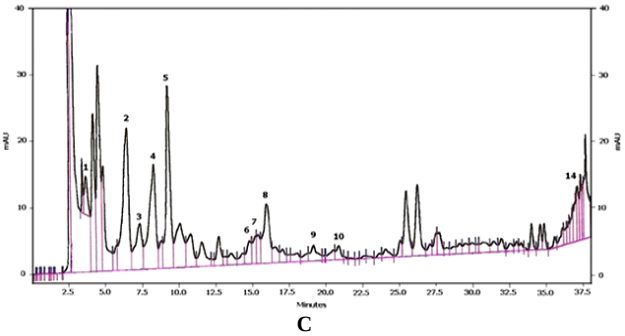

**C**

Figure 1. HPLC phenolic profile of standards (A), hazelnut (B), mixture of standards and hazelnut extract (C) as 1: gallic, 2: protocatechuic, 3: (+)-catechin, 4: catechol, 5: chlorogenic, 6: caffeic, 7: syringic, 8: vanillin, 9: *p*-coumaric, 10: ferulic or/and sinapic, 11: rutin, 12: ellaigic, 13: *o*- coumaric, 14: quercetin.

TABLE II. ANALYSIS OF THE HPLC FOR THE PHENOLIC STANDARDS AND DEFATTED HAZELNUT VARIETIES

| Peak No | Phenolic standards | Rt1 (min) | Rt2 (min) | $\lambda_{max}$ (nm) |
|---|---|---|---|---|
| Peak1 | gallic | 3.851 | 3.750 - 3.790 | 270 |
| Peak2 | protocatechuic | 6.235 | 5.833 - 6.593 | 258 |
| Peak3 | (+)-catechin | 7.011 | 7.054 - 7.083 | 191 |
| Peak4 | catechol | 8.527 | 8.434 - 8.715 | 194 |
| Peak5 | chlorogenic | 8.934 | 9.562 - 10.416 | 194 |
| Peak6 | caffeic | 12.704 | 12.625 - 12.918 | 194 |
| Peak7 | syringic | 13.752 | 13.500 - 13.775 | 194 |
| Peak8 | vanillin | 15.163 | 14.935 - 16.110 | 234 |
| Peak9 | *p* -coumaric | 18.900 | 19.166 - 19.396 | 194 |
| Peak10 | ferulic or/and sinapic | 20.379 - 20.495 | 20.718 - 20.833 | 308 - 322 |
| Peak11 | rutin | 27.873 | nd | 194 |
| Peak12 | ellaigic | 28.505 | nd | 194 |
| Peak13 | *o*- coumaric | 29.178 | nd | 275 |
| Peak14 | quercetin | 36.925 | 36.621 - 37.375 | 254 |

nd: unidentified, Rt1: Rt for phenolic standards, Rt2: for phenolics of defatted samples (min)

A similar research was rarely reported in literature. In addition, any data on quantity of hazelnut phenolics have not been published in previously studies. These results were similar to Yurttas et al. [4], Simsek [5] and Shahidi et al. [8] findings, where it was found that both hazelnut varieties contain similar phenolic compounds as gallic acid, p–hydroxy-benzoic acid (protocatechuic acid), caffeic acid (and or epicatechin), p-coumaric, sinapic acid, ferulic acid and quercetin. On the other hand, phenolic acids (gallic, caffeic and p–hydroxyl-benzoic acid) of filbert testa determined as so little (<10 ng/g sample). Protocatechuic acid was predominant (0.36 µg/g extract) but ferulic acid was not in hazelnut testa [18]. In other study, hazelnut skin and shell wastes were found to be very rich in tannins [26]. Our results revealed that gallic, caffeic, p–hydroxyl-benzoic acid and vanillin are condensed in defatted hazelnuts. In addition, phenolic contents of defatted hazelnuts increase when their skin is added. However, phenolic level decreases after roasting or bleaching applications due to the removing of testa (skin) [5]. Therefore, consumption of hazelnut with skin (natural) may be more useful than deskined hazelnut for human nutrition as an alternative source of phenolics. TPC and phenolic profile changes may have resulted from characteristic of varieties, tissue, maturity, the year

characteristic, climate and geographical region [8, 16, 27, 28]. Besides, of them, the levels of TPC and phenolic profile could be affected by the different extraction methodologies [6, 29]. In addition, the amount of phenolics of our samples may be affected with removed oil during extraction. Miraliakbari and Shahidi [21] were reported that the oil of tree nuts includes the important quantity of and strongly suggested chloroform/methanol was more effective than hexane for extraction of phenolic compounds of tree nut oil extracts

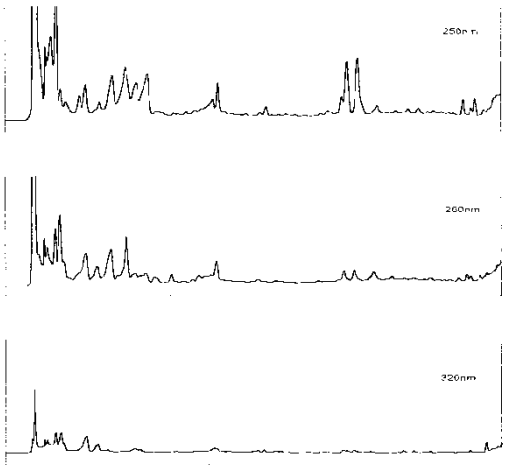


Figure 2. HPC chromatograms of hazelnut phenolic profile at different wavelength.

## IV. Conclusion

In this study, TPC and phenolic profile of 17 defatted hazelnuts were determined. The defatted meal of Mincane was rich for TPC and (+)-catechin, catechol, chlorogenic acid, and quercetin were the dominant compound in the phenolic profile of defatted hazelnuts. The effect of the variety on phenolics profile and TPC was significant in 1%. TPC and phenolic profile of defatted hazelnuts (with skin) may be useful to improve human health and to protect food lipids as natural antioxidant. Phenolic profiles of varieties are similar, the authentication of hazelnut in adulterated foods with other nuts as nut paste, meal and puree may be easily determined. Moreover, this study shows that commercial varieties as Tombul, Palaz, Foşa and Sivri are poorer than other cultivars in phenolic substance. Therefore, these varieties (Acı, İncekara, Kan, Karafındık, Kargalak, Kuş, etc.) should not be destructed from hazelnut orchard on the plea of fruitlessness, because extracts of defatted hazelnut may be alternative method for the production of phenolics and the enrichment of foods or pharmaceutical products. In addition, these varieties could serve as a tool to justify the geographic origin of these hazelnut varieties.

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