Impact of roasting on oxidation characteristics of less well-known hazelnut cultivar: Turkish hazelnut (*Corylus colurna*)

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In this work, the roasting processes on some quality parameters and oxidation of lipid fraction for a wild Turkish hazelnut (*Corylus colurna*) cultivar were studied and the sensitivity to lipid oxidation of the hazelnut samples stored under the accelerated conditions were determined. Changes in water activity, moisture content, oil content, colour values, free fatty acids, peroxide value and specific extinctions (K_{232}, K_{270}) were determined in the hazelnuts with different roasting conditions. The results showed that the roasting conditions significantly affected the fundamental characteristic parameters mentioned. In more detail, the water activity and moisture content of hazelnuts were found to decrease while L*- and b*-values of roasted hazelnut samples were observed to increase with roasting conditions. The higher values in free fatty acids and specific extinctions were experimentally measured in roasted samples at 165°C for the durations of 15 and 30 min. The fatty acid compositions of oils extracted from the hazelnuts were obtained to change slightly with the roasting process. The major fatty acid was determined as the oleic acid (ca. 80%). In accelerated conditions, the rates of the increment in the PV, K_{232}, K_{270} were noted to be significantly higher in the roasted as compared to the enhancement rates of those in the unroasted hazelnuts during the storage at 60°C. In the same conditions, the linoleic acid contents of oils extracted from the hazelnuts decreased with the storage. All in all, the roasting of hazelnuts led to decrease the oxidative stability throughout the storage in accelerated conditions. The study showed the effect of roasting temperature and time on some quality parameters of Turkish hazelnut cultivar.

Keywords: Turkish hazelnut, *Corylus colurna*, roasting, oxidation, fatty acid, hazelnut oil

1. INTRODUCTION

Hazelnut is an important agricultural product for Turkey and consumed worldwide due to its aroma, nutrients, and phytochemicals [2]. The hazelnut is an important ingredient of most food products such as snacks, chocolates, cereals, bakery, dairy, salad, entree, sauce, ice creams, and other dessert formulations, related to the organoleptic characteristics of the hazelnut. Besides, it has been noticed that hazelnuts improve the flavour and texture of the products mentioned above [18]. In addition to the advantages, the hazelnut is rich in important nutrients, including protein, oil, vitamins, and minerals [13, 19]. Within the nutritional components, the oil is important in terms of the quantity and quality of hazelnuts. The average oil content of hazelnuts was 60%, most of which is highly rich in oleic acid, contributing to human good health [3, 20].
Hazelnut kernels may be consumed raw (with skin) or roasted (without skin) [15]. It was noticed that some quality parameters such as texture, colour, aroma, oil, and fatty acid composition altered significantly during the roasting process [3, 4, 17].

A total of 18 hazelnut varieties are cultivated in Turkey. Seven hazelnut varieties, namely, Tombul, Çakıldak, Foşa, Kara fındık, Mincane, Palaz, and Sivri varieties are considered as the major commercialised ones [3, 21]. *Corylus colurna*, a wild and less known hazelnut variety, is a tree and reaches a height of up to 30 m. It is native to Southeast Europe, the Caucasus, Asia Minor, Iran, and the Himalayas. A major part of the natural distribution of Turkish hazelnuts in Turkey is located on the western Black Sea region [24]. *Corylus colurna* is known as Turkish *hazelnut* or wood hazelnut in literature. In Turkey, Ağaç Fındığı, Türk Fındığı, Ayı Fındığı, Balkan Fındığı and Kaya Fındığı could be local names for the hazelnut cultivar [22].

Bolu, where the hazelnut species of *Corylus colurna* is grown, is a city in the Western Black Sea region of Turkey. After the roasting process, the hazelnuts with the intrinsic aromatic nature may generally be used in a local chocolate product, "Bolu Chocolate".

To the best of our knowledge, there have only been limited studies on Turkish hazelnuts (*Corylus colurna*). In fact, there was no detailed information on the roasting of this hazelnut variety. The aim of this work is to assess the roasting processes on some quality parameters and oxidation of lipid fraction for the hazelnuts. For this purpose, some qualities like the colour, water activity, oil content, moisture content, free fatty acids, peroxide value, conjugated diene and trienes, fatty acid composition of raw and roasted hazelnuts were evaluated and compared with one another. Besides, this work enabled us to determine the sensitivity to the lipid oxidation of hazelnut samples stored under accelerated conditions.

2. MATERIALS AND METHODS

2.1 SAMPLES AND ROASTING

Raw shelled hazelnuts were obtained from the Bolu province of Turkey and shelled before the roasting process. Several roasting experiments were performed on a laboratory scale using an oven (Memmert UN 160). Roasting temperature and time were adjusted according to the method reported by Amaral et al. [4]. The following roasting conditions were tested: 125°C, 15 min; 125°C, 30 min; 145°C, 15 min; 145°C, 30 min; 165°C, 15 min; 165°C, 30 min; 185°C, 15 min; and 200°C, 5 min.

2.2 INITIAL ANALYSIS OF RAW AND ROASTED HAZELNUTS AND HAZELNUT OILS

2.2.1 Moisture content

Samples of raw and roasted hazelnuts were finely ground in a grinder (IKA-Werke, M20). The moisture of the ground hazelnuts was estimated using official methods (no. 925.40-1925) consisting in drying in an electrical oven at the temperature of 105°C up to reaching a constant weight [5].

2.2.2 Water activity

The water activity of all the ground hazelnut samples was measured using AquaLab Series 3 TE (Decagon Devices, Pullman, Washington, USA) water activity analyser at the temperature of 25°C.

2.2.3 Colour measurement

The colour of hazelnut samples was determined by using a Minolta CR-400 Chroma meter (Konica Minolta Sensing, Inc., Osaka, Japan). Changes in L* (lightness), a* (red-green) and b* (yellow-blue) colour values on the hazelnuts were determined during the roasting process.

2.2.4 Lipid extraction and oil content

The lipid extraction from the ground hazelnuts was performed with hexane in a Soxhlet apparatus. The oil content was expressed as % [12]. This extracted oil was used for the analysis of the fatty acid composition, free fatty acid, peroxide value and conjugated diene and trienes as described below.

2.2.5 Free fatty acid, Peroxide value, conjugated dine and trienes

The free fatty acids content, peroxide, K_{232} and K_{270} values in the hazelnut oils were determined with respect to AOCS Official Methods Cd 3d-63, Cd 8b-90 and Ch 5-91, respectively [6]. The acid value is the number of milligrams of potassium hydroxide necessary to neutralise the free acids in 1 gram of samples. The latter method determines all substances, in terms of milliequivalents of peroxide per 1000 grams of test sample, that oxidise potassium iodide under the testing conditions. The third method describes the procedure to perform a spectrophotometric examination of oils in the ultraviolet.

2.2.6 Fatty acid composition

The fatty acid composition of oils was determined with fatty acid methyl esters (FAME) by gas chromatography (GC). FAME were prepared according to the official method of IUPAC [11]. The fatty acid composition of hazelnut oils was separated and identified by a Shimadzu GC-2010 chromatograph equipped with a flame ionisation detector (FID) using an RTX-2330 fused-silica capillary column (60 m, 0.25 mm i.d., 0.20 µm film thickness, Restek, USA). Samples were introduced by injection system split–splitless in the split mode (within the ratio of 1:100). As the oven temperature was set at 140°C (held for 5 min); a temperature increase rate was adjusted to be 4°C/min up to the value of 240°C (held for 20 min). Throughout the experiments, the helium (1 mL/min) was the carrier gas. The temperatures of the injector and detector were set at 250°C and 260°C, respectively. The FAME were identified by comparison between their retention times and those of the reference standards.

2.3 ACCELERATED OXIDATION STORAGE

Raw and roasted hazelnut samples were exposed to the accelerated storage at 60°C in an oven. It is to be mentioned here that the preferred technique was the modified version of method firstly described by Alamprese et al. [1]. Here, the samples of 200 g were taken in separate glass jars and stored for 28 days. The oils were extracted separately every week to determine the variation in the fundamental aspects of free fatty acids content, peroxide value, fatty acid composition, K_{232} and K_{270} parameters of hazelnut samples.

2.4 STATISTICAL ANALYSIS

All analyses in this study were carried out in duplicated. Data were expressed in terms of the mean and standard deviation. Significant differences were determined using ANOVA in combination with a Duncan test with a significance level of $\alpha = 0.05$.

3. RESULTS AND DISCUSSION

As seen in Table I, the water activity of raw and roasted hazelnuts was noticed to vary slightly from the value of 0.35 (for the raw sample) to 0.40 (for the sample roasted at 200°C for 5 min). It is to be stressed here that the water activity values below such a value of 0.6 for the hazelnuts are generally considered as safe for the microbiological spoilage. Even the water activity parameters deduced in this work were noticed as in good agreement with the values reported earlier in a scientific study available in literature [10, 28]. One can observe all the total oil contents for the raw and roasted hazelnut samples in Table I. It is visible from the table that the oil content of samples is obtained as ranging from 47.56% until the value of 67.36%. Alasalvar et al. [3] reported that the roasting process resulted in rather higher amounts of water activity in the oils extracted from the Turkish hazelnut varieties. Amaral et al. [4] and Shafiei et al. [28] declared that the roasting process led to increase the oil content of hazelnuts slightly. In this respect, many of our results were clearly supported by the results of Alasalvar et al. [3], Amaral et al. [4] and Shafiei et al. [28]. Conversely, we realised in the study that the oil content decreased in some samples due to the inhomogeneous distribution of heat transfer along with the hazelnuts depending on the nonstandard characteristics. As for the moisture content parameters of hazelnuts, the slight decrements (from 2.38% to 0.96%) in the parameters emerged immediately for the roasted samples. Similar observations (degradation trend in the moisture content with the roasting process) were also reported by Saklar et al. [23]. (Tab I)

Additionally, L*-value, a*-value, and b*-value for the measurements of control and roasted whole hazelnuts (without shell) are given in Table II in detail. The L*- and b*-values of roasted hazelnut samples were found to be higher than those of raw samples. On the other hand, a*-values for the roasting samples were generally observed to be smaller as compared to those for the raw samples. In more detail, the higher roasting temperature and longer exposure time for the samples to be roasted, the greater a*-value (165°C, 30 min; 185°C, 15 min) was observed. The similar results for colour measurements were observed for the roasted hazelnuts [23]. Ozdemir and Devres [27] researched the effects of wide range temperature and time in the roasting processes on the colour of hazelnuts and confirmed the differentiation in the colourless of samples studied. In our research for this paper, we clearly examined the role of various temperatures and time on the colour, and realised some differences related to the reasons given above. (Tab. II)

Results of free fatty acids, peroxide value, K_{232} and K_{270} parameters are depicted in Table III. It is apparent from the table that the free fatty acid contents of oils extracted from the hazelnut samples (exposed to the different temperatures and times) were observed to range from 1.28% to 1.73%. Here, the maximum

Table I - Water activity, oil content and moisture content of hazelnut samples

Applications	Water activity	Oil content (%)	Moisture content (%)
Control	0.40±0.01^{a*}	63.15±2.57^{ab}	2.38±0.16^{a}
125-15	0.39±0.00^{b}	67.36±3.66^{a}	1.50±0.21^{b}
125-30	0.38±0.00^{b}	54.37±3.55^{cd}	1.18±0.26^{b}
145-15	0.38±0.00^{b}	48.42±0.34^{d}	1.15±0.37^{b}
145-30	0.39±0.00^{b}	56.87±0.66^{bc}	1.22±0.14^{b}
165-15	0.38±0.01^{b}	47.56±2.35^{d}	1.25±0.11^{b}
165-30	0.36±0.01^{c}	63.58±3.71^{ab}	0.96±0.16^{b}
185-15	0.35±0.00^{d}	65.65±3.45^{a}	0.98±0.22^{b}
200-5	0.35±0.00^{d}	61.04±5.44^{abc}	1.22±0.36^{b}

* Values are means ± standard deviation of two measurements. Means with different superscript letters in the column are significantly different (P<0.05)

Table II - Color values of hazelnuts during roasting

Applications	L*	a*	b*
Control	56.37±2.96[c*]	5.56±0.67[b]	15.94±0.36[e]
125-15	70.68±1.41[a]	1.56±0.21[e]	18.65±1.00[d]
125-30	68.37±2.53[a]	2.03±0.16[de]	20.31±0.99[cd]
145-15	68.83±0.86[a]	2.51±0.48[de]	21.29±1.15[c]
145-30	67.68±1.88[a]	3.80±0.17[c]	24.15±0.95[b]
165-15	67.60±0.33[a]	2.78±0.30[cd]	21.73±0.64[c]
165-30	62.76±1.24[b]	8.19±0.69[a]	27.74±0.17[a]
185-15	67.07±1.26[a]	5.44±0.81[b]	24.94±0.21[b]
200-5	68.03±0.52[a]	2.66±0.05[de]	21.33±1.21[c]

[*]Values are means ± standard deviation of three measurements. Means with different superscript letters in the column are significantly different (P<0.05)

Table III - Free fatty acids, peroxide value and spesific extinctions of hazelnut oils from raw and roasted hazelnuts

Applications	Free fatty acids	Peroxide value	K_{232}	K_{270}
Control	1.55±0.12[ab*]	0.91±0.09[a]	6.11±0.91[bc]	0.25±0.14[b]
125-15	1.73±0.07[a]	0.81±0.01[ab]	5.38±0.78[cd]	0.16±0.16[bc]
125-30	1.48±0.18[ab]	0.68±0.18[abc]	5.05±0.78[cde]	0.24±0.03[b]
145-15	1.49±0.03[ab]	0.61±0.27[abc]	5.60±0.16[cd]	0.22±0.07[bc]
145-30	1.57±0.17[ab]	0.37±0.01[c]	5.04±0.61[cde]	0.19±0.04[bc]
165-15	1.56±0.38[ab]	0.69±0.16[abc]	7.24±0.72[a]	0.30±0.08[ab]
165-30	1.67±0.05[ab]	0.55±0.01[bc]	6.87±1.07[ab]	0.42±0.06[a]
185-15	1.28±0.23[b]	0.44±0.15[c]	4.12±0.19[e]	0.16±0.17[bc]
200-5	1.32±0.03[ab]	0.52±0.05[bc]	4.78±0.11[de]	0.05±0.00[c]

[*] Values are means ± standard deviation of two measurements. Means with different superscript letters in the column are significantly different (P<0.05)

differentiation was observed for the sample exposed to the heat-temperature of 165°C and time of 15 min whereas the minimum value of 1.28% was associated with the sample prepared at the temperature of 185°C and time of 15 min. On this basis, the dependence of temperature on the free fatty acid content is clear. Likewise, the experimental findings in Table III confirms the role of duration on the free fatty acid content values of hazelnut samples. Besides, one can encounter the changes in the peroxide value of oil samples in the same table. It is obvious from the table that the peroxide values were noted to be in a range of 0.37-0.91 meq O_2/kg oil. The measurement results obtained were found to be consistent with those obtained by Ozdemir et al. [17] showing that PV of Giresun hazelnuts decreased with the increase of roasting temperatures. As seen in Table III, PV of samples was observed to decrease with the enhancement in the duration at the same roasting temperature. Yaacoub et al. [25] stated that the PV reached to the elevated values and but decreased immediately after an induction time because of hydroperoxide decomposition in case of the roasting of sesame seeds. It is just this last descriptor that the decrement in the PV of long roasted samples might be attributable to the hydroperoxide decomposition at the extended roasting times. Moreover, the values of K_{232} and K_{270} for the samples were obtained to change from 4.12 to 7.24 and 0.05 to 0.42, respectively. Except for two roasting conditions (165°C-15 min and 165°C-30 min), the values each were found to diminish with the roasting process compared to those of raw samples. Similar results can be encountered for the argan oils in the literature [7]. Like the findings of PVs, the values of K_{232} parameters were obtained to decrease generally with the enhancement of roasting time. (Tab. III).

The fatty acid composition of hazelnut oils extracted is shown in Table IV. Oleic acid (C18:1) was found as the predominant fatty acid (ranging from 81.09 to 82.68%), followed by linoleic acid (C18:2) (ranging from 9.64 to 11.11%), palmitic acid (C16:0) (ranging from 4.93 to 5.05%). Some minor changes occurred in the fatty acid compositions of roasted hazelnut in comparison with those of raw counterparts. A similar behaviour was already reported in previous works by Alasalvar et al. [3] and Shafiei et al. [28]. Moreover, levels of saturated fatty acids (7.19%), monounsaturated fatty acids (81.49%) and polyunsaturated fatty acids (11.25%) of raw hazelnut oil were in a well agreement with values (7.35%, 81.27% and 11.38 respectively) determined by Shafiei et al. [28]. (Tab. IV).

3.1. EFFECT OF ROASTING PROCESS ON LIPID OXIDATION AT ACCELERATED STORAGE

The influence of roasting process (during the storage) on free fatty acids in hazelnut samples is graphically shown in Figure 1. According to the findings for the free fatty acid content in all the samples analyzed, generally there was wavy changes in the curves during the storage. At the same time, the free fatty acid values for the raw samples were observed to be generally higher than those of roasted samples. The fact was confirmed by the results of Lin et al. [14] who reported that the free fatty acids for the whole raw almonds were obtained to be higher than those for the blanched samples during the storage at different temperature conditions. This is due to the presence of greater enzyme activity in the samples. The similar fluctuation trend in free fatty acids of hazelnut oils was observed for the almond samples mentioned in the same paper. This might partially be in attribution to the enzyme activity. (Fig. 1).

The change in the PVs of oils extracted from raw and roasted hazelnuts during the storage process is shown in Figure 2. The figure shows that all the PVs of oil samples (except for the sample roasted at 165°C for 30 min) were observed to increase slightly with the storage process. Namely, the PV was obtained to increase sharply and, indeed, reached the value of 29.08 meq O_2/kg at the end of storage. The experimental test results gathered were noted to be close to those obtained by Chun et al. [8] in which the PV of roasted peanuts was reported to increase much more sharply as compared to those of raw samples stored at the temperature value of 21°C. (Fig. 2).

The values of CD and CT for all the samples tested are graphically shown in Figure 3 and Figure 4. According to the figures, the values of CDs for all the stored hazelnut samples were not correlated with the PVs. While the initial CDs of roasted hazelnuts were found to be lower than those of their corresponding raw counterparts, PVs of roasted hazelnuts were observed to increase sharply and noted to be higher than those of raw samples. At the end of 28 days, the CD value was measured to be about 8.48 for the raw sample whereas the highest CD value of 10.84 was recorded for the sample roasted at 125°C for 30 min. Like the value of CD, the CT values were noticed to be higher for the roasted samples as compared to those for the raw samples at the end of storage. It is to be mentioned here that after 28 days storage, among the CT parameters the greatest value of 1.60 was found for the sample roasted at 125°C for 30 min. The increment behaviour in the CD and CT parameters with respect to roasting process showed simi-

Table IV - Fatty acid composition of hazelnut oils from raw and roasted samples (%)

Applications	C14:0	C16:0	C16:1	C17:0	C17:1	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	C22:0
Control	0.02±0.00*	5.05±0.18	0.25±0.01	0.04±0.00	0.08±0.00	1.96±0.04	81.09±0.23	11.11±0.07	0.14±0.00	0.10±0.00	0.15±0.01	0.02±0.00
125-15	0.02±0.00	5.05±0.05	0.26±0.01	0.03±0.00	0.08±0.01	1.88±0.09	82.68±0.62	9.64±0.56	0.12±0.01	0.10±0.01	0.14±0.00	0.02±0.00
125-30	0.02±0.00	5.02±0.08	0.26±0.00	0.04±0.01	0.08±0.01	1.89±0.08	82.23±0.26	10.10±0.14	0.13±0.02	0.10±0.01	0.15±0.01	0.02±0.00
145-15	0.02±0.00	5.05±0.03	0.26±0.01	0.03±0.00	0.07±0.01	1.94±0.02	81.93±0.30	10.33±0.35	0.13±0.00	0.10±0.00	0.14±0.00	0.02±0.00
145-30	0.02±0.00	4.96±0.06	0.26±0.01	0.03±0.00	0.07±0.00	1.89±0.05	82.47±0.01	9.93±0.01	0.12±0.00	0.10±0.00	0.14±0.01	0.02±0.00
165-15	0.02±0.00	5.05±0.13	0.26±0.00	0.04±0.01	0.08±0.01	1.92±0.04	81.90±0.64	10.36±0.42	0.13±0.01	0.10±0.01	0.14±0.01	0.02±0.00
165-30	0.02±0.00	5.05±0.16	0.26±0.01	0.04±0.01	0.08±0.01	1.99±0.06	81.77±0.63	10.43±0.72	0.12±0.01	0.11±0.01	0.15±0.01	0.02±0.00
185-15	0.02±0.00	4.93±0.02	0.25±0.01	0.03±0.00	0.08±0.00	1.90±0.05	82.24±0.60	10.17±0.66	0.14±0.01	0.10±0.00	0.15±0.01	0.02±0.00
200-5	0.02±0.00	4.97±0.01	0.25±0.00	0.03±0.00	0.08±0.00	1.92±0.08	81.41±0.26	10.94±0.16	0.14±0.00	0.10±0.00	0.15±0.01	0.02±0.00

*Values are means ± standard deviation of two measurement

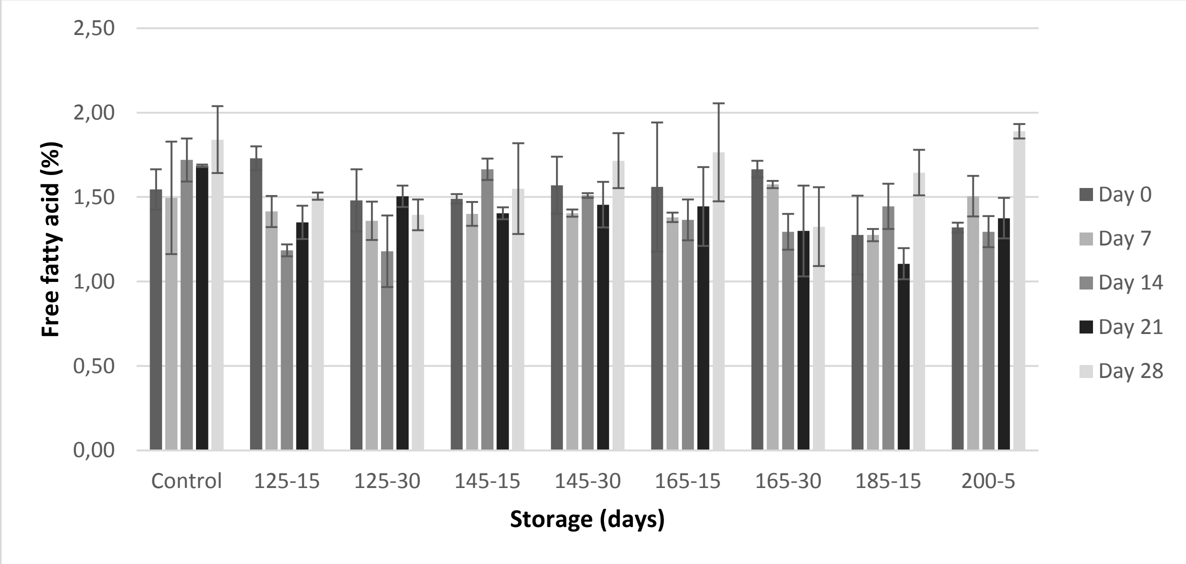

Figure 1 - Effect of roasting process on free fatty acids of hazelnut samples under accelerated storage at 60°C for 28 days. Each value is the average of two replicates, and vertical bars represent the standard deviation of replicates

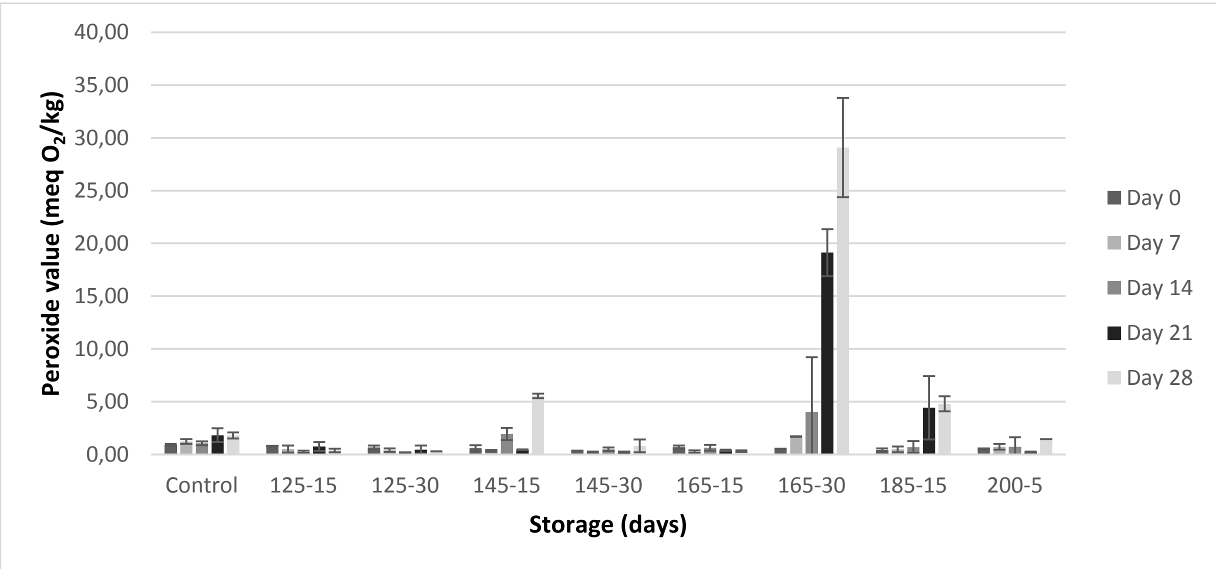

Figure 2 - Effect of roasting process on PV of hazelnut samples under accelerated storage at 60 °C for 28 days. Each value is the average of two replicates, and vertical bars represent the standard deviation of the replicates

larity with those results reported by Özkan et al. [16] who emphasised that the values of oils extracted from the hazelnut samples were measured to increase with the augmentation of roasting process.

Based on the findings of PV, K_{232} and K_{270} values during the storage, it can be discussed that the lipid oxidation was noted to be faster for the roasted samples than those of raw samples. This might be attributed to the skin of raw samples which have some bioactive compounds inhibiting the free fatty acid hydrolysis and lipid oxidation [26]. (Fig. 3, Fig. 4).

Table V shows numerically the major fatty acid compositions of hazelnut oil extracted from the hazelnuts before and after the roasting process. It is apparent from the table that the changes in palmitic ($C_{16:0}$) and stearic acid ($C_{18:0}$) contents for the hazelnut samples remained almost constant until 28 days. However, the oleic acid ($C_{18:1}$) content was recorded to increase at the end of the storage time while the linoleic acid ($C_{18:2}$) was detected to decrease regularly. The changes in the oleic and linoleic acid parameters discussed in the present work are found to show a good agreement with the experimental evidence in the works conducted by Ghirardello et al. [9]. In more detail, the linoleic acid content was reported to decrease while the value of oleic acid was measured to increase throughout the different storage conditions for the hazelnut oil. In the same work, the reduction

Table V - Changes in composition of predominant fatty acids of oils obtained from raw and roasted at different temperature and time

	Storage (days)					$C_{18:0}$	Storage (days)				
$C_{16:0}$	0	7	14	21	28		0	7	14	21	28
Control	5.05±0.18*	5.12±0.04	5.09±0.01	5.03±0.02	5.03±0.07	Control	1.96±0.04	1.98±0.03	1.92±0.07	2.01±0.03	1.91±0.01
125-15	5.05±0.05	5.06±0.08	4.95±0.11	5.09±0.00	5.04±0.10	125-15	1.88±0.09	1.96±0.01	1.92±0.03	1.93±0.01	1.92±0.06
125-30	5.02±0.08	5.00±0.08	5.06±0.09	5.15±0.08	5.09±0.02	125-30	1.89±0.08	1.90±0.00	1.94±0.04	2.00±0.02	1.97±0.06
145-15	5.05±0.03	4.85±0.16	5.15±0.12	5.06±0.02	5.05±0.01	145-15	1.94±0.02	1.85±0.02	2.01±0.01	1.95±0.04	1.98±0.03
145-30	4.96±0.06	4.95±0.05	5.08±0.13	5.11±0.09	5.11±0.01	145-30	1.89±0.05	1.94±0.04	1.97±0.01	1.94±0.03	1.98±0.00
165-15	5.05±0.13	4.93±0.04	5.03±0.01	5.01±0.04	5.17±0.13	165-15	1.92±0.04	1.90±0.09	1.90±0.01	1.90±0.06	1.93±0.04
165-30	5.05±0.16	4.95±0.04	4.94±0.09	5.03±0.03	5.08±0.12	165-30	1.99±0.06	1.92±0.05	1.93±0.07	1.97±0.01	1.98±0.06
185-15	4.93±0.02	4.91±0.02	5.10±0.11	4.92±0.02	5.04±0.05	185-15	1.90±0.05	1.86±0.02	1.94±0.05	1.89±0.01	1.94±0.09
200-5	4.97±0.01	5.04±0.07	5.10±0.05	5.04±0.00	5.09±0.01	200-5	1.92±0.08	1.97±0.08	1.97±0.02	2.02±0.00	1.97±0.00
$C_{18:1}$	0	7	14	21	28	$C_{18:2}$	0	7	14	21	28
Control	81.09±0.23	81.41±0.06	81.84±0.35	82.62±0.54	82.53±0.06	Control	11.11±0.07	10.68±0.06	10.35±0.27	9.56±0.59	9.76±0.14
125-15	82.68±0.62	82.26±0.19	82.82±0.51	83.01±0.16	83.35±0.17	125-15	9.64±0.56	9.97±0.13	9.56±0.37	9.21±0.18	8.94±0.22
125-30	82.23±0.26	82.37±0.14	82.77±0.14	83.06±0.22	83.60±0.16	125-30	10.10±0.14	9.95±0.23	9.47±0.29	9.02±0.33	8.60±0.07
145-15	81.93±0.30	82.80±0.50	82.25±0.42	83.05±0.01	83.29±0.06	145-15	10.33±0.35	9.75±0.69	9.82±0.28	9.17±0.00	8.92±0.08
145-30	82.47±0.01	82.55±0.30	82.35±0.01	82.68±0.46	82.67±0.01	145-30	9.93±0.01	9.79±0.21	9.85±0.12	9.52±0.34	9.47±0.01
165-15	81.90±0.64	82.44±0.65	82.15±0.25	82.96±0.06	83.10±0.57	165-15	10.36±0.42	9.96±0.59	10.14±0.25	9.38±0.07	9.04±0.65
165-30	81.77±0.63	82.71±0.46	83.01±0.76	83.08±0.01	83.16±0.59	165-30	10.43±0.72	9.66±0.56	9.37±0.59	9.16±0.03	9.03±0.38
185-15	82.24±0.60	82.85±0.43	82.53±0.08	83.09±0.40	83.14±0.49	185-15	10.17±0.66	9.62±0.37	9.66±0.01	9.35±0.41	9.12±0.45
200-5	81.41±0.26	81.94±0.20	82.53±0.11	82.27±0.00	82.99±0.15	200-5	10.94±0.16	10.27±0.03	9.63±0.14	9.88±0.00	9.17±0.17

*Values are means ± standard deviation of two measurement

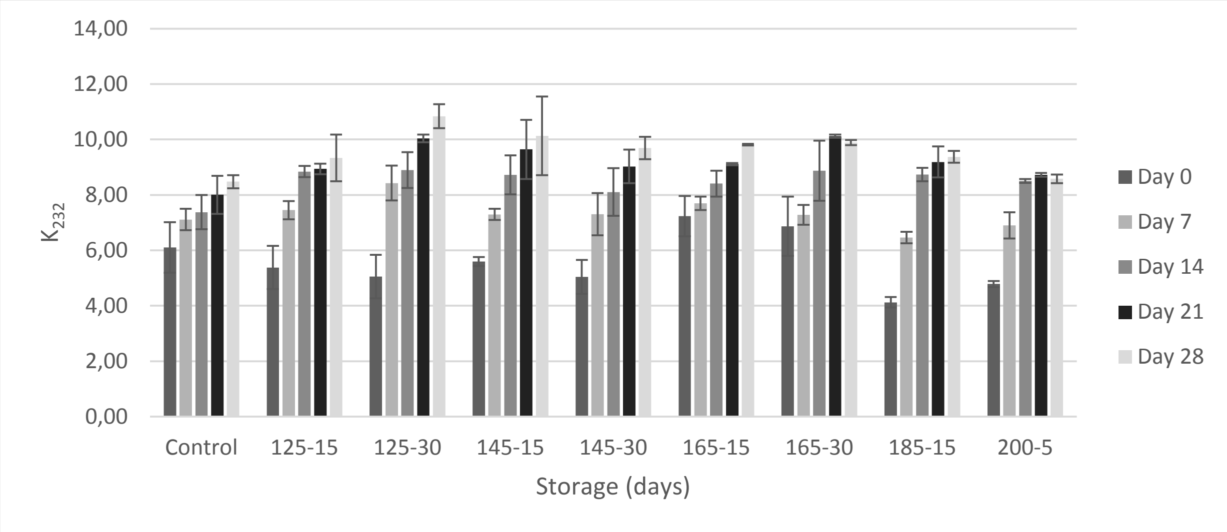

Figure 3 - Effect of roasting process on CD of hazelnut samples under accelerated storage at 60°C for 28 days. Each value is the average of two replicates, and vertical bars represent the standard deviation of the replicates

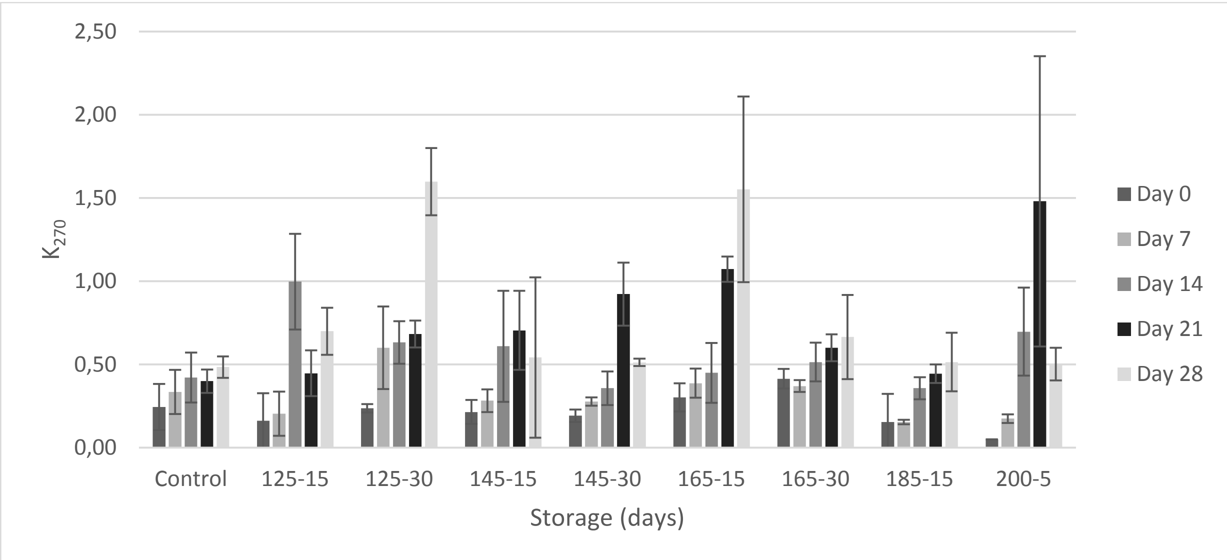

Figure 4 - Effect of roasting process on CT of hazelnut samples under accelerated storage at 60°C for 28 days. Each value is the average of two replicates, and vertical bars represent the standard deviation of the replicates

of linoleic acid might be attributed to the peroxidation and subsequent loss during the storage. (Tab. V).

4. CONCLUSION

Turkish hazelnut (*Corylus colurna*) is wildly grown in Turkey. The hazelnuts, being harvested from the ground due to the tall of trees, are roasted and used for the confectionary products. In this study, we examined experimentally the effect of roasting temperature and time on some chemical properties such as water activity, moisture content, colour values, free acidity, peroxide value, conjugated diene-triene value and fatty acid composition. The roasting process was carried out in the electrical oven, so the homogenous sample is difficult to obtain. It is to be emphasised here that there seemed some fluctuations in the chemical features provided above due to the lipid extraction from the ground samples. Regardless, the experimental findings demonstrate that the roasting process seriously affected some chemical properties provided above. Moreover, most of results showed that the higher roasting temperatures contributed to increase in the free fatty acid, peroxide value and conjugated diene-triene values. Besides, the roasting temperature was found to affect slightly the fatty acid composition. The linoleic acid content of roasted hazelnuts was detected to decrease slightly while the oleic acid content was recorded to much more enhance as compared to those of raw samples. In the accelerated storage conditions, the raw samples were noted to be more resistant to the lipid oxidation in comparison with those of roasted samples. All in all, the study including the scientific and especially food sector area is a leader to determine the effect of roasting temperature and time on some quality parameters (especially lipid oxidation) of Turkish hazelnut cultivar.

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Author Contributions
M. Kıiralan, E. Sarıca and Ö. Eren designed the study. M. Kıralan and E. Sarıca collected test data, interpreted the results, and drafted the manuscript.

Conflicts of Interest
The authors declare there is no conflict of interest.

REFERENCES

[1] C. Alamprese, S. Ratti, M. Rossi, Effects of roasting conditions on hazelnut characteristics in a two-step process. Journal of food engineering 95(2), 272-279 (2009)

[2] C. Alasalvar, F. Shahidi, J.S. Amaral, B.P.P. Oliveira, Compositional characteristics and health effects of hazelnut. C. Alasalvar, F. Shahidi (Eds.), Tree nuts composition, phytochemicals, and health effects, CRC Press Taylor & Francis Group, Boca Raton, FL 185-214 (2009)

[3] C. Alasalvar, E. Pelvan, B. Topal, Effects of roasting on oil and fatty acid composition of Turkish hazelnut varieties (Corylus avellana L.). International journal of food sciences and nutrition 61(6), 630-642 (2010)

[4] J.S. Amaral, S. Casal, R.M. Seabra, B.P. Oliveira, Effects of roasting on hazelnut lipids. Journal of agricultural and food chemistry 54(4), 1315-1321 (2006)

[5] AOAC, Official Methods of Analysis of the Association of the Official Analysis Chemists. Association of Official Analytical Chemists, (14th ed.), Washington, DC. (1984)

[6] AOCS, Official Methods Methods Cd 3d–63, Cd 8b–90, and Ch 5-91 Official Methods and Recommended Practices of the American Oil Chemists' Society (fifth ed.), AOCS Press, Champaign, IL (1997)

[7] R. Ben Mansour, H. Ben Slema, H. Falleh, M. Tounsi, M.S.A. Kechebar, R. Ksouri, W. Megdiche-Ksouri, Phytochemical characteristics, antioxidant, and health properties of roasted and unroasted Algerian argan (Argania spinosa) oil. Journal of Food Biochemistry 42(6) e12562. https://doi.org/10.1111/jfbc.12562 (2018)

[8] J. Chun, J. Lee, R.R. Eitenmiller, Vitamin E and oxidative stability during storage of raw and dry roasted peanuts packaged under air and vacuum. Journal of Food Science 70(4), C292-C297 (2005)

[9] D. Ghirardello, C. Contessa, N. Valentini, G. Zeppa, L. Rolle, V. Gerbi, R. Botta, Effect of storage conditions on chemical and physical characteristics of hazelnut (Corylus avellana L.). Postharvest Biology and Technology 81, 37-43 (2013)

[10] R.P. Guiné, C.F. Almeida, P.M. Correia, Influence of packaging and storage on some properties of hazelnuts. Journal of Food Measurement and Characterization 9(1), 11-19 (2015)

[11] IUPAC, IUPAC Standard methods for analysis of oils, fats and derivatives. International Union of Pure and Applied Chemistry Method 2.301, Report of IUPAC Working Group WG 2/87, Blackwell Scientific Publications, Palo Alto, CA, USA (1987)

[12] C.S. James, Analytical chemistry of foods. Publisher Blackie Academic and Professional, 176p., London (1995)

[13] F.G. Kirbaşlar, G. Erkmen, Investigation of the effect of roasting temperature on the nutritive value of hazelnuts. Plant Foods for Human Nutrition 58(3), 1-10 (2003)

[14] X. Lin, J. Wu, R. Zhu, P. Chen, G. Huang, Y. Li, W. Lin, California almond shelf life: Lipid deterioration during storage. Journal of Food Science 77(6), C583-C593 (2012)

[15] S. Lucchetti, R. Ambra, G. Pastore, Effects of peeling and/or toasting on the presence of tocopherols and phenolic compounds in four Italian hazelnut cultivars. European Food Research and Technology 1-8 (2018)

[16] G. Özkan, M. Kiralan, E. Karacabey, G. Çalik, N. Özdemir, T. Tat, ... M.F. Ramadan, Effect of hazelnut roasting on the oil properties and stability under thermal and photooxidation. European Food Research and Technology *242*(12), 2011-2019 (2016)

[17] M. Ozdemir, F. Açkurt, M. Yildiz, G. Biringen, T. Gürcan, M. Löker, Effect of roasting on some nutrients of hazelnuts (*Corylus Avellena L.*). Food Chemistry 73(2), 185-190 (2001)

[18] F. Ozdemir, I. Akinci, Physical and nutritional properties of four major commercial Turkish hazelnut varieties. Journal of Food Engineering 63(3), 341-347 (2004)

[19] M. Özdemir, F. Açkurt, M. Yildiz, G. Biringen, T. Gürcan, M. Löker, Effect of roasting on some nutrients of hazelnuts (*Corylus Avellena L.*).

Food Chemistry 73(2),185-190 (2001)

[20] J. Parcerisa, D.G. Richardson, M. Rafecas, R. Codony, J. Boatella, Fatty acid distribution in polar and nonpolar lipid classes of hazelnut oil (*Corylus avellana L.*). Journal of agricultural and food chemistry 45(10), 3887-3890 (1997)

[21] E. Pelvan, C. Alasalvar, S. Uzman, Effects of roasting on the antioxidant status and phenolic profiles of commercial Turkish hazelnut varieties (*Corylus avellana L.*). Journal of agricultural and food chemistry 60(5), 1218-1223 (2012)

[22] S. Polat, Türk fındığı'nın (*Corylus colurna*) Türkiye'deki yeni bir yayılış alanı. Marmara Coğrafya Dergisi 29, 136-149 (2014)

[23] S. Saklar, S. Ungan, S. Katnas, Microstructural changes in hazelnuts during roasting. Food Research International 36(1), 19-23 (2003)

[24] F. Temel, M. Arslan, D. Çakar, F.Ö. Değirmenci, A. Ateş, Z. Kaya, Türkiye'deki Doğal Türk Fındığı (*Corylus Colurna*) Popülasyonları. IV. Ulusal Ormancılık Kongresi 42 (2017)

[25] R. Yaacoub, R. Saliba, B. Nsouli, G. Khalaf, I. Birlouez-Aragon, Formation of lipid oxidation and isomerization products during processing of nuts and sesame seeds. Journal of Agricultural and Food Chemistry, 56(16), 7082-7090 (2008)

[26] B. Zhou, Y. Sun, J. Li, Q. Long, H. Zhong, Effects of seed coat on oxidative stability and antioxidant activity of apricot (Prunus armeniaca L.) kernel oil at different roasting temperatures. Journal of the American Oil Chemists' Society *95*(10), 1297-1306 (2018)

[27] M. Ozdemir, O. Devres, Analysis of color development during roasting of hazelnuts using response surface methodology. Journal of Food Engineering 45, 17-24 (2000)

[28] G. Shafiei, M Ghorbani, H. Hosseini, A.S. Mahoonak, Estimation of oxidative indices in the raw and roasted hazelnuts by accelerated shelf-life testing. Journal of Food Science and Technology 57, 2433-2442 (2020)