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Changes in the Physicochemical Properties Caused by Irrigation at the Pre-Harvest Cluster Drop Period in 'Tombul' Hazelnut Cultivar

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Abstract: This research was carried out to evaluate the changes of physicochemical contents during storage of 'Tombul' hazelnut cultivar irrigated at the pre-harvest cluster drop period, which is critical for cluster drops, in a conventional rain-fed 'Tombul' hazelnut orchard in Giresun province (Turkey) in 2015 and 2016. The experiment was designed as randomized plots with 3 replications. The plants (multi-stemmed bush) were irrigated with drip irrigation on 16 July (46.08 mm/60 cm), 26 July (44.68 mm/60 cm), 30 July (43.68 mm/60 cm) and 06 August (44.08 mm/60 cm). The dried in-shell hazelnuts were grouped as irrigated and unirrigated (control) samples. 12 kg of in-shell hazelnuts were used in each replication. The hazelnuts were stored in mesh bags under laboratory conditions (20-22 ºC and 70-80% relative humidity) for 12 months. The results showed that moisture, ash, oil, and palmitic acid values were significantly affected by the irrigation application. The lowest moisture and ash values, and the highest oil and palmitic acid values were obtained from the samples of irrigated plants. On the other hand, the changes in protein, rancidity, peroxide and vitamin E, and other fatty acids, except for the palmitic acid, were not significant. In conclusion, it can be said that supplementary irrigation in the pre-harvest period has a significant effect on some physicochemical changes during storage in hazelnuts. According to these results, supplementary irrigation can be recommended for hazelnut storage quality in case of insufficient precipitation during the last cluster drop period.

Keywords: *Corylus avellana, Cluster drop, Irrigation, Physicochemical, Storage*

'Tombul' Fındık Çeşidinde Hasat Önü Çotanak Döküm Periyodundaki Sulamanın Depolama Süresince Meydana Getirdiği Fizikokimyasal Değişimler

Öz: Bu araştırma, Giresun ilinde geleneksel olarak yağmurla beslenen 'Tombul' fındık çeşidi ile tesis edilmiş bir bahçede, çotanak dökümleri için kritik olan son döküm döneminde uygulanan damla sulamanın depolanma sırasında fizikokimyasal içeriklerindeki değişimlerin belirlenmesi amacıyla 2015 ve 2016 yıllarında yürütülmüştür. Deneme tesadüf parselleri deneme desenine göre 3 tekerrürlü olarak tasarlanmıştır. Ocaklardaki bitkiler (çok gövdeli çalı) 16 Temmuz (46.08 mm/60 cm), 26 Temmuz (44.68 mm/60 cm), 30 Temmuz (43.68 mm/60 cm) ve 06 Ağustos (44.08 mm/60 cm) tarihlerinde damla sulama ile sulanmıştır. Kurutulmuş kabuklu fındıklar sulu ve susuz olarak gruplandırılmıştır. Her tekerrürde 12 kg kabuklu fındık kullanılmıştır. Fındıklar, 12 ay boyunca laboratuvar koşullarında (20-22 ºC ve %70-80 bağıl nem) file çuvallarda muhafaza edilmiştir. Sonuçlar, nem, kül, yağ ve palmitik asit değerlerinin ilave sulama uygulamasından önemli ölçüde etkilendiğini göstermiştir. En düşük nem ve kül değerleri ile en yüksek yağ ve palmitik asit değerleri sulanan bitki örneklerinden elde edilmiştir. Öte yandan, protein, ransidite, peroksit ve E vitamini ile palmitik asit dışındaki diğer yağ asitlerindeki değişimler önemli bulunmamıştır. Sonuç olarak, fındıkta depolama sırasında bazı fizikokimyasal değişiklikler üzerinde hasat öncesi dönemde ilave sulamanın önemli bir etkiye sahip olduğu söylenebilir. Bu sonuçlara göre, son çotanak döküm döneminde yetersiz yağış olması durumunda fındıkta depolama kalitesi için ilave sulama önerilebilir.

Anahtar Kelimeler: *Corylus avellana, Çotanak dökümü, Sulama, Fizikokimyasal, Depolama*

1. Introduction

In the hazelnut production areas especially Trabzon, Giresun and Ordu provinces in Turkey, climatic conditions can vary greatly in the region due to the land structure. One of the most important reasons for the yield fluctuations in hazelnut production from year to year is adverse climatic conditions (Bostan, 2009).

In the Eastern Black Sea region of Turkey, hazelnut production takes place in very hilly areas. Since the hazelnut root system has an exposed structure, it is very sensitive to drought, especially in sloping areas. Yield is significantly affected by precipitation, especially between May and July. For this reason, irrigation in the critical period at least in areas where natural conditions, water resources and irrigation systems allow can be an effective solution in dry years (Tonkaz & Bostan, 2010; Bostan & Tonkaz, 2013).

Hazelnut trees should be irrigated, especially in regions with limited rainfall and years, and on soils with low water capacity, due to its positive effects on productivity. Hazelnut is generally accepted as a water stress sensitive species due to its low stomatal regulation

capacity. The water potential in the growing season affects the vegetative and generative activities and causes a decrease in quality and yield. At a time when different vegetative and generative developments (end of leaf area development, nut set, nut development, flower bud initiation and differentiation) overlap between June and August, abundant water is an important factor in overcoming developmental competition (Bignami et al., 2009; Bignami et al., 2011; Cristofori et al., 2014; Cristofori et al., 2019). Since irrigation during the development period has a very important effect on physiological characteristics and nut quality, long annual data on irrigation applications are needed for precise results (Dias et al., 2005).

The fact that the topography of the hazelnut growing areas in the first standard hazelnut region in Turkey is very rugged and inclined can cause significant changes in yield and pomological characteristics even within the cultivar as well as among the cultivars. As a matter of fact, it has been stated that the technological properties of hazelnut varieties grown in the Central and Eastern Black Sea Region of Turkey show significant changes according to the varieties, regions and years (Şahin et al., 1990).

It has been stated that the hot and dry months of June and July in the Central and Eastern Black Sea Region cause an increase in pre-harvest cluster drop in hazelnuts, a negative relationship is observed between the sunny days in July and hazelnut production, while the number of rainy days in the same month has a positive and significant effect on the yield (Bostan, 2005; Bostan & Tonkaz, 2013). Modern irrigation techniques should be applied to ensure increased plant water consumption due to temperature increases in the region (Tonkaz & Bostan, 2016). Among ecological factors, the drought especially in July (pre-harvest) and the falling below 60% of relative humidity of the air in this period cause low kernel percent and an increase in the cluster drop (Okay et al., 1986). Considering that the daily and monthly total precipitation values between June and August gradually decrease, it can be said that the average temperature and total precipitation values have a more critical effect on the ratio of cluster drop in the pre-harvest period where most of the cluster drop occur (Top & Bostan, 2020). On the other hand, Milosevic & Milosevic (2012) stated that lack of water is an important factor on the severity of the cluster drop, in other words, low yield; Mingeau et al. (1994) also stated that 15-20% water restriction during the kernel development period doubled the pre-harvest fruit drop and the empty fruit rate.

There are significant differences in crude protein, fat, fiber, ash content and energy among hazelnut varieties, which are a good source of energy and rich in protein (Ozdemir & Akinci, 2004). Hazelnut has a high level of chemical components that are important for nutrition and health. The high fat content is believed to result in reduced shelf life and rancidity, but the possible adverse effect on fruit storability can be mitigated by the presence of phenolics and the low level of total unsaturated fatty acids (Cristofori et al., 2008). The direct effect of malate and other organic acids on the taste and quality of hazelnuts is very low, on the contrary, sugar, lipid, linoleic acid and tocopherol contents are important parameters to be considered in the preservation and quality evaluation of hazelnut varieties (Botta et al., 1994).

Determination of sources of quality losses in hazelnut and preventive measures is important to achieve and maintain high quality products. Microbial, chemical/biochemical changes contribute to the shelf life of the hazelnut and its products. Due to insufficient/inadequate harvest, drying and storage methods and conditions, mould activities bring about significant quality losses. Improvement of the harvest, post-harvest and processing stages may improve the quality, but the best quality can only be attained if the whole production and processing line is designed and operated for that (Özdemir 1998). As well as during storage (Ghirardello et al., 2013), pre-storage growing conditions and some treatments also affect the shelf quality of hazelnuts (Kaya et al., 2005; Turan & İslam, 2016; Koç Güler et al., 2017a; Turan & İslam, 2018; Turan, 2019; Turan & Karaosmanoğlu, 2019).

While it is possible to come across many studies on the effect of irrigation on yield and quality in other hazelnut growing countries, these studies in Turkey are still in their infancy. No studies were found on the effect of irrigation on storage quality and shelf life. In this study, physicochemical changes during storage of 'Tombul' hazelnut cultivar irrigated at last cluster drop period which is the critical period were investigated. The cultivar 'Tombul' is currently one of the most important commercial cultivars in Turkey and in the world.

2. Material and Methods

2.1. Plant materials and experimental site

This study was carried out in Giresun province, which is an important hazelnut production region in Turkey, in 2015 and 2016. There is no irrigation in the hazelnut orchards in the region and the water needs of

the plants are conventionally met by rain. However, especially in recent years, due to the increase in temperatures in the region, additional irrigation in hazelnut farming has become inevitable for the need for plant water consumption (Tonkaz & Bostan, 2016).

The main cultivar 'Tombul' hazelnut (cv) in an orchard, in the Barça village (Location:40.87222338441944°, Latitude:40.872222900390625°, Longitude:38.44194412231445°) was used in the study. The altitude of the research orchard is 110 meters, the slope is about 60% and the distance between the ocaks (multi-stemmed bush) 4 meters. Excess stems were cut in 2014 dormant period, with 5 stems in each ocak. Soil pH of the trial area was determined as 5.79-6.37 in 2015 and 5.86-6.28 in 2016. This pH value is among the most suitable values for hazelnut cultivation and is slightly acidic.

In the study, drip irrigation was performed on 16 July (46.08 mm/60 cm), 26 July (44.68 mm/60 cm), 30 July (43.68 mm/60 cm) and 06 August (44.08 mm/60 cm), in the third nut and kernel development period (Bostan, 1998).

2.2. Preparation of samples:

Harvesting of clusters in the experimental area was done by hand picking from tree branches. In 2015, the hazelnuts collected on August 15 were separated from their husks with a husker machine the next day. The hazelnuts were laid in a single row on the concrete floor and dried in the sun for 7 days. In 2016, the harvest was made on August 8 and the hazelnuts were dried in the sun for 5 days. The drying process was terminated when the moisture content fell below 10% in-shell hazelnuts and below 5% in kernels. The dried in-shell hazelnuts were grouped as irrigated and unirrigated samples. 12 kg of in-shell hazelnuts were used in each replication. The first analyses (beginning) were made 2 days after the samples were placed in the laboratory. After the first analysis, the nuts were stored in mesh bags under laboratory conditions (20-22 ºC and 70-80% relative humidity) for 12 months.

Moisture, ash, protein and fat analyses were performed twice, at the beginning of storage and at the 12th month; rancid, peroxide, vitamin E and fatty acids composition analyses were also performed 3 times, at the beginning of storage, at the 6th month and at the 12th month.

2.3. Analyse Methods:

Moisture content (%): 3±0.01 g of each sample ground in the blender was weighed with a balance with an accuracy of 0.01 g. The weighed samples were kept in an oven at 105±2ºC until they reached a constant weight. Then it was cooled in a desiccator and weighed (AOAC, 2000a).

Calculation:

$$\text{Moisture (\%)} = (A_0\text{-}A1)x100/A_0 \quad (1)$$

A_0: Beginning weight of sample (g)

A_1: Dry weight of sample (g)

Ash content (%): 3±0.01 g of each sample ground in the blender was weighed with a balance with an accuracy of 0.01 g. The samples placed in the crucibles were kept in an oven at 105±2ºC until they reached a constant weight. It was then cooled in a desiccator and immediately burned in the incinerator at 530°C for 8 hours. After incineration, it was cooled in a desiccator and weighed. (AOAC, 2000b).

Calculation:

$$\text{Ash (\%)} = A_0x100/A_1 \quad (2)$$

A_0: Ash weight (g)

A_1: Dry weight of sample (g)

Protein content (%): For crude protein analysis, 0.5 g of each sample was weighed and placed in kjeldahl tubes. A tablet (K_2SO_4:$CuSO_4$) was placed in the tube as a catalyst, and 12 ml of concentrated sulfuric acid was added and burned in a protein device (Gerhardt Vap40) incinerator for 1 hour at 420°C until the color became completely clear. After the gas escape was finished, the balloon was cooled down to about 40°C. The sample, which was placed in the distillation unit after the incineration process, was distilled with boric acid (3% H_3BO_3) and sodium hydroxide (33%) solutions. Then, the collected distillate was titrated with 0.2 N hydrochloric acid solution. The amount of protein was calculated according to the formula below (AOAC, 2000c):

$$\text{Protein (\%)} = VxSxNx100x5.30/m \quad (3)$$

V: HCl spent for titration (ml)

m: Sample weight (g)

S: 0.014

N: Normality of HCl solution

Fat content (%): Fat content was determined using the soxhlet device (Anonymous, 2000). The glass containers of the device were brought to a constant weight by drying in an oven, and the beakers to be filled with n-hexane were tared after drying. The temperature of the device is adjusted to 130ºC, which is the appropriate temperature for n-hexane. 5 g of the ground hazelnut kernels were weighed on a 0.001 g sensitive balance and put into the cartridge. The cartridges are placed in the Soxhlet extraction device. 60 ml of n-

hexane was placed in each beaker. The first stage (immersion) of the device took 30 minutes and the second stage (washing) took 150 minutes. The last stage (recovery) was completed in 30 minutes. After the recovery was completed, the samples were put in an oven at 105±2ºC. It was kept in the oven for one hour. The samples taken from the oven were weighed on the balance after cooling in the desiccator. After taking the total weight of the beaker, the % crude oil was calculated with the following formula:

Fat (%) = (A2−A1)/mx100 (4)

A1: Weight of beaker brought to constant weighing (g),

A2: Total amount in beaker at last weighing (g),

m: Sample weight (g)

Rancidity value (h): Rancid value was determined in 743 Rancimat device from Metrohm according to (Anonymous, 1997) using 2.50±0.01 g of oil obtained from hazelnut kernel samples by cold pressing. All samples were examined under constant airflow (20 L h-1) at five different temperatures (100, 110, 120, 130 and 140°C). Induction times were obtained automatically with the device software with an accuracy of 0.005.

Peroxide value (%): Peroxide value was calculated by potentiometric titration method (Anonymous, 1990). Acetic acid/Isooctane was used as 3/2 (v/v), potassium iodide solution as saturated (14 g/10 ml purified water), starch solution as 1% and sodium thiosulfate solution as 0.01 N.

2-3 ml of sample was taken into the beaker and 100 ml of acetic acid/isooctane (3/2) solution was placed on it and the oil was dissolved. 0.2 ml of potassium iodide was added and kept in the dark for 5 minutes, then 50 ml of distilled water was added. At the end of the period, 75 ml of water and 1 ml of starch were added and titrated with sodium thiosulfate.

Peroxide value = VxN/P (5)

V: Spent sodium thiosulfate (ml)

N: Normality of sodium thiosulfate (0.01 N)

P: Sample amount

Vitamin E (α-tocopherol) (%): Hazelnut oil was obtained by pressing the hazelnut kernels in the cold press oil extraction device. The obtained extract was dissolved in 2 ml of heptane:tetrahydrofuran (THF) (95:5 v/v) before injection and passed through a 45µm filter. Analyzes were performed using the Agilent HPLC system (1260 Infinity). α-tocopherol was identified with a DAD detector at a wavelength of 292 nm. Phenomenex Luna silica column (250 x 4.6 mm i.d., 5 µm in particle size) was used for separation. The mobile phase (heptane: THF, 95:5) was passed through the column with isocratic flow at a flow rate of 1.2 ml/min at 25°C. The separation process was completed in 20 minutes. The results were calculated from standard curves prepared using standard substances and expressed in µg tocopherol/g dry matter (Balz et al., 1992).

Fatty acid composition (%): The oil of the hazelnut kernels was obtained by pressing in a cold press oil extraction device. 40 mg of hazelnut oil samples were taken and dissolved with 4 ml of hexane. It was vortexed for 60 seconds by adding 3 ml of 2 M KOH (prepared in methanol). After the phases were separated, 1 ml of the upper phase (hexane phase) was taken into a GC vial and analyzed under the following conditions (Sushchik et al., 2003): Oven program

Beginning temperature: 120°C with 2°C/min heating rate to 180°C, then 4°C/min to 200°C, then 7°C/min to 230°C and left for 0.71 min. The furnace program used in gas chromatography is given in Table 1.

Table 1. Oven program used in gas chromatography
Çizelge 1. Gaz kromatografisinde kullanılan fırın programı

Beginning temperature (ºC)	Standby time (min)	Temperature rise rate (ºC/min)	End temperature (ºC)
120	2	2/min	180
180	0	4/min	200
200	3	0	200

GC terms

Device: Perkin Elmer Clarus 500 model

Column: Restek RTX 2330 (30 mx0.25 mm, 0.25 µm film thickness)

Injection volume: 1 µl

Injection port temperature: 250°C

FID terms

Detector temperature: 250°C

Dry air: 450 ml/min

Hydrogen: 45 ml/min

A mixture of methyl esters of 37 fatty acids was used as a standard for the identification of fatty acids. By comparing the chromatograms obtained from the samples and the chromatograms obtained from the standards, fatty acid types and relative % amounts were determined.

Carrier gas: Helium (1 ml/min)

Split ratio: 50/

2.4. Statistical Analysis:

Experimental design was arranged in randomized plots with 3 replications and 6 ocaks (multi-stemmed bush) in each replication. Analysis of variance was

performed to determine the variation of the investigated parameters according to the storage time. Statistical analyses were made in the SAS JMP 13.2.0 statistical package program and LSD test was applied to determine the differences between the means.

3. Results and Discussion

Moisture content: In the first year, moisture change was found to be significant during storage and according to irrigation. While the moisture increased regularly during the storage period, it was determined that the irrigated samples were lower than the control samples. In the second year, the interaction of storage and sample was found to be significant for moisture content change. The moisture content increased during storage in both sample groups, as in the first year, and at the end of storage, it was found to be higher in the control samples (4.20%) than the irrigated samples (3.88%). The moisture content of all samples remained below 5% in both years, and there was a difference between years in terms of the moisture content change according to the samples. According to the samples and storage time, the moisture content showed similar changes in both years (Table 2).

Table 2. Moisture, ash, protein and fat contents of 'Tombul' hazelnut kernels
Çizelge 2. 'Tombul' iç fındıklarının nem, kül, protein ve yağ içerikleri

	Moisture (%)	Ash (%)	Protein (%)	Fat (%)
			2015	
Treatment				
Control (C)	4.03±0.74a**	2.20±0.32a*	16.42±0.95	58.73±1.50b**
Irrigation (I)	3.72±0.82b	2.07±0.34b	16.16±0.85	60.67±2.09a
$LSD_{0.05}$	0.20	0.11	ns	1.29
Storage (months)				
0	3.13±0.38c**	2.39±0.18a**	16.50±1.07	59.55±1.92
6	3.67±0.22b	2.25±0.05a	16.52±0.87	59.38±1.63
12	4.83±0.36a	1.75±0.26b	15.84±0.57	60.17±2.57
$LSD_{0.05}$	0.24	0.14	ns	ns
Treatment * Storage				
C*0	3.37±0.32	2.46±0.13	17.02±1.25	58.67±1.48
C*6	3.83±0.13	2.27±0.05	16.30±0.59	58.37±0.89
C*12	4.90±0.51	1.87±0.33	15.93±0.64	59.17±2.07
I*0	2.90±0.30	2.33±0.20	15.99±0.54	60.43±2.01
I*6	3.50±0.15	2.23±0.04	16.75±1.10	60.40±1.60
I*12	4.75±0.12	1.64±0.11	15.76±0.53	61.17±2.80
$LSD_{0.05}$	ns	ns	ns	ns
			2016	
Treatment				
Control (C)	4.00±0.42	2.31±0.25	15.88±1.04	59.77±1.40b**
Irrigation (I)	4.08±0.64	2.26±0.30	16.23±0.69	60.94±1.28a
$LSD_{0.05}$	ns	ns	ns	0.85
Storage (months)				
0	3.40±0.10c**	2.52±0.17a**	15.95±1.27	61.08±1.53a*
6	4.17±0.19b	2.27±0.25b	16.03±0.71	59.74±1.16b
12	4.55±0.34a	2.07±0.18c	16.18±0.59	60.24±1.42ab
$LSD_{0.05}$	0.11	1.16	ns	1.05
Treatment * Storage				
C*0	3.45±0.11d**	2.42±0.13ab*	15.20±1.21b*	60.92±1.17
C*6	4.30±0.18b	2.37±0.34bc	16.30±0.93a	58.94±1.06
C*12	4.26±0.11b	2.15±0.19d	16.15±0.70ab	59.44±1.29
I*0	3.35±0.14d	2.63±0.06a	16.71±0.86a	61.23±1.93
I*6	4.04±0.06c	2.17±0.08cd	15.76±0.25ab	60.55±0.54
I*12	4.85±0.13a	2.15±0.18d	16.21±0.53a	61.04±1.11
$LSD_{0.05}$	0.15	0.22	0.95	ns

*: P<0.05, **: P<0.01

Ash content: In the present study, ash change during storage and according to irrigation was significant in the first year. While the ash decreased regularly during storage, the ash content of the irrigated samples was lower than the control. Storage and sample interaction were found to be significant for ash content change in the second year. In both sample groups, as in the first year, the ash content decreased during storage and was less at the end of storage in irrigated samples (2.26%) than control samples (2.31%). According to the samples and storage time, the ash content showed similar changes in both years (Table 2).

Protein content: The protein content changes according to storage time and samples were found to be insignificant in the first year. In the second-year storage and sample interaction were found to be significant for protein content change (Table 2). The highest protein value was observed with irrigated samples (16.23%), while the lowest value was observed with control samples (15.88%).

Fat content: The fat content was significantly affected by the samples in both years, and it was determined more in irrigated samples. The change according to the storage time was significant only in the second year, and fat content significantly increased during storage. At the end of storage, it was found to be higher in the irrigated samples (60.94%) than the control samples (59.77%). In the interaction, the fat ratio change was insignificant in both years (Table 2).

Rancidity value: Rancidity value was significantly affected by storage time only in the first year, and the value after 12 months of storage was lower than the beginning value. There was no significant difference in rancidity value by samples (Table 3 and 4).

Peroxide value: The change in peroxide value according to application, storage and interaction were similar in both years, only the change according to storage time was significant, and the value increased after 12 months of storage (Table 3 and 4). The effect of irrigation on the peroxide content of the samples during storage was insignificant. While the peroxide value was determined lower in the second year samples, increased from zero to 0.47 $meqO_2kg^{-1}$ in the first year and from 0.26 $meqO_2kg^{-1}$ to 1.64 $meqO_2kg^{-1}$ in the second year after 12 months of storage.

Vitamin E (α-tocopherol) amount: The amount of vitamin E changed similarly to the rancidity value and was significantly affected by the storage time, only in the first year (Table 3 and 4). The amount of vitamin E was slightly higher in hazelnuts irrigated in both years. The value at the end of storage was also determined less than the beginning value.

Fatty acid composition: A total of 13 fatty acids were examined in the study. Among them, heptadecanoic acid (C17:0), stearic acid (C18:0), oleic acid (C18:1n9c), linoleic acid (C18:2n6c) and linolenic acid (C18:3n3) were not significantly affected by irrigation and storage time (Tables 2 and 3). The ones with the highest ratio of 13 fatty acids were oleic acid (C18:1n9c), linoleic acid (C18:2n6c), palmitic acid (C16:0) and stearic acid (C18:0), respectively. Of the major fatty acids, only palmitic acid (C16:0) was significantly affected by irrigation application and storage time in the first year (Table 3 and 4). While palmitic acid was found to be higher in irrigated samples, the value at the end of storage was higher than the beginning value. Irrigation application and storage time did not significantly affect the change in the content of the other major fatty acids.

Since no similar research could be found except for research in which only the change of oleic acid was examined during storage in irrigated and non-irrigated hazelnuts (Bignami et al., 2009), the results of this study could not be directly compared with other studies in terms of the physicochemical changes during storage in irrigated and unirrigated hazelnut. Therefore, our results could be compared with the results of some different applications and especially storage studies in hazelnut.

Moisture and water vapor in different parts of the hazelnut can cause physical changes as well as make differences in flavor or texture and even encourage microbial activity (Özdemir, 1998). During blending, care should be taken to ensure that the hazelnut dries well, and that the moisture content does not exceed 12% in-shell hazelnuts and 6% in hazelnut kernels. Thus, hazelnuts can be stored for a long time (Okay et al., 1986). In the other studies, it was stated that the kernel moisture content was nearly stable during storage (Ghirardello et al., 2013); not significant according to the storage times (in 'Tombul' cultivar separated by hand) (Akar & Bostan, 2018); decreased slightly during storage (Kaya et al., 2005); decreased significantly during storage (Koyuncu et al., 2005; Koç Güler et al., 2017a; Turan & Karaosmanoğlu, 2019); showed a tendency to decrease with fluctuation, and the highest values were determined at 12 months and then again decreased (Turan & İslam, 2018).

Our findings are in compliance with the results of the moisture content reaching the maximum in the 12th month in other studies. As can be understood from other results, moisture content can vary considerably according to many factors such as variety, year, storage conditions, and storage material of samples, whether the stored samples are shelled or kernel, storage period, pre-harvest applications.

Ash content of hazelnut kernels, which mainly reflects the content of inorganic elements (Fan et al., 2020), changes significantly according to cultivars, years, and locations (Şahin et al., 1990). Akar & Bostan (2018) stated that the change in ash content of 'Tombul' hazelnut cultivar during 9 months of storage was insignificant. In the present study, the ash content decreased gradually during storage, which can be explained by different storage conditions.

Table 3. Rancidity, peroxide, vitamin E, and fatty acid compositions of 'Tombul' hazelnut kernels in 2015
Çizelge 3. *2015 yılında 'Tombul' iç fındıklarının ransimat, peroksit, E vitamini ve yağ asidi bileşimleri*

	Treatments			Storage periods (months)			Treatment * Storage period				
Parameters	Control	Irrigation	$LSD_{0.05}$	0	12	$LSD_{0.05}$	C*0	C*12	I*0	I*12	$LSD_{0.05}$
Rancidity	4.52±0.71	4.99±0.85	ns	5.08±0.49a*	4.42±0.93b	0.63	4.78±0.53	4.26±0.81	5.39±0.14	4.59±1.09	ns
Peroxide	0.35±0.46	0.12±0.35	ns	0.00±0.00b**	0.47±0.47a	0.27	0.00±0.00	0.70±0.42	0.00±0.00	0.23±0.48	ns
Vitamin E	393.71±56.30	396.60±61.91	ns	439.30±49.44**	351.01±17.64	32.25	429.76±60.90	357.66±12.10	448.84±38.09	344.36±20.78	ns
C14:0	0.03±0.00	0.03±0.00	ns	0.03±0.00	0.03±0.00	ns	0.03±0.00	0.03±0.00	0.03±0.00	0.03±0.00	ns
C16:0	5.14±0.16b**	5.34±0.11a	0.11	5.18±0.17b*	5.30±0.15a	0.11	5.05±0.15	5.22±0.13	5.31±0.07	5.38±0.14	ns
C16:1	0.12±0.02	0.13±0.02	ns	0.11±0.01b**	0.14±0.01	0.01	0.11±0.01	0.14±0.01	0.12±0.01	0.14±0.01	ns
C17:0	0.05±0.01	0.05±0.01	ns	0.05±0.01	0.05±0.01	ns	0.05±0.00	0.05±0.01	0.04±0.01	0.05±0.01	ns
C17:1	0.06±0.01	0.07±0.01	ns	0.07±0.01	0.06±0.01	ns	0.07±0.01a**	0.05±0.01b	0.06±0.01ab	0.07±0.00a	0.01
C18:0	2.56±0.09	2.68±0.27	ns	2.69±0.23	2.56±0.17	ns	2.58±0.05	2.55±0.12	2.81±0.28	2.56±0.21	ns
C18:1n9nc	82.81±1.51	83.55±1.05	ns	83.30±1.62	83.06±1.01	ns	82.93±1.91	82.69±1.14	83.67±1.34	83.44±0.79	ns
C18:2n6c	8.90±1.40	7.84±1.14	ns	8.28±1.71	8.45±0.97	ns	8.89±1.82	8.91±1.00	7.68±1.50	8.00±0.75	ns
C18:3n3	0.14±0.01	0.14±0.03	ns	0.13±0.02	0.15±0.02	ns	0.13±0.01	0.15±0.02	0.14±0.03	0.15±0.02	ns
C18:3n6	0.09±0.04	0.09±0.03	ns	0.06±0.01b**	0.12±0.01a	0.01	0.06±0.01c*	0.13±0.01a	0.06±0.01c	0.11±0.01b	0.01
C20:0	0.06±0.05	0.05±0.04	ns	0.10±0.01a**	0.02±0.02b	0.01	0.10±0.01	0.03±0.03	0.09±0.02	0.01±0.00	ns
C20:3n6	0.01±0.01b*	0.02±0.02a	0.004	0.00±0.00b**	0.03±0.01a	0.004	0.00±0.00c*	0.02±0.00b	0.00±0.00c	0.03±0.01a	0.006
C23:0	0.01±0.02	0.02±0.01	ns	0.00±0.00b**	0.03±0.02a	0.01	0.00±0.00	0.03±0.02	0.00±0.00	0.02±0.01	ns

*: P<0.05, **: P<0.01

Table 4. Rancidity, peroxide, vitamin E and fatty acid compositions of 'Tombul' hazelnut kernels in 2016
Çizelge 4. *2016 yılında 'Tombul' iç fındıklarının ransimat, peroksit, E vitamini ve yağ asidi bileşimleri*

	Treatments			Storage periods (months)			Treatment * Storage period				
Parameters	Control	Irrigation	$LSD_{0.05}$	0	12	$LSD_{0.05}$	C*0	C*12	I*0	I*12	$LSD_{0.05}$
Rancidity	4.73±0,51	5.09±0,38	ns	4.97±0,48	4.86±0,49	ns	4.86±0,56	4.60±0,47	5.07±0,42	5.11±0,38	ns
Peroxide	0.86±0,71	1.04±1,02	ns	0.26±0,38b**	1.64±0,61a	0.42	0.32±0,49	1.40±0,40	0.20±0,24	1.88±0,72	ns
Vitamin E	331.04±57,76	354.40±48,24	ns	362.02±49,34	323.43±52,10	ns	343.07±57,03	319.01±61,16	380.97±35,24	327.84±46,75	ns
C14:0	0.03±0,01	0.03±0,00	ns	0.02±0,00*	0.03±0,00	0.001	0.02±0,01b*	0.03±0,00a	0.03±0,00a	0.03±0,00a	0.004
C16:0	5.29±0,17	5.30±0,11	ns	5.25±0,14	5.34±0,13	ns	5.26±0,17	5.32±0,18	5.24±0,12	5.36±0,05	ns
C16:1	0.14±0,01	0.14±0,01	ns	0.14±0,01	0.14±0,01	ns	0.14±0,01	0.14±0,00	0.14±0,01	0.13±0,01	ns
C17:0	0.05±0,01	0.05±0,01	ns	0.05±0,00	0.05±0,01	ns	0.05±0,01	0.05±0,01	0.05±0,00	0.05±0,01	ns
C17:1	0.08±0,01	0.07±0,01	ns	0.07±0,00b**	0.08±0,01a	0.005	0.07±0,01	0.08±0,01	0.07±0,00	0.08±0,01	ns
C18:0	2.63±0,24	2.67±0,10	ns	2.67±0,22	2.63±0,13	ns	2.66±0,31	2.60±0,16	2.68±0,12	2.66±0,09	ns
C18:1n9nc	83.25±1,76	83.87±0,52	ns	83.69±1,31	83.43±1,35	ns	83.36±1,85	83.14±1,83	84.02±0,31	83.73±0,67	ns
C18:2n6c	8.11±1,47	7.44±0,50	ns	7.66±1,05	7.90±1,24	ns	7.99±1,44	8.24±1,64	7.33±0,34	7.56±0,63	ns
C18:3n3	0.16±0,01	0.16±0,01	ns	0.16±0,01	0.16±0,01	ns	0.17±0,01	0.16±0,01	0.16±0,01	0.15±0,01	ns
C18:3n6	0.12±0,01	0.13±0,01	ns	0.13±0,01a**	0.12±0,01b	0.008	0.13±0,01	0.12±0,01	0.13±0,01	0.13±0,01	ns
C20:0	0.08±0,01	0.08±0,01	ns	0.09±0,01	0.08±0,01	ns	0.09±0,01	0.08±0,00	0.09±0,02	0.08±0,01	ns
C20:3n6	0.02±0,01	0.03±0,01	ns	0.03±0,01	0.02±0,01	ns	0.03±0,01	0.02±0,01	0.03±0,01	0.03±0,01	ns
C23:0	0.02±0,01	0.02±0,01	ns	0.03±0,01a**	0.01±0,00b	0.002	0..03±0,01	0.01±0,01	0.03±0,00	0.01±0,00	ns

*: P<0.05, **: P<0.01

The protein content fluctuated as an increase-decrease in the control samples, and as a decrease-increase in the irrigated samples during storage. Similarly, Çakırmelikoğlu & Çalışkan (1993) stated that protein content did not show a one-sided change during storage; Bostan & Koç Güler (2016) stated that the crude protein content fluctuated as decreased- increased in in-shell hazelnuts stored for 12 months; Koç Güler et al. (2017a) stated that during the storage period, crude protein contents exhibited fluctuated variations; Akar & Bostan (2018) stated that the crude protein increased with storage in all samples; Turan & İslam (2018) stated that the protein content was increased with fluctuation during the storage for 24 months; Turan & Karaosmanoğlu (2019) stated that protein content significantly increased during storage, but the increase was not constant; Turan (2019) stated that the protein content showed fluctuation at the 12th month, but generally increased and decreased again at the end of the storage period. These fluctuations in protein content during storage may be related to changes in moisture content.

Contrary to Bignami et al. (2009) and Külahçılar et al. (2018), the effect of irrigation on fat content was found to be significant in the second year of the present study. This is thought to be due to the difference in irrigation treatments. On the other hand, in the other studies also found that the fat content did not change significantly during storage (Çakırmelikoğlu & Çalışkan, 1993; Ghirardello et al., 2013; Bostan & Koç Güler, 2016), increased at the end of storage (Ağar et al., 1995; Koyuncu, 2004; Koyuncu et al., 2005; Akar & Bostan, 2018); increased at the end with irregular change during storage (Koç Güler et al., 2017a; Turan & Karaosmanoğlu, 2019), and no statistically significant change during storage (Turan & İslam, 2018). Our results were similar to the results of some other studies in that the fat content increased during storage.

Fat is the predominant component in hazelnuts, and resistance to oxidation of lipids (rancidity) is generally associated with shelf life (Ghirardello et al. 2013). Similar to the others (Momchilova et al., 2017; Turan & İslam, 2018; Turan & Karaosmanoğlu, 2019; Turan, 2019), the rancidity value decreased during storage in our study.

The peroxide value, which is an important parameter in determining the storage life of hazelnuts, emerges at the end of the oxidation of unsaturated fatty acids. Peroxides cause secondary oxidation products, and these products can make hazelnuts unusable by negatively affecting color, crispness, flavor and, odor (Demirci Ercoşkun, 2009). It is stated that bitter tastes cannot be perceived until peroxide values above 2.0 are reached in hazelnuts (Çakırmelikoğlu & Çalışkan, 1993). In the present study, peroxide value increased after 12 months of storage. Also in other studies, there are findings that the peroxide value increases at the end of storage (Ebrahem et al., 1994; Çetin et al., 2000; Demirci Ercoşkun, 2009; Santis et al., 2009; Ghirardello et al., 2013; Bostan & Koç Güler, 2016; Koç Güler et al., 2017a; Akar & Bostan, 2018; Turan, 2018; Turan & İslam, 2018; Karaosmanoğlu & Üstün, 2019; Turan, 2019; Turan & İslam, 2019).

Hazelnut oil is an excellent source of vitamin E and the 'Tombul' cultivar has the highest value. In this respect, there are significant differences between the lipids of different cultivars (Alasalvar et al., 2009). As a result of a previous study on the same cultivar, it was determined that the vitamin E content was higher in the samples of irrigated plants (Bostan, 2020). Although insignificant, the value was found to be higher in the samples of irrigated plants in this study. Moreover, it was stated that the tocopherols amount gradually decreased and that trend was slightly stronger at 20ºC than at 4ºC as well as for nuts in the shell than the kernels (Momchilova et al., 2017). Also, Koç Güler et al. (2017a) determined that the vitamin E content of hazelnut kernels stored in vacuum packages (18 months of storage at 20 ºC, at 55-60% RH) decreased with significant but unstable changes during storage. As in other studies, vitamin E content decreased at the end of storage in our study.

The main saturated fatty acid in fresh hazelnuts is palmitic acid, followed by stearic acid. The most unsaturated fatty acids are oleic acid and linoleic acid, and oleic and linoleic acids are very important for Turkish hazelnut varieties (Ağar et al., 1995). It was observed that a higher acidity (oleic acid %) was detected after three months storage in shelled nuts of the untreated control (0% ETc) whereas similar values were observed after six and ten months in control and irrigation treatments and stated that this situation changed depending on the variety, year and interaction (Bignami et al., 2009). In our study, the change of oleic acid according to the storage period and treatments was almost similarly insignificant. The researchers stated that except for palmitoleic acid and linolenic acid, the changes in other fatty acids were not significant (Koç Güler et al., 2017b); palmitic and linoleic acid contents during storage were changed significantly, palmitic acid was higher than at the beginning of storage, and no

significant differences were found for other fatty acids (Koyuncu, 2004); in 'Tombul' cultivar, palmitic acid contents increased at the end of storage but this was insignificant (Koyuncu et al., 2005); palmitic acid, stearic acid, oleic acid significantly increased during storage in the 'Tombul' cultivar (Karaosmanoğlu & Üstün, 2019); fatty acids have not been changed during hazelnut storage up to 12 months (Momchilova et al., 2017); the palmitic and stearic acids increased at the end of the storage time, while the oleic, linoleic, linolenic decreased (Ghirardello et al., 2013); while oleic acid content decreased with fluctuation during storage, linoleic acid, palmitic and stearic acid increased with fluctuation (Turan, 2018; Turan & İslam, 2019). In our study, the results of the change of palmitic acid during storage agree with the literature findings.

4. Conclusions

In this study, physicochemical changes during storage for 12 months in hazelnuts which irrigated at the pre-harvest period, when the cluster drops were the highest especially due to drought were investigated. In conclusion, it can be said that the variation of moisture and ash values according to the application was significant and lower in irrigated samples; the variation of oil content according to the application was significant and higher in irrigated samples; the changes in protein, rancidity, peroxide and vitamin E according to the application were not significant; one of the major fatty acids, only the change of palmitic acid according to the application was significant and it was higher in irrigated samples; the other composition was not significantly affected in general, and this situation may differ from year to year.

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References

Ağar, İ.T., Kafkas, S., & Balıkçı, Ö. (1995). Türk fındık çeşitlerinde derim zamanında, iç ve kabuklu halde soğukta depolandıktan sonra yağ içerikleri ve yağ asitleri karakteristikleri. Türkiye II. Ulusal Bahçe Bitkileri Kongresi, 499-504, 3-6 Ekim, Çukurova Üniversitesi, Adana-Türkiye.

Akar, A., & Bostan, S.Z. (2018). Chemical changes during storage in hazelnuts separated from husks by patoz and hand. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 28 (Special Issue), 45-49.

Alasalvar, C.S., Amaral, J., Satır, G., & Shahidi, F. (2009). Lipid characteristics and essential minerals of native Turkish hazelnut varieties (*Corylus avellana* L.). *Food Chemistry*, 113, 919-925. https://doi.org/10.1016/j.foodchem.2008.08.019.

Anonymous, (1990). (TS EN ISO 3960). This standard specifies a method for the determination of the peroxide value of animal and vegetable fats and oils.

Anonymous, (1997). ISO 6886:1997. Animal and vegetable fats and oils-determination of oxidation stability (accelerated oxidation test). International Organization for Standardization, Geneva, Switzerland.

Anonymous, (2000). The total fat content was determined in accordance with the method of the Association of Official Analytical Chemists methods total fat by Soxhlet extraction (method 920.39C).

AOAC, (2000a). Official methods of analysis of AOAC international (17th ed.). Gaithersburg, MD: AOAC International. Percentages of moisture by vacuum oven (method 934.06).

AOAC, (2000b). Official methods of analysis of AOAC international (17th ed.). Gaithersburg, MD: AOAC International. Ash by direct analysis (method 940. 26).

AOAC, (2000c). Official methods of analysis of AOAC international (protein by Kjeldahl nitrogen (method 920.152)).

Balz, M., Schulte, E., & Their, H.P. (1992). Trennung von tocopherolen und tocotrienolen durch HPLC. *Fat Science Tehnologi*, 94, 209-213.

Bignami, C., Cristofori, V., Ghini, P., & Rugini, E. (2009). Effects of irrigation on growth and yield components of hazelnut (*Corylus Avellana* L.) in Central Italy. *Acta Horticulturae*, (845), 309-314. https://doi.org/10.17660/ActaHortic.2009.845.47.

Bignami, C., Cristofori, V., & Bertazza, G. (2011). Effects of water availability on hazelnut yield and seed composition during fruit growth. *Acta Horticulturae*, (922), 333-340. https://doi.org/10.17660/ActaHortic.2011.922.43.

Bostan, S.Z. (1998). Bazı önemli fındık çeşitlerinde tohum taslağı gelişimi üzerine bir araştırma. *Turkish Journal Agriculture and Forestry*, 22, 295-298.

Bostan, S.Z. (2005). Orta ve Doğu Karadeniz bölgesinde fındık üretim ve verimi ile bazı önemli iklim değerleri arasındaki ilişkiler. Doğu Karadeniz Bölgesi Kalkınma Sempozyumu, 1-10, 13-14 Ekim, Karadeniz Teknik Üniversitesi, Trabzon-Türkiye.

Bostan, S.Z. (2009). The interrelationships among hazelnut production and yield with some important climatic data in Giresun province (Northern Turkey). *Acta Horticulturae*, (825), 413-419. https://10.17660/ActaHortic.2009.825.65.

Bostan, S.Z. (2020). 'Tombul' fındığında E vitamini ve yağ asidi bileşenlerine sulamanın etkisi. *International Journal of Agriculture and Wildlife Science*, 6(2), 108-114. https://doi: 10.24180/ijaws.682331.

Bostan, S.Z., & Koç Güler, S. (2016). Kabuklu olarak depo edilen bazı fındık çeşitlerinde kalite değişimleri. *Bahçe*, 45(2), 41-53.

Bostan, S.Z., & Tonkaz, T. (2013). The effects of arid and rainy years on hazelnut yield in the Eastern Black Sea region of Turkey. 24th International Scientific-Expert Conference on Agriculture and Food Industry, 467-470. 25-28 September, University of Sarajevo, Sarajevo- Bosnia and Herzegovina.

Botta, R., Richardson, D., Suwanagul, A., & Sanz, C.L. (1994). Hazelnut variety organic acids, sugars, and total fatty acids. *Acta Horticulturae*, (351), 693-699. https://10.17660/ActaHortic.1994.351.77.

Cristofori, V., Ferramondo, S., Bertazza, G., & Bignami, C. (2008). Nut and kernel traits and chemical composition of hazelnut (*Corylus avellana* L.) cultivars. *Journal of the Science of Food and Agriculture*, 88, 1091-1098. https://doi.org/10.1002/jsfa.3203.

Cristofori, V., Muleo, R., Bignami, C., & Rugini, E. (2014). Long term evaluation of hazelnut response to drip irrigation. *Acta Horticulturae*, (1052), 179-185. https://10.17660/ActaHortic.2014.1052.23.

Cristofori, V., Speranza, S., & Silvestri, C. (2019). Developing Hazelnuts as a sustainable and industrial crop, Pp. 465-503. In: Serdar, Ü. and Fulbrifht, D. (eds). *Achieving Sustainable Cultivation of Tree Nuts*, Burleight Dodds Science Publication, Sawston Cambridge CB22 3HJ UK, 552 pp.

Çakırmelikoğlu, C., & Çalışkan, N. (1993). Bazı fındık çeşitlerinde hasat olum kriterlerinin belirlenmesi. Tarım ve Köyişleri Bakanlığı, Tarımsal Araştırmalar Genel Müdürlüğü, Fındık Araştırma Enstitüsü Müdürlüğü, Sonuç Raporu.

Çetin, Ö., Nazlı, B., Bostan, K., & Alperden, İ. (2000). Depolamanın çiğ iç fındığın kalitesi üzerine etkileri. *İstanbul Üniversitesi Veteriner Fakültesi Dergisi*, 26(2), 413-419.

Demirci Ercoşkun, T. (2009). Bazı işlenmiş fındık ürünlerinin raf ömrü üzerine araştırmalar. Phd Thesis, Ankara University, Institute of Science, Department of Horticulture, 205p, Ankara.

Dias, R., Conçalves, B., Moutinho-Pereira, J., Carvalho, J.L., & Silva, A.P. (2005). Effect of irrigation on physiological and biochemical traits of hazelnuts (*Corylus Avellana* L.). *Acta Horticulturae*, (686), 201-206. https://10.17660/ActaHortic.2005.686.27.

Ebrahem, K.S., Richardson, D.G., & Tetley, R.M. (1994). Effects of storage temperature, kernel intactness, and roasting temperature on vitamin E, fatty acids and peroxide value of hazelnuts. *Acta Horticulturae*, (351), 677-684. https://10.17660/ActaHortic.1994.351.75.

Fan, L., Ren, J., Yang, Y., & Zhang, L. (2020). Comparative analysis on essential nutrient compositions of 23 wild hazelnuts (*Corylus heterophylla*) grown in Northeast China. *Journal of Food Quality*, Article ID 9475961, 9 pages. https://doi.org/10.1155/2020/9475961.

Ghirardello, D., Contessa, C., Valentini, N., Zeppa, G., Rolle, L., Gerbi, V., & Botta, R. (2013). Effect of storage conditions on chemical and physical characteristics of hazelnut (*Corylus avellana* L.). *Postharvest Biology and Technology*, 81, 37-43. https://doi.org/10.1016/j.postharvbio.2013.02.014.

Karaosmanoğlu, H., & Üstün, N.Ş. (2019). Variations in fatty acid composition and oxidative stability of hazelnut (*Corylus avellana* L.) varieties stored by traditional method. *Grasas y Aceites*, 70(1), e288-e288. https://doi.org/10.3989/gya.0463181.

Kaya, H., Ozenc, N., & Sirin, H. (2005). Effects on quality and shelf life of drying hazelnuts in an electrical coffer system. *Acta Horticulturae*, (686), 491-498. https://10.17660/ActaHortic.2005.686.67.

Koç Güler, S., Bostan, S.Z., & Con, A.H. (2017a). Effects of gamma irradiation on chemical and sensory characteristics of natural hazelnut kernels. *Postharvest Biology and Technology*, 123, 12-21. https://10.1016/j.postharvbio.2016.08.007.

Koç Güler, S., Bostan, S.Z., Çon, A.H., & Şen, F. (2017b). Effects of gamma irradiation treatments and storage durations on fatty acid composition of natural hazelnut kernels. *Akademik Ziraat Dergisi*, 6(2), 95-100. https://doi.org/10.29278/azd.371080.

Koyuncu, M.A. (2004). Change of fat content and fatty acid composition of Turkish hazelnuts (*Corylus avellana* L.) during the storage. *Journal of Food Quality*, 27, 304-309. https://10.1111/j.1745-4557.2004.00624.x.

Koyuncu, M.A., Islam, A., & Küçük, M. (2005). Fat and fatty acid composition of hazelnut kernels in vacuum packages during storage. *Grasas y Aceites*, 56(4), 263-266. https://doi.org/10.3989/gya.2005.v56.i4.91.

Külahçılar, A., Tonkaz, T., & Bostan, S.Z. (2018). Effect of irrigation regimes by mini sprinkler on chemical composition of Tombul hazelnut kernels. *International Journal of Environmental Trends*, 2(2), 57-60.

Milosevic, T., & Milosevic, N. (2012). Cluster drop phenomenon in hazelnut (*Corylus avellana* L.). Impact on productivity, nut traits and leaf nutrients content. *Scientia Horticulture*, 148 (4), 131-137. https://doi.org/10.1016/j.scienta.2012.10.003.

Mingeau, M., Ameglio, T., Pons, B., & Rousseau, P. (1994). Effects of water stress on development growth and yield of hazelnut trees. *Acta Horticulturae*, (351), 305-314. https://10.17660/ActaHortic.1994.351.33.

Momchilova, S.M., Taneva, S.P., Zlatanov, D., Antova, G.A., Angelova-Romova, M.J., & Blagoeva, E. (2017). Fatty acids, tocopherols and oxidative stability of hazelnuts during storage. *Bulgarian Chemical Communications*, 49, 65-70.

Okay, A.N., Kaya, A., Küçük, V.Y., & Küçük, A. (1986). Fındık Tarımı. T.C. T.O.K.B. Teşkilatlanma ve Destekleme Genel Müdürlüğü Yayın No: Genel 142, TEDGEM-12, Ankara.

Ozdemir, F., & Akinci, I. (2004). Physical and nutritional properties of four major commercial Turkish hazelnut varieties. *Journal of Food Engineering*, 63(3), 341-347. https://doi.org/10.1016/j.jfoodeng.2003.08.006.

Özdemir, M. (1998). Factorts influencing shelf life of hazelnut. *Food Technology*, 3(3), 66-71.

Santis, D.D., Fardelli, A., & Mencarelli, F. (2009). Storage hazelnuts: Effect on aromatic profile and sensory attributes. *Acta Horticulturae*, (845), 693–699. https://10.17660/ActaHortic.2009.845.109.

Sushchik, N.N., Gladyshev, M.I., Moskvichova, A.V., Makhutova, O.N., & Kalachova, G.S. (2003). Comparison of fatty acid composition in major lipid classes of the dominant benthic invertebrates of the Yenisei River. Comp. *Biochem. Physiol*., 134, 111-122. https://doi.org/10.1016/S1096-4959(02)00191-4.

Şahin, İ., Erkut, A., Öztek, L., Üstün, Ş., & Oysun, G. (1990). Orta ve Doğu Karadeniz bölgesinde yetiştirilen fındık çeşitlerinin teknolojik özellikleri üzerinde araştırmalar. Ondokuz Mayıs Üniversitesi Yayınları No: 63, 54p. Samsun.

Tonkaz, T., & Bostan, S.Z. (2010). Giresun ili standardize yağış indeksi değerlerinin fındık verimi ile ilişkilerinin incelenmesi. I. Ulusal Sulama ve Tarımsal Yapılar Sempozyumu, 362-369. Kahramanmaraş Sütçü İmam Üniversitesi, 27-29 Mayıs, Kahramanmaraş-Türkiye.

Tonkaz, T., & Bostan, S.Z. (2016). Climatic trends in the Eastern Black Sea Region, Turkey. *Ordu University Journal of Science and Technology*, 6 (1), 1-7.

Top, G., & Bostan, S.Z. (2020). Fındıkta çotanak dökümü ile bitki ve meyve özellikleri arasındaki ilişkiler-İlk sonuçlar. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi*, 10(2), 125-142.

Turan, A. (2018). Effect of drying methods on fatty acid profile and oil oxidation of hazelnut oil during storage. *European Food Research and Technology*, 244(12), 2181-2190. https://doi.org/10.1007/s00217-018-3128-y.

Turan, A. (2019). Effect of drying on the chemical composition of Çakıldak (cv) hazelnuts during storage. *Grasas y Aceites*, 70(1), e296-e296. https://doi.org/10.3989/gya.0693181.

Turan, A., & İslam, A. (2016). Çakıldak fındık çeşidinde kurutma ortamları ve muhafaza süresine bağlı olarak meydana gelen değişimler. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi*, 6(2), 272-285.

Turan, A., & İslam, A. (2018). Effect of drying methods on some chemical characteristics of hazelnuts (*Corylus avellana* L.) during storage. *Journal of the Institute of Science and Technology*, 8(3), 11-19. https://10.21597/jist.458541.

Turan, A., & İslam, A. (2019). Postharvest differences between conventional and artificial drying of hazelnut. *Turkish Journal of Agriculture-Food Science and Technology*, 7(11), 1766-1772. https://10.24925/turjaf.v7i11.1766-1772.2481.

Turan, A., & Karaosmanoğlu, H. (2019). Effect of drying methods on long term storage of hazelnut. *Food science and Technology*, 39, 406-412. https://doi.org/10.1590/fst.20518