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THE MORPHOLOGICAL AND CHEMICAL VARIABILITY OF TURKISH HAZEL (*CORYLUS COLURNA* L.) FRUITS IN TURKEY

MORFOLOŠKA I KEMIJSKA VARIJABILNOST PLODOVA MEDVJEĐE LIJESKE (*CORYLUS COLURNA* L.) NA PODRUČJU TURSKE

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ABSTRACT

Turkish hazel (*Corylus colurna* L.) is naturally distributed in southeast Europe, Anatolia, the Caucasus and Western Himalayas. In Turkey, there are many isolated populations in the Black Sea, Marmara, Aegean, and Central Anatolian Regions. Many of the small populations in Turkey are endangered. In this study, the morphological and chemical characteristics of Turkish hazelnut fruits collected from seven populations were researched. In this regard, considering the morphological characteristics of fruits and kernels, significant differences were observed between the populations. Length, width, thickness, and weight averages were 15.98 mm, 15.38 mm, 12.00 mm and 1.4651 g in the fruits, and 13.03 mm, 11.22 mm, 7.64 mm and 0.5047 g in the kernels, respectively. The average shell thickness was 1.92 mm, shell weight was 0.9604 g, and kernel ratio was 35.16%. Statistically significant differences were found out between the populations whose chemical contents were analyzed. As a result of the analysis, the average fat content, protein, starch, and ash were 64.1%, 15.9%, 10.2 g, and 2.5%, respectively. According to the averages in the obtained fatty acids, the main fatty acids were oleic acid (79.53%), linoleic acid (11.34%), palmitic acid (5.68%), and stearic acid (2.03%), while the rest of other oils were found in trace amounts. Overall, our results suggest that the information relating to morphological and chemical characteristics of Turkish hazelnut can be useful for discriminating among populations.

KEY WORDS: hazel, hazelnut, fruits, morphometric analysis, chemical analysis, hazelnut oil

INTRODUCTION
UVOD

Turkish hazel or Turkish filbert (*Corylus colurna* L.) is a deciduous, monecious, self-incompatible, wind-pollinated species belonging to the Betulaceae family. The species is native to southeast Europe and southwest Asia, from the Balkans through northern Turkey to northern Iran, and in Western Himalayas. In addition, this hazel species is widely grown as an ornamental tree in Europe and the USA for centuries. In Turkey it can be found in the Balıkesir, Bolu, Ankara, Zonguldak, Kastamonu, Rize and Trabzon regions (Temel *et al.* 2017; Aksoy 2018). In the world literature Turkish hazel is also called Turkish filbert, tree hazelnut, bear hazelnut, Balkan hazelnut, and rock hazelnut (Yaltırık 1993).

Turkish hazel is the largest species of hazel with a single-trunk reaching a height of 15-25 m. The leaves of this hazel species are broad-ovoid, heart-shaped at the bottom, and pointed at the tip, 6–15 cm long and 5–13 cm across. The leaf margins are sharply double-serrate or coarse, sometimes shallowly lobed. The unisexual flowers are bloom in early spring before the leaves. The male catkins are pale yellow and 5–10 cm long, and the female flowers are very

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small with only red 1–3 mm long styles visible from greenish buds. The nuts mature in September, and they have edible kernels, with a taste very similar to kernels of common hazels (*Corylus avellana* L.). Nuts are about 1–2 cm long, surrounded by a thick, softly spiny, and bristly involucre. Three to eight nuts can be usually found together in tight clusters (Pamay 1992; Yaltırık 1993; Aksoy 2018).

The vertical distribution of *C. colurna* is between 100-1700 meters above sea level (Palashev and Nikolov 1979; Yaltırık 1993). It grows in areas where an annual average temperature is between 5-13°C and minimum annual precipitation 500 mm (Palashev and Nikolov 1979). Turkish hazel is a species with a high demand for light and moisture, which is thrifty in terms of its habitat requirements, like loamy soils. It creates strong root structure both vertically and horizontally (Yılmaz 1998; Polat and Güney 2015).

Hazelnuts are used in many areas of the pharmaceutical and food industry all over the world, especially in chocolates, ice creams, sauces, bakery, dairy, dessert, and pastry industry (Mitrović *et al.* 1997; Kaleoğlu *et al.* 2004; Özdemir and Akıncı 2004; Erdoğan and Aygün 2005; Amaral *et al.* 2006; Oliveira *et al.* 2008; Alasalvar *et al.* 2009). In addition, thanks to the substances it contains, the species is valuable for both its fruits (Çelik and Demirel 2004; Erdoğan and Aygün 2005) and leaves (Benov and Georgiev 1994; Alaca and Arabacı 2005; Coşkun 2005) in terms of human health.

Many studies have been conducted that elaborately reveal *Corylus avellana* (Açkurt *et al.* 1999; Kaleoğlu *et al.* 2004; Amaral *et al.* 2006; Köksal *et al.* 2006; Oliveira *et al.* 2008; Alasalvar *et al.* 2009; Bacchetta *et al.* 2013; Rezaei *et al.* 2014; Vujevic *et al.* 2014; Rovira *et al.* 2017; Wang *et al.* 2018; Król *et al.* 2019; Çetin *et al.* 2020). However, there are a few limited studies (Erdoğan and Aygün 2005; Ayan *et al.* 2018a, 2018b) in Turkey regarding the seed characteristics of Turkish hazel which is why this research was designed to comprehensively determine the morphological and chemical characteristics of Turkish hazelnuts in different natural populations in Turkey.

MATERIALS AND METHODS
MATERIJALI I METODE

Materials – *Materijali*

The fruits for this study were collected from seven populations in Turkey, during the October 2021 (Table 1; Figure 1). 3-4 kg of fully developed and ripe fruits was collected from 10-16 trees in each population.

Table 1. Locations from which samples of hazelnuts were collected.
Tablica 1. Lokacije na kojima su sakupljeni uzorci lješnjaka.

Population Populacija	Latitude Geografska širina	Longitude Geografska dužina	Altitude (m) Nadmorska visina (m)
Çorum-İskilip	40.77	34.58	1240
Kastamonu-Tosya	40.90	34.04	1100
Bolu-Mengen	40.86	31.83	800
Bolu-Seben	40.46	31.59	1215
Bolu-Pelitçik	40.61	31.45	1090
Eskişehir-Mihalıcçık	39.97	31.26	1150
Afyon-Sultandağı	38.45	31.23	1720

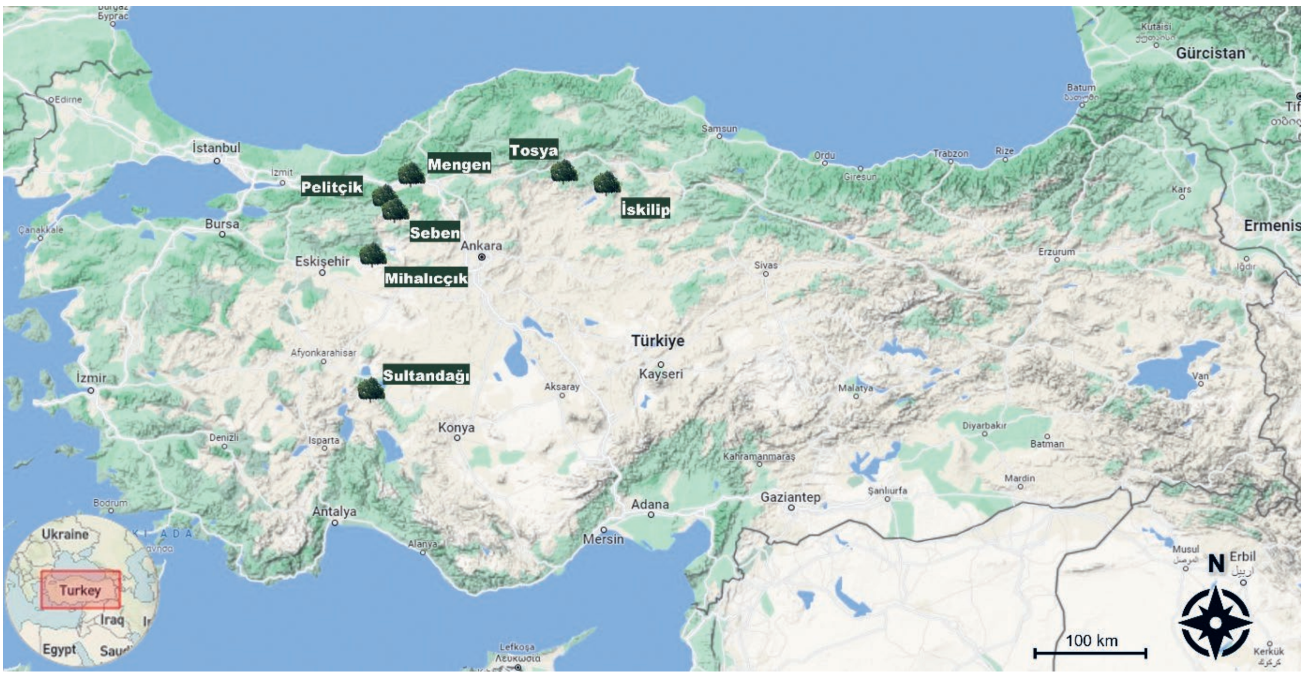

Figure 1. Researched populations of Turkish hazel.
Slika 1. Istraživane populacije medvjeđe lijeske.

Morphometric analysis – *Morfometrijska analiza*

Nuts were extracted from their involucre and the fruits were dried for about two weeks until their moisture content was reduced to 6.5%, at room temperature in the laboratory. The dried fruits were stored in light-proof amber bottles in the refrigerator.

Analyses of measured morphological traits were performed on 120 (3×40) randomly selected fruits in each population. The length, width and thickness values were measured with a sensitivity of 0.00 mm by using a digital caliper, and the weight values were measured with a sensitivity of 0.0000 g by using an analytical scale for each fruit and kernel. Also, the thickness of the shell was measured in the middle axis of the cracked nutshell by compressing the inner and outer surfaces into the mouth of the digital caliper. The kernel ratio was calculated as a percentage (%) by subtracting the kernel weight from the total fruit weight. In addition, 1,000 seed weight from 800 (8×100) seeds (fruits) was calculated according to ISTA (2020) rules.

Chemical analyses – *Kemijske analize*

The shell of the hazelnut was cracked with the help of vise and the kernel was taken out. In order to determine the chemical composition of the kernel, total fat (%), total protein (%), starch (g/kg) and ash (%) values were analyzed. The tests were carried out by TUBITAK Bursa Test and Analysis Laboratory. The kernel was removed by cracking the nutshell with the help of a vise.

Total fat content analysis was done in Soxhlet device (AOAC 2000). From the dried and ground hazelnut samples at 105°C in an oven, 5 g were weighed and extracted with 300 mL of hexane in a Soxhlet device for 4 hours. The amount of crude fat after evaporation was calculated as %. Protein analyzes of the samples were made by Kjeldahl method according to AOAC International (AOAC 2000). The percentage of crude protein was determined by multiplying the total nitrogen content by a factor of 5.30.

The samples were dried in an oven at 105°C until they reached constant weight. 5 g hazelnut sample was burned in a 550°C muffle furnace for about 9 hours until white ash was formed, and the amount of ash was calculated gravimetrically.

The fatty acid composition of the kernel fat was determined using gas chromatography-flame ionizing detector. The AOCS (2000) method was used to obtain methyl esters of fatty acids. Gas chromatography analyzes were performed with Agilent 6890 series instrument. In the analysis using a high polarity fatty acid column (20 m × 0.25 mm × 0.25 µm), the carrier gas was helium, the flow rate was set to 1.0 ml/min. Injection and detector temperatures were set at 250°C and 280°C, respectively. The oven temperature was determined as 40°C and the temperature increase rate to 240°C was adjusted to be 5°C/min. Analysis was performed with a split ratio of 1:50 and an injection volume of 1 µl.

Ewers polarimetric method was used for the determination of starch content. For this purpose, approximately 5 g of the ground hazelnut samples were taken and put into a 100 ml measuring flask, and 50 ml of 1% HCl solution was added twice using a pipette, and the sample was shaken. The flask was kept in a water bath at 95-100°C for 15-20 minutes and was shaken intermittently. After the process, it was taken from the water bath and 30-35 ml of distilled water was added and cooled. In order to precipitate nitrogenous substances in the sample, 10 ml of 4% phosphotungstic acid was added to the measuring flask. Distilled water was added until the flask volume was 100 ml, and a clear solution was obtained with filter paper. The obtained filtrate was placed in a 2 dm polarimeter tube and the amount of starch in the sample was calculated with the help of the factor by reading the degree of rotation.

Statistical analysis – *Statistička analiza*

The morphological and chemical characteristics of the fruits and kernels were evaluated by analysis of variance. The one-way analysis of variance (ANOVA) was used to determine inter-population variability. Differences among groups were determined using Duncan's multiple range test when a significant effect was identified. Also, correlation analysis was performed in order to reveal the interaction of the obtained data with each other.

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

The limited number of reports (Erdoğan and Aygün 2005; Ayan *et al.* 2018a, 2018b) in Turkey on Turkish hazelnuts' morphological and chemical characteristics necessitated this research. In this study, morphological and chemical characteristics were determined and evaluated of Turkish hazelnut fruits and kernels from seven populations.

Morphological characteristics – *Morfološke karakteristike*

In terms of morphological characteristics, significant differences between the studied populations have been revealed (Table 2, Figure 2). The average 1,000-seed (fruit) weight at about 6.5% MC (Moisture Content) for the seven populations was 1438.8 g. The average fruit dimensions (length × width × thickness) of the seven populations of *C. colurna* were 15.98 × 15.38 × 12.00 mm, and average fruit weight 1.4651 g. The populations with the lowest-highest values were Seben-Iskilip (15.38-16.71 mm) for fruit length, Mengen-Sultandağı (14.57-16.28 mm) for fruit width, Tosya-Sultandağı (10.94-13.01 mm) for fruit thickness and Tosya-Sultandağı (1.2726-1.6477 g) for fruit weight (Table 2). Ninić-Todorović and Cerović (1987) reports biotypes with fruit size 16.4-18.6 × 14.4-17.8 × 11.0-15.8 mm, and fruit weight 1.17-2.54 g. Miletić *et al.* (2007) state that fruit dimensions of *C. colurna* are 14.7 (12.0-17.5) × 14.1 (11.5-16.5) × 12.1 (9.3-16.0) mm and weight 1.15 (0.68-1.55) g for Turkish hazel populations in the central-eastern and east-southern Serbia. Ayan *et al.* (2018b) reported that the Turkish hazelnuts from four natural populations from the North Western Black Sea Region of Turkey have following dimensions 11.04-18.83 × 10.32-19.61 × 7.67-16.92 mm, and weight 0.61-2.61 g. Popović *et al.* (2021) studied morphological nut traits of Turkish hazel which was collected from one cultivated and seven natural populations in the Republic of Serbia. They determined in their research that the average of fruit size is 15.24-7.76 × 14.17-15.80 × 10.92-12.38 mm and weight 1.23-1.45 g.

The average kernel dimensions of analyzed populations were determined as 13.03 (12.15-13.72) × 11.22 (10.55-11.75) × 7.64 (7.27-8.04) mm and average kernel weight 0.5047 (0.4828-0.5332) g. Kernel dimension values match up with similar populations in fruit dimensions in terms of lowest and highest values (Table 3). Miletić *et al.* (2007) revealed that the kernel dimensions of *C. colurna* are 11.5 (13.0-10.2) × 10.2 (12.6-7.2) × 9.2 (12.5-5.0) mm and weight 0.70 g (0.56-0.85 g). Ayan *et al.* (2018b) state that kernel dimensions are 9.16-15.45 × 8.05-16.64 × 4.52-10.09 mm and weight 0.25-0.83 g.

Figure 2. Section through a Turkish hazel fruit.
Slika 2. Presjek kroz plod medvjeđe lijeske.

Table 2. Morphological characteristics of the Turkish hazel fruits in the studied populations.
Tablica 2. Morfološke karakteristike plodova medvjeđe lijeske u istraživanim populacijama.

Population Populacija	Length Dužina [mm]	Width Širina [mm]	Thickness Debljina [mm]	Weight Težina [g]	Shell thickness Debljina ljuske [mm]	1,000-seed weight Težina 1,000-sjemenki [g]
İskilip	16.71[a1]	15.41[bc]	11.97[c]	1.5072[b]	1.98[bc]	1486.8
Tosya	15.79[c]	14.73[d]	10.94[d]	1.2726[d]	1.73[e]	1243.7
Mengen	16.51[a]	14.57[d]	11.13[d]	1.3257[cd]	1.82[de]	1300.5
Seben	15.38[d]	15.74[b]	11.86[c]	1.3957[c]	1.90[cd]	1399.0
Pelitçik	15.89[c]	15.71[b]	12.48[b]	1.5434[b]	1.86[d]	1538.8
Mihalıcçık	16.16[b]	15.22[c]	12.63[b]	1.5637[b]	2.09[a]	1593.4
Sultandağı	15.46[d]	16.28[a]	13.01[a]	1.6477[a]	2.02[ab]	1658.8
Overall Mean Srednja vrijednost	15.98	15.38	12.00	1.4651	1.92	1460.1

[1] The values on the same column followed by the same small letters are not significantly different at $P<0.05$.
[1] Vrijednosti u istom stupcu iza kojeg slijede ista mala slova ne razlikuju se značajno pri $P<0.05$.

Table 3. Morphological characteristics of the Turkish hazel kernels in the studied populations.
Tablica 3. Morfološke karakteristike jezgri medvjeđe lijeske u istraživanim populacijama.

Population Populacija	Length Dužina [mm]	Width Širina [mm]	Thickness Debljina [mm]	Weight Težina [g]	Shell weight Težina ljuske [g]	Kernel Ratio Omjer jezgre [%]
İskilip	13.72[a]	11.04[c]	7.47[de]	0.5332[a]	0.9740[c]	35.89[b1]
Tosya	13.08[bc]	11.36[b]	7.27[e]	0.4741[d]	0.7985[e]	37.68[a]
Mengen	13.30[b]	10.55[d]	7.52[cd]	0.4917[cd]	0.8340[de]	37.88[a]
Seben	12.15[e]	11.75[a]	7.80[b]	0.5079[bc]	0.8878[d]	36.81[ab]
Pelitçik	13.02[c]	11.50[ab]	7.72[bc]	0.5199[ab]	1.0235[bc]	34.10[c]
Mihalıcçık	13.25[bc]	10.82[cd]	7.67[bcd]	0.4828[d]	1.0809[ab]	31.33[d]
Sultandağı	12.69[d]	11.55[ab]	8.04[a]	0.5233[ab]	1.1244[a]	32.41[d]
Overall Mean Srednja vrijednost	13.03	11.22	7.64	0.5047	0.9604	35.16

[1] The values on the same column followed by the same small letters are not significantly different at $P<0.05$.
[1] Vrijednosti u istom stupcu iza kojeg slijede ista mala slova ne razlikuju se značajno pri $P<0.05$.

The average of shell thickness, shell weight and kernel ratio in seven populations was determined 1.92 (1.73-2.09) mm, 0.9604 (0.7985-1.1244) g and 35.16% (31.33-37.88%), respectively (Table 3). Mitrović *et al.* (2001), in their research of Turkish hazelnuts in Serbia, determined that the shell thickness was 1.0-1.3 mm, and the kernel ratio was 29-40.1%. Erdoğan and Aygün (2005) conducted a study on *C. colurna* and found out that shell thickness was 0.67-3.69 mm and the kernel ratio 25-36%. Miletić *et al.* (2007) reported the average kernel ratio of 40.2% (36.7-43.9%) for Turkish hazelnuts. Ayan *et al.* (2018b) determined in their study that the average shell thickness and kernel ratios are 2.28 mm (0.92-11.88 mm) and 34.8% (18.1-57.9%), respectively.

The shell thickness and percent kernel ratio are commercially important in hazelnuts (Ayfer *et al.* 1986; Richardson 1996; Açkurt *et al.* 1999; Özdemir and Akıncı 2004). The thin shell thickness may affect the high kernel rate. Preferring thin-shelled Turkish hazelnuts in commercial areas will provide high yields in terms of product quantity. According to our investigations, the highest value of the shell thickness was recorded in the population of the Mihalıççık (2.09 mm) and the lowest in the Tosya population (1.73 mm). In addition, it was determined that the highest kernel rate was in the Mengen population (37.88%) and the lowest in the Mihalıççık population (31.33%) (Table 3).

According to the results of the correlation analysis, it was determined that there was a significantly negative correlation between kernel ratio and shell weight, shell thickness, fruit thickness, fruit weight and fruit width, respectively from highest to lowest ($P<0.01$). Positive correlations between other parameters of morphological characteristics are shown in Table 4. Likewise, similar correlations were reported by Ayan *et al.* (2018b).

Chemical characteristics – *Kemijske karakteristike*

The analysis of the chemical content of Turkish hazelnuts is summarized in Table 5. In terms of chemical traits of kernels significant differences between the studied populations have been determined. As a result of the analysis, the average fat content (%), protein (%), starch (g/kg) and ash (%) were 64.1%, 15.9%, 10.2 g and 2.5%, respectively (Table 5).

According to the results of this study, the percentage of total protein content was in range from 14.8% (Seben) to 17.6% (Mengen). Furthermore, it was revealed that the starch content varied in the range of 5.96 g (Sultandagi) to 13.5 g (Pelitçik), and the ash content in the range of 2.30% (Sultandagi) to 2.58% (Mengen). The percentage of protein content in *C. colurna* was determined by Miletić *et al.* (2007) and Ayan *et al.* (2018a) as 12.4% (10.9-14.4%) and 16.32% (14.80-18.34%), respectively. Srivastava *et al.* (2010) carried out their study on 41 genotypes of *C. colurna* in Kashmir and noted that the average protein content is 16.37%.

Table 4. Correlation matrix of morphological traits.
Tablica 4. Korelacijska matrica morfoloških svojstava.

	Variables Varijable	FRUIT PLOD					KERNEL JEZGRA					
		Length Dužina	Width Širina	Thickness Debljina	Weight Težina	Shell thickness Debljina ljuske	Length Dužina	Width Širina	Thickness Debljina	Weight Težina	Shell weight Težina ljuske	Kernel ratio Omjer jezgre
FRUIT PLOD	Length – *Dužina*	1										
	Width – *Širina*	0.172**	1									
	Thickness – *Debljina*	0.211**	0.668**	1								
	Weight – *Težina*	0.421**	0.831**	0.862**	1							
	Shell thickness – *Debljina ljuske*	0.112**	0.488**	0.467**	0.545**	1						
KERNEL JEZGRA	Length – *Dužina*	0.819**	0.085*	0.132**	0.339**	0.056	1					
	Width – *Širina*	0.131**	0.799**	0.453**	0.625**	0.177**	0.110**	1				
	Thickness – *Debljina*	0.157**	0.426**	0.612**	0.527**	0.067	0.088*	0.477**	1			
	Weight – *Težina*	0.501**	0.664**	0.565**	0.731**	0.151**	0.480**	0.774**	0.702**	1		
	Shell weight – *Težina ljuske*	0.343**	0.788**	0.860**	0.972**	0.615**	0.250**	0.498**	0.403**	0.550**	1	
	Kernel ratio – *Omjer jezgre*	-0.031	-0.412**	-0.568**	-0.562**	-0.617**	0.068*	0.014	0.073*	0.126**	-0.731**	1

** correlation is significant at the 0.01 level; * correlation is significant at the 0.05 level.
** korelacija je značajna na razini 0,01; * korelacija je značajna na razini 0,05.

Table 5. Chemical content of Turkish hazel kernels in the studied populations. The values are presented as arithmetic mean±standard deviation.
Tablica 5. Kemijski sastav jezgri medvjeđe lijeske u istraživanim populacijama. Vrijednosti su prikazane kao aritmetička sredina±standardna devijacija.

Population Populacija	Fat Content Masti (%)	Protein Protein (%)	Starch Škrob (g/kg)	Ash Pepeo (%)
İskilip	54.9±2.9^{f}	17.5±0.2^{a}	9.23±0.78^{c}	2.54±0.06^{a1}
Tosya	62.7±3.3^{d}	15.0±0.2^{cd}	11.4±0.8^{b}	2.56±0.02^{a}
Mengen	59.0±3.1^{e}	17.6±0.3^{a}	11.4±0.8^{b}	2.58±0.02^{a}
Seben	73.1±3.8^{a}	14.8±0.1^{e}	9.78±0.01^{bc}	2.38±0.03^{b}
Pelitçik	65.6±3.4^{c}	15.0±0.1^{cd}	13.5±0.8^{a}	2.32±0.02^{b}
Mihalıcçık	65.1±3.4^{c}	16.3±0.3^{b}	10.3±0.8^{bc}	2.49±0.04^{a}
Sultandağı	68.2±3.5^{b}	15.4±0.2^{c}	5.96±0.79^{d}	2.30±0.03^{b}
Average Srednja vrijednost	64.1±3.3	15.9±0.2	10.2±0.68	2.5±0.03

[1] the values on the same column followed by the same small letters are not significantly different at $P<0.05$.
[1] vrijednosti u istom stupcu iza kojeg slijede ista mala slova ne razlikuju se značajno pri $P<0.05$.

The İskilip population has the lowest fat content (54.9%), whereas the Seben population has the highest fat content (73.1%) among the seven populations of Turkish hazelnut. Oleic and linoleic acids were the predominant fatty acids, together representing 90.87% of the total. The amount of palmitic and stearic acids was low while palmitoleic, eicosenoic, α- linolenic, arachidic, and heptadecanoic acids were present in trace amounts (Table 6). Erdogan and Aygün (2005) for Turkish hazelnuts reported that the fat content was 64.4-71.9%, and that the oleic and linoleic acids constituted 91.7% of the total amount. Ayan *et al.* (2018a), determined that the fat content of the Turkish hazelnut populations ranged from 59.8% to 64.1%. Ninić-Todorović *et al.* (2019) in their study for Turkish hazelnuts stated that the fat content was 36.50-60.8%, oleic acid 79.3-83.0% and linoleic acids 7.5-10.8%. Similar fat content (48.6–69.9%) and fatty acid composition for Turkish hazel kernels was reported for the samples from Serbia (Ninić-Todorović 1990; Miletić *et al.* 2007).

The average values for oleic acid (C18:1c), linoleic acid (C18:2c), palmitic acid (C16:0) and stearic acid (C18:0), i.e., principal fatty acids, were as follows: 79.53%, 11.34%, 5.68% and 2.03%, respectively. Among the total fatty acids of hazelnuts, total monounsaturated fatty acids (avg. 80.13%) exhibited the highest ratio, while saturated fatty acids presented the lowest content (avg. 7.92%). The oleic acid in Turkish hazel populations vary from 78.6% (Tosya) to 80.1% (İskilip), linoleic acid from 9.45% (Mihalıcçık) to 12.6% (Tosya), palmitic acid from 5.07% (Seben) to 6.95% (Mihalıcçık) and stearic acid from 1.56% (Tosya) to 2.54% (Mihalıcçık) (Table 6).

Król and Gantner (2020) investigated some cultivars of *C. avellana*, which are most widespread and prominent in certain countries (Croatia, Iran, Italy, Oregon, Poland, Portugal, Spain, and Turkey), in a review. Considering the chemical

Table 6. Fatty acid compositions in Turkish hazel kernels from seven natural populations. The values are presented as arithmetic mean±standard deviation.
Tablica 6. Sastav masnih kiselina jezgri medvjeđe lijeske iz sedam prirodnih populacija. Vrijednosti su prikazane kao aritmetička sredina±standardna devijacija.

Population Populacija	Palmitic acid Palmitinska kiselina (C16:0)	Palmitoleic acid Palmitoleinska kiselina (C16:1)	Heptadecanoic acid Heptadekanska kiselina (C17:1)	Stearic acid Stearinska kiselina (C18:0)	Oleic acid Oleinska kiselina (C18:1c)	Linoleic acid Linolna kiselina (C18:2c)	α-Linolenic acid α-Linolna kiselina (C18:3n3)	Arachidonic acid Arahidonska kiselina (C20:0)	Eicosenoic acid Eikozenska kiselina (C20:1)	Saturated fatty acids Zasićene masne kiseline ΣSAFAs	Monounsaturated fatty acids Mononezasićene masne kiseline ΣMUFAs	Polyunsaturated fatty acids Polinezasićene masne kiseline ΣPUFAs
İskilip	5.79±0.48^{b}	0.34±0.01^{c}	0.09±0.01^{a}	2.24±0.17^{b}	80.1±6.1^{a}	10.5±0.8^{d}	0.14±0.01^{c}	0.12±0.01^{b}	0.18±0.01^{ab}	8.25±1.30^{b}	80.7±2.5^{a}	10.7±0.6^{d1}
Tosya	5.44±0.45^{e}	0.36±0.01^{b}	0.09±0.01^{a}	1.56±0.12^{g}	78.6±6.0^{d}	12.6±0.9^{a}	0.11±0.01^{e}	0.11±0.01^{ef}	0.18±0.01^{a}	7.18±1.13^{f}	79.2±2.5^{d}	12.8±0.7^{a}
Mengen	5.30±0.44^{f}	0.31±0.01^{d}	0.08±0.01^{c}	1.85±0.14^{f}	79.1±6.0^{c}	12.5±0.9^{a}	0.15±0.01^{b}	0.11±0.01^{e}	0.18±0.01^{a}	7.36±1.16^{e}	79.6±2.5^{c}	12.8±0.7^{a}
Seben	5.07±0.42^{g}	0.32±0.01^{d}	0.08±0.01^{c}	2.11±0.16^{c}	79.9±6.1^{ab}	11.5±0.9^{b}	0.13±0.01^{d}	0.12±0.01^{c}	0.18±0.01^{ab}	7.39±1.16^{e}	80.5±2.5^{b}	11.7±0.6^{b}
Pelitçik	5.56±0.46^{d}	0.35±0.01^{bc}	0.08±0.01^{b}	2.00±0.15^{d}	79.6±6.1^{b}	11.2±0.8^{c}	0.15±0.01^{b}	0.11±0.01^{d}	0.17±0.01^{bc}	7.81±1.23^{c}	80.2±2.5^{b}	11.4±0.6^{c}
Mihalıcçık	6.95±0.58^{a}	0.51±0.01^{a}	0.08±0.01^{b}	2.54±0.20^{a}	79.7±6.1^{b}	9.45±0.71^{e}	0.10±0.01^{f}	0.15±0.01^{a}	0.17±0.01^{c}	9.73±1.53^{a}	80.4±2.5^{b}	9.64±0.53^{e}
Sultandağı	5.65±0.47^{c}	0.34±0.01^{c}	0.07±0.01^{d}	1.90±0.15^{e}	79.7±6.1^{b}	11.6±0.9^{b}	0.15±0.01^{a}	0.10±0.01^{f}	0.16±0.01^{d}	7.70±1.21^{d}	80.3±2.5^{b}	11.8±0.7^{b}
Overall Mean Srednja vrijednost	5.68±0.47	0.36±0.01	0.08±0.01	2.03±0.16	79.53±6.07	11.34±0.84	0.13±0.01	0.12±0.01	0.17±0.01	7.92±1.25	80.13±2.50	11.55±0.63

[1] the values on the same column followed by the same small letters are not significantly different at $P<0.05$.
[1] vrijednosti u istom stupcu iza kojeg slijede ista mala slova ne razlikuju se značajno pri $P<0.05$.

Table 7. Correlation matrix of chemical traits.
Tablica 7. Korelacijska matrica kemijskih svojstava.

Variables Varijable	Fat-Masti	Protein-Proteini	Starch-Škrob	Ash-Pepeo	Palmitic acid Palmitinska kiselina	Palmitoleic acid Palmitoleinska kiselina	Heptadecanoic acid Heptadekanska kiselina	Stearic acid Stearinska kiselina	Oleic acid Oleinska kiselina	Linoleic acid Linolna kiselina	Arachidonic acid Arahidonska kiselina	α-Linolenic acid α-Linolna kiselina	Eicosenoic acid Eikozenska kiselina	SAFA ΣSAFAs	MUFA ΣMUFAs
Protein Proteini	–0.816**														
Starch Škrob	–0.169	–0.017													
Ash Pepeo	–0.708**	0.657**	0.289												
Palmitic acid Palmitinska kiselina	–0.151	0.221	–0.085	0.125											
Palmitoleic acid Palmitoleinska kiselina	0.039	0.015	0.036	0.116	0.950**										
Heptadecanoic acid Heptadekanska kiselina	–0.518**	0.186	0.622**	0.587**	0.098	0.145									
Stearic acid Stearinska kiselina	0.023	0.281	–0.113	–0.070	0.713**	0.638**	0.034								
Oleic acid Oleinska kiselina	0.131	0.115	–0.362	–0.445*	0.207	0.069	–0.225	0.704**							
Linoleic acid Linolna kiselina	0.019	–0.161	0.114	0.125	–0.824**	–0.742**	–0.118	–0.938**	–0.665**						
Arachidonic acid Arahidonska kiselina	–0.058	0.234	0.043	0.163	0.851**	0.841**	0.284	0.913**	0.414*	–0.913**					
α-Linolenic acid α-Linolna kiselina	–0.105	0.164	–0.176	–0.363	–0.593**	–0.763**	–0.476*	–0.345	0.216	0.423*	–0.670**				
Eicosenoic acid Eikozenska kiselina	–0.390*	0.302	0.531**	0.638**	–0.412*	–0.337	0.583**	–0.296	–0.327	0.384*	–0.177	–0.098			
SAFA ΣSAFAs	–0.102	0.261	–0.069	0.066	0.961**	0.900**	0.102	0.877**	0.405*	–0.928**	0.941**	–0.544**	–0.379*		
MUFA ΣMUFAs	0.119	0.125	–0.336	–0.408*	0.312	0.184	–0.182	0.771**	0.993**	–0.744**	0.512**	0.115	–0.338	0.504**	
PUFA ΣPUFAs	0.014	–0.156	0.117	0.121	–0.826**	–0.747**	–0.119	–0.937**	–0.661**	1.000**	–0.916**	0.435*	0.380*	–0.929**	–0.741**

** correlation is significant at the 0.01 level; * correlation is significant at the 0.05 level.
** korelacija je značajna na razini 0,01; * korelacija je značajna na razini 0,05.

compositions of the cultivars, the lowest- highest values were reported to be in the range of 50.81-66.29% for fat content, 7.03-24.61% for protein, 7.82-21.79% for carbohydrate, and 2.00-5.20% for ash. In terms of the composition of fatty acids, cultivars of common hazelnuts have oleic acid (69.30-83.59%), linoleic acid (7.57-15.0%), palmitic acid (4.80-9.60%) and stearic acid (1.75-4.10%), as indicated according to investigated studies in the review (Köksal *et al.* 2006; Oliveira *et al.* 2008; Bacchetta *et al.* 2013; Rezaei *et al.* 2014; Vujevic *et al.* 2014; Rovira *et al.* 2017; Wang *et al.* 2018; Król *et al.* 2019). Turkish hazel kernels are similar in fat, protein, and ash content, oleic acid, linoleic acid, palmitic acid, and stearic acid to common hazel kernels.

According to the correlation analysis of chemical characteristics of studied Turkish hazel populations shown in Table 7; there is a significantly negative correlation between fat and protein content. It was determined that oleic acid, one of the major fat acids, has a significant negative correlation with ash, linoleic acid, PUFA and a significantly positive correlation with stearic acid, arachidonic acid, SAFA, MUFA. Linoleic acid, another one of the major fat acids, was monitored a significant negative correlation between palmitic acid, palmitoleic acid, stearic acid, oleic acid, arachidonic acid, SAFA and MUFA while a significantly positive correlation was determined between α- linolenic acid, eicosenoic acid and PUFA. Significant negative and positive correlations were observed between the other chemical characteristics (Table 7). In addition, a study on *C. avellana* reported similar correlations between some parameters of fatty acids (Çetin *et al.* 2020).

It is well known that unsaturated fatty acids have an important effect on human health and nutrition (Oster *et al.* 1980; Salonen *et al.* 1988; Sabate *et al.* 1993; Kris-Etherton *et al.* 2001). Namely, the fatty acid profile of hazelnuts, which is high in unsaturated fatty acids such as oleic acid and low in saturated fatty acids, increases the high-density lipoprotein (HDL) in the blood, contributing to lower cholesterol and therefore reduced risk of coronary heart disease (Sabate *et al.* 1993; Richardson 1996; Alphan *et al.* 1997; Kris-Etherton *et al.* 2001). Turkish hazel kernels are rich in unsaturated fatty acids and their consumption will have similar health benefits as the common hazel kernels.

In the fruits of woody plant species, the morphometric and chemical characteristics of the fruit have attracted attention over the years and gained importance in terms of different usage areas (Martins *et al.* 2017). The wide geographic variation can significantly affect the fruit and seed chemical composition as well as the fruit and seed morphological traits of wild (Izhaki *et al.* 2002; Yanar *et al.* 2011; Poljak *et al.* 2021a, 2022; Sun 2021) and cultivated populations (Poljak *et al.* 2016, 2021b). It can be said that the morphological and chemical differences between the populations depend on the interactions of factors such as habitat conditions and geographical origin.

CONCLUSIONS
ZAKLJUČCI

This study provided results that allowed for the first time to determine the morphological and chemical characteristics of Turkish hazel populations in different regions in Turkey. Statistically significant differences between the populations studied were detected.

It was found out that the Sultandağı population had the highest values in terms of morphological characteristics among the studied populations (fruit width, fruit thickness, fruit weight, shell thickness, kernel width, kernel thickness, kernel weight and shell weight). Contrarily, the same population was characterized with the second lowest kernel rate. At the same time, morphological values were lowest in Tosya and Mengen populations, which have the highest kernel rate among the studied populations.

The correlation analysis revealed that the kernel ratio is in a significant negative correlation with shell weight, shell thickness, fruit thickness, fruit weight, and fruit width.

The highest fat content was recorded in the Seben population, and the lowest in the Mengen and İskilip populations. However, this was the opposite when we take into the consideration the protein values, Mengen and İskilip populations have the highest protein content and Seben the lowest. The significant negative correlation between fat and protein values also confirmed these results.

At the end it is important to highlight that besides the food and pharmaceutical industry, Turkish hazelnuts are preferred by the people of the region for its more delicious and aromatic taste than the common hazelnuts. The research is continuing by our team on the physiological characteristics and storage conditions of this hazel species.

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SAŽETAK

Medvjeđa lijeska (*Corylus colurna* L.) prirodno je rasprostranjena u jugoistočnoj Europi, Anatoliji, Kavkazu i zapadnoj Himalaji. U Turskoj postoje mnoge izolirane populacije ove vrste u regijama Crnog mora, Mramornog mora, Egeja i središnje Anatolije. Mnoge male populacije medvjeđe lijeske u Turskoj su ugrožene. U ovoj studiji istraživana su morfološka i kemijska svojstva lješnjaka prikupljenih iz sedam populacija na području Turske. Provedenim istraživanjem utvrđene su statistički značajne razlike između populacija s obzirom na morfološke karakteristike plodova i sjemenki. Prosječne vrijednosti za dužinu, širinu, debljinu i masu plodova bile su 16,04 mm, 15,38 mm, 12,00 mm i 1,4650 g te za dužinu, širinu, debljinu i masu sjemenke 13,03 mm, 11,21 mm, 7,64 mm i 0,5047 g. Prosječna debljina ljuske bila je 1,91 mm, težina ljuske 0,9603 g, a omjer jezgre 34,64%. Utvrđene su statistički značajne razlike između populacija čiji je kemijski sastav analiziran. Kao rezultat analize, prosječni sadržaj masti, proteina, škroba i pepela iznosio je 64,1%, 15,9%, 10,2 g, odnosno 2,5%. Prema prosjeku u dobivenim masnim kiselinama, glavne masne kiseline bile su oleinska (79,53%), linolna (11,34%), palmitinska (5,68%) i stearinska kiselina (2,03%), dok su ostale masti bile pronađena u tragovima. Naši rezultati upućuju na to da se morfološke i kemijske karakteristike plodova medvjeđe lijeske mogu uspješno koristiti za razlikovanje populacija.

KLJUČNE RIJEČI: lijeska, lješnjak, plodovi, morfometrijska analiza, kemijska analiza, ulje lješnjaka