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Article

Chemical and Physical Properties of Some Cultivars of Hazelnuts Grown in Azerbaijan

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Abstract. Hazelnuts are one of the most valuable nuts in the world due to their unique organoleptic properties and nutritional characteristics. This work was intended to analyze some physical and chemical properties of various hazelnut cultivars grown in Zakataly (Azerbaijan), namely Ata-baba, Elbari, Topqara, Firovan, Nasimi, Qalib, Mirzebeyli, Tala, Dash findiq, Barli, Azeri and Sachaqli. In general, the results showed statistically significant differences between the studied cultivars. The density of kernels, depending on the hazelnut cultivars, varied from 0.71 g/cm³ (Azeri) up to 1.03 g/cm³ (Sachaqli). The peeled fruits of Dash findiq were heavier on average (1.64±0.34 g), and the peeled fruits of Nasimi, Qalib, Mirzebeyli and Sachaqli were lighter on average (0.8±0.23 g, 0.8±0.31 g, 0.8±0.20 g and 0.80±0.09 g, respectively). In the unpeeled form, Dash findiq nuts were the heaviest (3.70±0.34 g), and Nasimi and Qalib nuts were the lightest of all cultivars (2.0±0.48 g and 2.0±0.36 g, respectively). Ata-baba nuts account for 49 masses per kernel. %, in other studied cultivars - 33.3-45.3 wt. %. Nasimi nuts are rounded (in the equatorial zone); Tala, Ata-baba, Firovan and Azeri - rounded-oblong; Topqara, Barli and Dash findiq - oblong; Elbari, Qalib, Mirzebeyli and Sachaqli - elongated. Firovan, Tala and Topqara have thicker shells. Ata-baba is significantly ahead of other varieties in the yield of kernels (490 kg / 1 ton of nuts), Tala is in second place in this indicator (453 kg / 1 ton of nuts), Topqara is in third (433 kg / 1 ton of nuts). According to the maximum fat content, the cultivars Mirzebeyli (77.00±2.20 g/100 g of kernels) and Firovan (75.0±3.08 u/100 kernels), protein - Sachaqli (16.02±0.50 u/100 kernels) and Ata-baba (15.92±0.48 g/100 g of kernels) were distinguished. The results of this study help to better understand the differences between some varieties of hazelnuts grown in Azerbaijan, which provides important clues for all players involved in this sector.

Keywords: Azerbaijan; hazelnuts; local varieties; biometric characteristics; physical properties; chemical composition

1. Introduction

Hazelnut (*Corylus avellana* L.), belonging to the Betulaceae family, is the second most produced nut among hard-shelled fruits in the world after almonds. It was first grown in the Anatolian region of Turkey. It is known that it spread to Greece and then to Italy through the Roman Empire after spreading throughout Europe in the Middle Ages. In the late 1500s, Spain presented it to the American continent. Although there are various species of walnut trees belonging to the genus *Corylus* (such as *Corylus americana*, *C. avellana*, *C. heterophylla*, *C. yunnanensis*, *C. colchica*, *C. cornuta*, *C. maxima*, *C. sieboldiana*, (syn. *C. mandshurica*) *C. chinensis*, *C. colurna*, *C. fargesii*, *C. jacquemontii*, *C. wangii* and *C. ferox.*), many of them are wild and have no economic significance [1].

The most common and important representative of the genus *Corylus*, *Corylus avellana*, namely Turkish hazelnuts, is mainly grown in the coastal areas of the Black Sea region of Turkey. Italy, Spain, the USA, Georgia, Chile, Azerbaijan and Iran are other hazelnut producing countries where the risk of frost is rare, and the average temperature in winter does not fall below -8°C and above 36°C–37°C. Happy summer. According to the data published in 2019, Turkey (776,046 tons), Italy (98,530 tons), Azerbaijan (53,793 tons) and the USA (39,920 tons) are the leading countries in the production of peeled hazelnuts. Turkey produced about 75% of the world's total hazelnut production in the same year (FAO, 2019) [2].

Azerbaijan, which ranks third in the world in terms of hazelnut production, plans to increase the hazelnut harvest to 60,000 tons in 2023. Here it is grown on Absheron, where such cultivars as "Yagli findiq", "Qalib", "Qizil findiq" are common; in the Ganja-Gazakh region ("Yagli findiq", "Qalib", "Qizil findiq", "Gendje findigi"); in the Sheki-Zagatala region ("Yagli findiq", "Ata-baba", "Çshrefi", "Qalib", "Qizil findiq", "Chrrkez", "Kudryavchik", "Ag lombard", "Sachaxli", "Azeri", "Arzu", "Ataulla", "Barli", "Bomba", "Qahfarash", "Nasimi", "Topqara", "Perzivan zerifi"); in the Guba-Khachmaz region (Yagli findiq, Qalib, Qizil findiq) [3].

Hazelnuts are used as a snack and also as an ingredient in many food products, such as confectionery and confectionery, in various forms. It is mainly consumed after roasting, as it has a characteristic burnt, coffee, fried and chocolate smell. As a result of the firing treatment, numerous reactions and significant changes occur, both in its textural properties and organoleptic parameters. Lipids, proteins, carbohydrates, vitamins, minerals and sterols are the main components of hazelnuts, and their amount varies depending on its variety [4].

Hazelnut kernels accumulate a significant amount of oil (52.2-60.9 %) [5]. Various studies have been conducted to determine the beneficial activity of lipophilic bioactive compounds present in hazelnuts of different varieties [6,7]. In recent years, hazelnuts have also been processed into edible oil rich in oleic acid and having beneficial dietary properties. This product is widely used in cooking, deep frying, salad dressing and as a flavoring ingredient [8].

In recent years, chocolate and chocolate-nut pastes, similar to peanut butter, with the addition of hazelnuts, have been gaining popularity. For example, in 2018, a large chocolate manufacturer Lindt launched a chocolate paste consisting of 40% hazelnuts on the UK market. M&M's has also released its own chocolates, in which the central part of the hazelnut filling is covered with delicious milk chocolate. Hazelnuts are used in many Ferrero products, including Nutella, Ferrero Rocher and Kinder Bueno. In fact, 25% of the world's hazelnut supply goes to the production of Ferrero products. Nutella has become a culinary phenomenon all over the world, its growing popularity has led to an increase in demand for hazelnuts.

There are various standards for measuring the quality of hazelnuts in terms of size, appearance and hidden defects [9]. Knowledge of the physical and chemical properties of hazelnuts is crucial, as they are necessary to determine numerous parameters of extreme importance in order to guarantee the quality of the product. Moreover, the determination of these parameters also leads to a decision as to what kind of care should be provided to the product; for example, as to whether it should undergo any transformation before it becomes available to the end user [10]. According to Lopez et al. [11], the quality of hazelnuts is associated not only with its nutritional and chemical properties, but also with some visual aspects, such as the absence of broken kernels and clarity and uniformity of color. According to their characteristics, different varieties may be more suitable for industry or fresh consumption.

Despite the importance of this topic, the physical and chemical properties of hazelnut varieties grown in Azerbaijan have not been studied much. Therefore, the purpose of this study was to evaluate the physical and chemical properties of various varieties of hazelnuts grown in Azerbaijan.

2. Materials and Methods

2.1. Hazelnut samples

The hazelnut samples used in this study belonged to different varieties, namely Ata-baba, Elbari, Topqara, Firovan, Nasimi, Qalib, Mirzebeyli, Tala, Dash findiq, Barli, Azeri and Sachaqli, collected in the Zakatala Stronghold of the Research Institute of Fruit and Tea Growing of the Ministry of Agriculture of the Republic of Azerbaijan. In 2022, three sets of 1 kg of each hazelnut fruit were collected in a state of maturity, and then they were stored (whole hazelnuts) until analysis at a temperature of 5 ° C.

2.2. Biometric Assessment

For biometric analysis, 50 hazelnuts of each variety were used, and measurements were carried out with a caliper with a precision scale. Analyses were carried out for whole fruits and corresponding kernels, and the number of hollow fruits was also recorded.

Various biometric parameters were evaluated, namely width (wider equatorial zone) and height (distance between centers). These parameters were evaluated for unpeeled and peeled nuts [12].

The percentage of the kernel was calculated as $(\text{kernel weight}/\text{nut weight}) \times 100$ [13].

The density (in g/cm^3) was determined by the volume of displaced water by hazelnut kernels, the mass of which was preliminarily determined.

2.3. Chemical Analyses

To perform chemical analyses with respect to humidity, nitrogenous substances and fat, generally accepted procedures were fully followed [14], and only the kernels were analyzed after grinding and homogenization. The moisture content of the kernels was determined by drying the crushed kernels at $100 \pm 5^\circ \text{C}$ (5.0 g per sample) until they reached a constant weight. The fat content of the kernel was determined by Soxhlet extraction in hexane. The quantitative protein content was determined by the Kjeldahl method, the conversion factor used to calculate the protein content was 6.25.

2.4. Statistical Analysis

The data were analyzed using basic descriptive tools such as the mean and standard deviation of a set of repeated measurements.

The significance level of 5% ($p < 0.05$) was considered for all tests, and data analysis was performed using Statistical Software for Social Sciences (SPSS) from IBM Inc. (Armonk, New York, USA, version 26).

3. Results and Discussion

3.1. Physical Properties

3.1.1. Biometric Characteristics

Biometric assessment is important not only for the differentiation of hazelnut varieties, but also for making decisions about their use and the development of processing equipment. For example, in the food industry, preference is given to spherical nuts, since they are easily processed [15]. Table 1 shows the values of the weight of the fruit, kernels and shells of nuts related to the varieties studied by us. It shows that the peeled fruits of Dash findiq were heavier on average (1.64 ± 0.34 g), and the peeled fruits of Nasimi, Qalib, Mirzebeyli and Sachaqli were lighter on average (0.8 ± 0.23 g, 0.8 ± 0.31 g, 0.8 ± 0.20 g and 0.80 ± 0.09 g, respectively). In the unpeeled form, Dash findiq nuts were the heaviest (3.70 ± 0.34 g), and Nasimi and Qalib nuts were the lightest of all varieties (2.0 ± 0.48 g and 2.0 ± 0.36 g, respectively).

Table 1. Weight of fruits and hazelnut kernels (average value \pm standard deviation).

Образец	Fruit weight (g)	Kernel weight (g)	Shell weight (g)
Ata-baba	2.04 ± 0.25	1.00 ± 0.13	1.04 ± 0.15
Elbari	2.50 ± 0.42	1.00 ± 0.14	1.50 ± 0.41
Topqara	3.00 ± 0.40	1.30 ± 0.19	1.70 ± 0.28
Firovan	2.90 ± 0.25	1.20 ± 0.17	1.70 ± 0.13
Nasimi	2.00 ± 0.48	0.80 ± 0.23	1.20 ± 0.26
Qalib	2.00 ± 0.36	0.80 ± 0.31	1.20 ± 0.20
Mirzebeyli	2.08 ± 0.26	0.80 ± 0.20	1.28 ± 0.17
Tala	3.20 ± 0.26	1.45 ± 0.06	1.75 ± 0.15

Dash findiq	3.70±0.34	1.64±0.34	2.06±0.31
Barli	3.00±0.15	1.25±0.09	1.75±0.10
Azeri	3.10±0.33	1.23±0.18	1.87±0.14
Sachaqli	2.40±0.19	0.80±0.09	1.60±0.20
p-value	<0.05	<0.05	<0.05

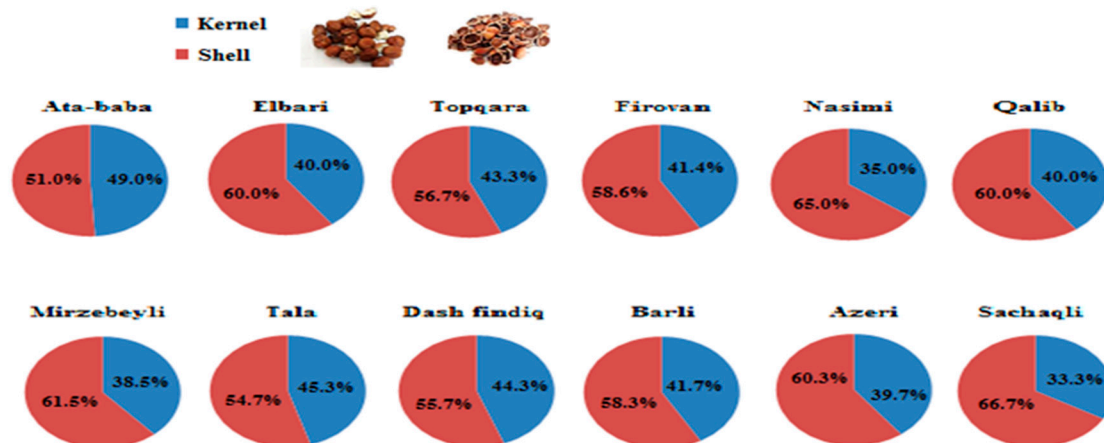


Figure 1. The percentage ratio between the weight of the kernel and the weight of the hazelnut shell.

Figure 1 shows the mass ratio (in %) between the kernel and the shell in the nuts of the studied hazelnut cultivars. It shows that Ata-baba nuts account for 49 masses per kernel. %, which is significantly higher than in other studied varieties (33.3-45.3 wt. %). It was noticed that the differences found between some varieties were statistically significant ($p < 0.05$).

The percentage of the kernel is an important parameter because it determines which part is edible. The results showed that the percentage of the kernel of the cultivars can be divided into three different groups: the first includes Ata-baba (49.0%), Tala (46.3%) and Dash findiq (44.3%), the second includes Elbari (40%), Firovan (41.4%), Qalib (40.0%) and Barli (41.7%), and the third group includes Sachaqli (33.3%), Azeri (39.7%), Mirzebeyli (38.6%) and Nasimi (36.0%). In published studies, it was found that in some other countries and regions the percentage of cores was higher than 40.0% [16,17] or below 40.0 % [18,19].

As shown in Table 2, in the studied hazelnut cultivars, the fruit height varies from 1.53 ± 0.07 cm (Ata-baba) to 1.85 ± 0.13 cm (Azeri) with some differences between some varieties ($p < 0.05$), width – from 1.59 ± 0.10 sm (Nasimi) to 2.22 ± 0.14 sm (Dash findiq). It is important to emphasize that height and width have the same variation profile for each cultivar. The further the value of the width/height ratio is from 1, the fruits are more asymmetric, and values close to 1 indicate that these fruits are more rounded in the equatorial zone. The Nasimi cultivar has rounded nuts in the equatorial zone (the ratio between their width and height is equal to 1.00 ± 0.01); the cultivars Tala, Ata-baba, Firovan and Azeri have rounded-oblong (the ratio between their width and height is within 1.04 ± 0.14 - 1.08 ± 0.08); the varieties Elbari, Qalib Mirzebeyli and Sachaqli are elongated (the ratio between their width and height is within 0.59 ± 0.05 - 0.94 ± 0.04); Topqara, Barli and Dash findiq varieties are oblong (the ratio between their width and height varies from 1.17 ± 0.09 to 1.22 ± 0.11).

Table 2. Biometric characteristics of hazelnut fruits (mean value \pm standard deviation).

Sample	Fruit			Shell Thickness (mm)
	Height (sm)	Width (sm)	Width/Height	
Ata-baba	1.53 ± 0.07	1.65 ± 0.08	1.08 ± 0.06	1.1 ± 0.01
Elbari	1.68 ± 0.09	1.90 ± 0.04	0.60 ± 0.04	1.1 ± 0.02

Topqara	1.76±0.05	2.09±0.17	1.19±0.02	1.3±0.02
Firovan	1.78±0.06	1.91±0.09	1.07 ±0.06	1.6±0.03
Nasimi	1.59±0.10	1.59±0.10	1.00±0.01	1.1±0.01
Qalib	1.55±0.09	1.76±0.16	0.59±0.05	1.1±0.01
Mirzebeyli	1.75±0.07	1.65±0.07	0.94±0.04	1.1±0.02
Tala	1.80±0.13	1.88±0.22	1.04±0.14	1.4± 0.03
Dash findiq	1.82±0.15	2.22±0.14	1.22±0.11	1.3±0.02
Barli	1.69±0.13	1.97±0.14	1.17±0.09	1.1±0.01
Azeri	1.85±0.13	2.00±0.12	1.08±0.08	1.1±0.01
Sachaqli	1.83±0.09	1.70±0.01	0.92±0.03	1.1±0.02
p-value	<0.05	<0.05	<0.05	<0.05

Taking into account the data in Table 3, which presents the average values of the height and width of the smallest and largest kernels for each studied hazelnut variety and their yield (in kg per 1 ton of nuts), it can be concluded that varieties have less limits for varying the height of the kernels, and varieties have their widths. Ata-baba (1.5-1.6 sm), Elbari (1.5-1.6 sm), Topqara (1.5-1.6 sm) and Dash findiq (1.5-1.7 sm) are distinguished by maximum values and less asymmetry in the width of the core.

Table 3. Limits of variation of height and width of hazelnut kernels (average value) and the yield of kernels from 1 ton of hazelnuts, taking into account the percentage of hollow fruits.

Sample	Height (sm)		Width (sm)		Yield of kernels (kg/1 ton of nuts)
	Minimum	Maximum	Minimum	Maximum	
Ata-baba	0.9	1.2	1.2	1.5	490
Elbari	0.9	1.2	1.5	1.6	400
Topqara	1.0	1.9	1.5	1.6	433
Firovan	1.1	1.2	1.3	1.7	424
Nasimi	1.0	1.4	1.2	1.5	360
Qalib	0.8	1.1	1.0	1.6	400
Mirzebeyli	0.9	1.3	1.1	1.5	386
Tala	1.3	1.5	1.2	1.9	453
Dash findiq	0.9	1.1	1.5	1.7	398.7
Barli	1.2	1.3	1.3	1.8	375.3
Azeri	1.0	1.4	1.4	1.7	397
Sachaqli	1.1	1.2	1.1	1.4	299.7
p-value	<0.05	<0.05	<0.05	<0.05	<0.05

According to Yao and Melenbacher [20], cores with a diameter of 1.1 to 1.3 sm are the most suitable for the core market.

As can be seen from the same table, from 1 ton of Ata-baba, Elbari, Topqara, Firovan, Qalib and Tala fruits, ≥400 kg of kernels can be obtained, Ata-baba is significantly ahead of other varieties in the yield of kernels (490 kg / 1 ton of nuts), Tala is in second place in this indicator (453 kg / 1 ton of nuts), Topqara - on the third (433 kg / 1 ton of nuts).

3.1.2. Color and Hardness

The evaluation of color is crucial because it is one of the most important internal properties of food products that influence the choice of food by consumers [21]. According to Fig. 2, it is possible to judge the color of nuts and kernels and shells of the studied varieties of hazelnuts. As for the color of the shell, it was noticed that red color prevailed in all varieties with three distinct groups: the first with a higher intensity of red (varieties Firovan, Dash findiq, Barli, Sachaqli), the second with an average intensity of red (Nasimi, Tala), the third with the lowest intensity of red (Elbary, Topqara, Qalib, Azeri). Whereas Ata-baba and Mirzebeyli varieties occupied an intermediate place between the second and third groups.

According to the yellowness of the shell, more differences were revealed between the varieties and Azeri, Qalib, Topqara and Elbari had the greatest yellowness.

The darkest fruits were Firovan, Dash findiq, Barli and Sachaqli.



Figure 2. Hazelnut color change depending on its cultivar.

Such a textural characteristic as hardness is associated with the mechanical strength necessary for the destruction of the product [22], which in the case of hazelnuts is associated with the mechanical strength necessary for the destruction of the outer shell, which is an important factor because it ensures the physical integrity of the product. It also ensures its ability to withstand the mechanical loads associated with the packaging and transportation process. However, if the hardness is too high, it can create difficulties for industrial workers who need to remove the shell to process hazelnut kernels.

The results showed that the hardness of the shell differed significantly depending on the cultivar: the cultivars with the hardest shell were assigned to the first group, these are Ata-baba, Sachaqli, Mirzebeyli, Dash findiq; the second group (with a shell of slightly lower hardness than the cultivars of the first group) included Elbary, Firovan, Qalib, Tala; to the third – Barli, Nasimi; finally, Topqara and Azeri were assigned to the fourth group with the most easily splitting nuclei. This suggests that the forces required to crush the kernel and perform the cutting of hazelnuts depend on the cultivar.

3.2. Chemical Composition

The results obtained during the physico-chemical analysis of the studied hazelnut fruits are presented in Table 4.

Knowledge of physical properties, such as porosity, in addition to density is very important for the design of storage facilities [23].

The density of kernels, depending on the hazelnut variety, varied from 0.71 ± 0.03 g/sm³ (Azeri) up to 1.03 ± 0.08 g/sm³ (Sachaqli). When analyzing the results obtained, it turned out that, as a rule, the density values of hazelnuts without a shell were higher than those of hazelnuts with a shell, which is expected, given the presence of a significant number of voids between the shell and the core. It was also noted that there were statistically significant differences between the values of densities among the studied samples ($p < 0.05$). Similar results were obtained in a study by Guiné et al. [10].

The moisture content of hazelnut kernels varied from 1.32 ± 0.05 (Dash findiq) to 10.00 ± 0.40 g/100 g (Sachaqli). According to Silva et al. [according to Ferrão et al., 16], the moisture content in hazelnuts in their natural state is 4% - 6 wt. %. As you can see, some of the analyzed samples showed values exceeding the above limit, which may jeopardize the quality of fruits during their storage.

Table 4. Physico-chemical properties of hazelnuts (mean value \pm standard deviation determined for the kernel).

Sample	Moisture (g/100 g)	Fat (g/100 g)	Protein (g/100 g)	Density (kg/cm ³)
Ata-baba	5.01 ± 0.22	64.02 ± 1.10	15.92 ± 0.48	0.89 ± 0.05
Elbari	5.02 ± 0.24	64.04 ± 1.00	11.80 ± 0.36	0.95 ± 0.07
Topqara	10.00 ± 0.39	70.00 ± 2.50	12.40 ± 0.35	0.89 ± 0.04
Firovan	5.03 ± 0.22	75.0 ± 3.08	12.60 ± 0.36	0.92 ± 0.06
Nasimi	1.02 ± 0.04	60.00 ± 1.00	12.50 ± 0.38	0.87 ± 0.05
Qalib	10.00 ± 0.41	50.00 ± 0.20	13.90 ± 0.42	0.96 ± 0.05
Mirzebeyli	1.50 ± 0.06	77.00 ± 2.20	15.04 ± 0.45	0.78 ± 0.05
Tala	1.50 ± 0.07	60.00 ± 1.00	11.90 ± 0.37	0.76 ± 0.04
Dash findiq	1.32 ± 0.05	68.00 ± 2.00	15.02 ± 0.43	0.92 ± 0.06
Barli	5.10 ± 0.24	64.20 ± 1.05	13.90 ± 0.40	0.86 ± 0.05
Azeri	5.20 ± 0.23	64.30 ± 1.00	13.80 ± 0.38	0.71 ± 0.03
Sachaqli	10.00 ± 0.40	60.02 ± 2.03	16.02 ± 0.50	1.03 ± 0.08
p-3value	<0.05	<0.05	<0.05	<0.05

It is important to emphasize that fat was the main component for all varieties, from 50.00 ± 0.20 g/100 g (Qalib) to 77.00 ± 2.20 g/100 g (Mirzebeyli). However, taking into account statistical analysis, the only result on fat content that significantly differed was the result with a low value presented for Qalib. These results are slightly higher than the results obtained by Oliveira et al. [24] and Ferrao et al. (16) for Portul hazelnuts (from 46.04 ± 1.53 g/100 g to 72.50 ± 3.79 g/100 g).

In the studied samples, the quantitative protein content ($p < 0.05$) varied from 11.80 ± 0.36 g/100 g (Elbari) to 16.02 ± 0.50 g/100 g (Sachaqli). Oliveira et al. [24] reported protein values in the range of 14.8–15.7 g/100 g, and, consequently, some of the samples evaluated in this work had higher values, while others had lower protein content.

According to studies by other authors, the composition of the hazelnut kernel on average consists of 60% fat, 15% crude protein and 4% moisture [25].

Thus, these results can be very important for hazelnut producers and specialists engaged in this sector of the food industry.

4. Conclusions

This study has yielded results that have made it possible to compare different cultivars of hazelnuts; they are important for Azerbaijani agricultural producers and retailers to better understand the characteristics of different cultivars of hazelnuts and can become a tool that facilitates the choice for all players in the hazelnut sector, taking into account its specific future applications.

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