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ORIGINAL ARTICLE

Evaluation of some Biochemical Properties of Kernel in Different Hazelnut Cultivars

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K E Y W O R D S

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A B S T R A C T

European hazelnut (*Corylus avellana* L.) is one of the most widely used nuts because of its nutritional and health-beneficial properties. This study was carried out to determine some biochemical kernel constituents including fatty acid composition and protein content in 25 different hazelnut cultivars collected from three regions in the north of Iran. The total saturated fatty acid content and the total unsaturated fatty acid content were significantly different. Also, the amounts of both main saturated and unsaturated fatty acids were found to be significantly different. Oleic and linoleic acids were the main unsaturated fatty acids existing in the studied cultivars. The highest (78.02%) and the lowest (72.89%) content of oleic acid were determined in the cultivars ‘Vartashen’ and ‘Atrak’, respectively. Also ‘Ganjeh’ contained the highest (10.91 %) and ‘Bootkhaneki’ contained the lowest (9.48%) levels of linoleic acid, respectively. The major saturated fatty acids were palmitic acid (ranging from 5.73% in ‘Alipour’ to 6.87 % in ‘Atababa’) and stearic acid (ranging from 2.14% in ‘Atrak’ to 3.62 % in ‘Nemsa’). In addition, protein content ranged from 14.75% (Kolaparak) to 17.74% (Gerde-Eshkevar). The results obtained from the studied cultivars can be important for establishing new orchards and also in breeding programs.

Introduction

The European hazelnut (*Corylus avellana* L.) is one of the most important tree nut crops mostly grown in temperate climate zones with relatively high humidity and a high rainfall rate (Kole, 2011). Iran is the eighth main hazelnut producer in the world (FAOSTAT, 2019).

About 400 kinds of hazelnut cultivars have been selected from the wild, from which about 20 are grown commercially worldwide (Mehlenbacher, 1991; Vahdati *et al.*, 2023). Hazelnuts are mostly grown on their own roots while some clonal rootstocks have been introduced and used recently (Vahdati *et al.*, 2011).

Almost 90% of the hazelnut crop is used as kernels in the food industry, and the rest is sold in-shell for fresh consumption (Valentini *et al*., 2006). Nut fruits are cholesterol-free and rich in important nutrients, including vegetable protein, fiber, and unsaturated fatty acids (Brufau *et al*., 2006; Sarikhani *et al*., 2021; Ghezel *et al*., 2022). The lipid characteristics are crucial factors in determining the nut quality and shelf life that can be imperative in

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taste, the nutritional quality of the fresh and processed kernel, and human health Chatrabnous *et al.*, 2018; Pakrah *et al.*, 2021).

The nutritional properties of hazelnuts and their health benefits regarding the richness of high-value fatty acids have been highlighted (Richardson, 1997; Salas-Salvadò & Megias, 2005). Hazelnut has a main role in human nutrition and health because of its particular fat content (about 60%), predominantly oleic acid, protein, carbohydrate, vitamins, and minerals (Alasalvar *et al*., 2003, 2006, 2010; Bacchetta *et al*., 2013; Ciarmiello *et al*., 2014). In hazelnut kernels similar to many other nut trees, oleic and linoleic acids are essential components (more than 90% of the fatty acid composition) besides small amounts of palmitic and stearic acids (Alasalvar *et al*., 2006; Xu *et al*., 2007; Ghezel *et al*., 2022). In addition, because of the particular fatty acid profile and biochemical and nutritional properties of hazelnuts, its oil is considered beneficial for food processing and industrial purposes (Xu & Hanna, 2010). There is a growing interest in evaluating the role of hazelnuts in human nutrition and health as a promising source of oleochemicals (Alasalvar *et al*., 2006).

The total lipid content and fatty acid composition contribute to hazelnut nutritional quality (Botta *et al*., 1994) and nut shelf life (Bonvehí & Coll, 1993). Studying the characteristics of nut and kernel can help understand the relationship between traits of hazelnut cultivars and the environmental factors affecting this nut tree's growth. Therefore, hazelnut cultivars should be studied to analyze these parameters. Such information can greatly help postharvest processes and the food industry (Köksal *et al*., 2006; Turan, 2018). Cristofori *et al*. (2008) studied some nut and kernel characteristics and chemical composition in 24 hazelnut cultivars grown in Italy for three consecutive years and found significant differences.

This study aimed to determine some biochemical traits of the kernel in 25 hazelnut cultivars grown in Iran, including the types and amounts of total and main saturated and unsaturated fatty acids in three consecutive years.

Materials and Methods

This study was carried out in three years (2020, 2021, and 2022) in three parts of Guilan Province, Iran namely Astara (38° 25′N), Roodsar (36° 51′N), and Amlash (37° 52′N). 25 selected hazelnut cultivars and genotypes were as follows: ‘Ronde du Piemonte’, ‘Barcelona’, ‘Segorbe’, ‘Atrak’, ‘Ganjeh’, ‘Morfineski’, ‘Sochi’, ‘Nemsa’, ‘Footborami’, ‘Fosha’, ‘Boliba’, ‘Docomineski’, ‘Dorercheh’, ‘Vartashen’, ‘Atababa’, ‘Koban’, ‘Pioner’, ‘Kestien’, ‘Kalib’, ‘Proones’, ‘Bootkhaneki’, ‘Nakhonie’, ‘Kolaparak’, ‘Alipour’, and ‘Gerde-Eshkevar’. The experiments were conducted in the central laboratory at the University of Mohaghegh Ardabili, Ardabil, Iran.

Hazelnuts were cracked before chemical analysis, and then the kernels were chopped. Kernel fat content was determined through the Soxhlet extraction method using hexane as the solvent (AOAC, 1990). The dried powdery sample (2.5 g) was used, and the oil was extracted in a SOX606 Automatic Soxhlet Extractor (SOX606 Automatic Soxhlet Extractor-China) for 2 hours with the heating source at 135°C. The oil content was calculated as follows:

$$\%\ \text{Oil Content} = \frac{\text{Weight of Oil}}{\text{Weight of Sample}} \times 100$$

The kernel's protein quantity was measured by the micro Kjeldahl method (MQ3868B/E-UK). Protein content was calculated as a total N × 6.25 (James, 1995).

Analysis of kernel oil was carried out through gas chromatography (GC) (Agilent 7820 A-USA) to determine the fatty acid composition. The method described by Ficarra *et al*. (2010) was applied to prepare the methyl esters of fatty acids.

All analyses were performed in triplicate for each cultivar. The data were analyzed by analysis of variance (ANOVA) using the GLM procedure of SAS software version 9.1 for Windows (SAS Institute, 2001). The Duncan comparison test was used to distinguish differences among the cultivars.

Results

Fatty acid content

The total content of unsaturated and saturated fatty acids significantly differed among the studied cultivars ($P \leq 0.05$). In all cultivars, the amounts of unsaturated fatty acids, mostly oleic and linoleic, were significantly higher than the saturated fatty acids, mostly palmitic and stearic acids (Tables 1 and 2). Among the studied hazelnut cultivars, the highest unsaturated fatty acid belonged to 'Vartashen' (88.09 %) and 'Dorercheh' (88.03 %), and the lowest amounts of them were determined in 'Kestien' (83.72 %) and 'Atrak' (83.74 %) (Table 1).

The highest oleic acid (78.02 %) was recorded in the cultivar 'Vartashen which was not significantly different from the cultivars 'Dorercheh', 'Kalib', 'Nemsa', 'Proones', 'Gerde-Eshkevar', 'Ronde du Piemonte', 'Sochi', 'Ganjeh', 'Segorbe', 'Morfineski', and 'Barcelona' (Table 1). The lowest oleic acid content (72.89 %) was observed in the cultivar 'Atrak', which was not significantly different from the cultivars, 'Kestien', 'Pioner', 'Alipour', 'Footborami', 'Koban', 'Docomineski', and 'Fosha' ($P \leq 0.05$) (Table 1).

Linoleic acid, ranking the second main unsaturated fatty acid in the selected cultivars, was the highest in the cultivars 'Ganjeh' (10.91 %) and 'Barcelona' (10.89 %). They did not show significant difference with the cultivars 'Atrak', 'Pioner', 'Proones', 'Nakhoni', 'Ronde du Piemonte', 'Fosha', 'Morfineski', 'Segorbe', 'Docomineski' and 'Sochi'. And the lowest content of this fatty acid (9.48 %) was found in the cultivar 'Bootkhaneki' which was statistically similar to the cultivars 'Alipour' and 'Kalib' (Table 1).

Table 1. Content of two main unsaturated fatty acids in kernel of 25 hazelnut cultivars.

Cultivar	UNSFA* (%)	Oleic Acid (%)	Linoleic Acid (%)
Ronde du Piemonte	87.01^{ae}	76.54^{ae}	10.47^{ag}
Barcelona	87.32^{ad}	76.43^{af}	10.89^{a}
Segorbe	86.65^{af}	76.22^{af}	10.42^{ah}
Atrak	83.74^{h}	72.89^{j}	10.84^{ab}
Ganjeh	87.39^{ac}	76.48^{ae}	10.91^{a}
Morfineski	86.64^{af}	76.19^{af}	10.44^{ah}
Sochi	87.21^{ad}	76.52^{ae}	10.69^{ac}
Nemsa	87.74^{ab}	77.53^{ac}	10.2^{ch}
Footborami	84.88^{fh}	74.51^{fj}	10.36^{bh}
Fosha	85.31^{ch}	74.85^{ej}	10.45^{ag}
Boliba	86.23^{ag}	76.02^{bg}	10.21^{ch}
Docomineski	85.09^{dh}	74.66^{ej}	10.42^{ah}
Dorercheh	88.03^{a}	77.89^{ab}	10.13^{dh}
Vartashen	88.09^{a}	78.02^{a}	10.07^{eh}
Atababa	85.4^{ch}	75.18^{di}	10.22^{ch}
Koban	84.62^{fh}	74.61^{ej}	10^{eh}
Pioner	84.45^{fh}	73.82^{hj}	10.62^{ad}
Kestien	83.72^{h}	73.35^{ij}	10.37^{bh}
Kalib	87.82^{ab}	77.85^{ab}	9.97^{gi}
Proones	87.85^{ab}	77.29^{ac}	10.55^{ae}
Bootkhaneki	84.39^{gh}	74.9^{ei}	9.48^{i}
Nakhonie	85.48^{ch}	74.99^{di}	10.48^{af}
Kolaparak	85.64^{bg}	75.71^{ch}	10.3^{ch}
Alipour	84.15^{gh}	74.08^{gj}	9.93^{hi}
Gerde-Eshkevar	87.19^{ad}	76.88^{ad}	10.07^{eh}

*UNSFA: Unsaturated Fatty Acid

On the other hand, palmitic and stearic acids were determined as the dominant saturated fatty acids in the studied cultivars (Table 2). In this research, the cultivars ‘Atababa’ (6.87 %) and ‘Alipour’ (5.73 %) contained the highest and lowest palmitic acid, respectively (Table 2). In addition, the stearic acid content in the evaluated cultivars ranged from 3.62 % (Nemsa) to 2.14 % (Atrak) (Table 2).

Table 2. Content of saturated fatty acids in kernel of 25 hazelnut cultivars.

Cultivar	SFA*(%)	Palmitic acid (%)	Stearic acid (%)
Ronde du Piemonte	10.34^{pv}	6.16^{rx}	2.85^{hp}
Barcelona	10.56^{jr}	6.61^{jq}	2.85^{gp}
Segorbe	9.84^{az}	6.44^{kt}	2.45^{pq}
Atrak	9.17^{hk}	6.43^{lt}	2.14^{q}
Ganjeh	9.72^{bf}	6.3^{ov}	2.5^{oq}
Morfineski	9.99^{az}	6.38^{mu}	3.17^{cj}
Sochi	11.17^{ce}	6.37^{nu}	3.56^{ad}
Nemsa	11.16^{ce}	6.79^{fm}	3.62^{ab}
Footborami	9.97^{az}	6.57^{kr}	3.04^{fl}
Fosha	9.74^{af}	6.45^{kt}	2.68^{lp}
Boliba	8.94^{kl}	5.75^{xy}	2.78^{ip}
Docomineski	10.14^{sy}	6.12^{sy}	3.13^{dj}
Dorercheh	10.38^{nu}	6.47^{kt}	2.98^{fm}
Vartashen	10.64^{iq}	6.69^{io}	2.93^{fo}
Atababa	10.15^{sy}	6.87^{dk}	2.53^{nq}
Koban	9.93^{az}	6.72^{ho}	2.51^{oq}
Pioner	9.39^{fi}	6.45^{kt}	2.51^{nq}
Kestien	9.94^{az}	6.24^{pw}	2.75^{jp}
Kalib	10.56^{jr}	6.63^{jp}	3.08^{el}
Proones	10.87^{ek}	6.81^{fl}	3.1^{el}
Bootkhaneki	10.26^{rx}	6.52^{ks}	3.03^{fl}
Nakhonie	9.50^{eh}	6.2^{qw}	2.53^{nq}
Kolaparak	9.36^{gj}	5.84^{wy}	2.68^{kp}
Alipour	10.09^{az}	5.73^{y}	2.77^{ip}
Gerde-Eshkevar	10.31^{qw}	5.98^{uy}	2.77^{jp}

*SFA: Saturated Fatty Acid

Protein content in kernel

In this study, ‘Gerde-Eshkevar’, as a local cultivar, contained the highest amount of protein (17.74 %). ‘Kolaparak’, as another local cultivar, had the lowest protein content (14.75 %) (Table 3).

Table 3. Protein content in kernel of 25 hazelnut cultivars.

Cultivar	Protein (%)
Ronde du Piemonte	16.94[aw]
Barcelona	17.15[ar]
Segorbe	15.56[iw]
Atrak	15.6[hw]
Ganjeh	14.94[tw]
Morfineski	16.91[aw]
Sochi	17.22[ar]
Nemsa	16.69[aw]
Footborami	15.66[hw]
Fosha	15.18[pw]
Boliba	14.88[uw]
Docomineski	16.50[aw]
Dorercheh	16.94[aw]
Vartashen	16.65[aw]
Atababa	15.68[hw]
Koban	15.31[nw]
Pioner	14.96[sw]
Kestien	16.19[cw]
Kalib	16.67[aw]
Proones	16.36[aw]
Bootkhaneki	15.13[rw]
Nakhonie	14.85[vw]
Kolaparak	14.75[w]
Alipour	17.44[ao]
Gerde-Eshkevar	17.74[ah]

Discussion

The amounts of unsaturated fatty acids were in agreement with the results reported by Xu *et al*. (2007), Oliveira *et al.* (2008), Cristofori *et al*. (2008), Rovira *et al*. (2014), and Turan (2018). Fatty acid content of hazelnut kernel varies based on several factors such as cultivar, soil and climatic conditions, cultural practices, nut maturity, and harvest time (Alasalvar, 2010). According to Cittadini *et al*. (2020), oleic acid predominated largely (78.4-84.4 %) in hazelnut oil. Köksal *et al*. (2006) reported that oleic acid (74.2-82.8%) was the dominant fatty acid in 17 evaluated Turkish hazelnut cultivars. The minimum amount of oleic acid in the cultivars evaluated by Müller *et al*. (2020) (65.1 %) was lower than the result of the studied cultivars in this study (72.89 %). However, the highest content of this substance in this research (78.02 %) was lower than the amount reported by Müller *et al*. (2020) (81.7%). In addition, this fatty acid was found to be the main one (80.6%) in American hazelnut (*C. americana* Marshall) (Lane *et al*., 2012).

According to Müller *et al*. (2020), the content of this fatty acid in hazelnut can make up as much as 70% of all existing fatty acids in the kernel. This fact highlights how crucial this substance can be in the quality of the final produced kernel. Oleic acid is considered the main reported monounsaturated fatty acid in human body fat (Tsikas *et al*., 2011) and plays a main role in immune function (Yaqoob, 2002). It can also control cardiovascular risk factors and decrease total cholesterol and low-density lipoprotein cholesterol (Flider, 2022).

In terms of linoleic acid, the same results have been reported by Cristofori *et al*. (2008), Baldwin (2009), and Rovira *et al*. (2014). Linoleic acid, like other dietary fatty acids, is a considerable biological regulator and has main medicinal health-related properties (Yang *et al*., 2015). It is the most existing polyunsaturated fatty acid in the human diet and is known as an essential fatty acid and has a major role in the growth of infants (Marangoni *et al*., 2020).

Content of palmitic acid has been recorded 5.87 % in the cultivars ‘Tombul’ and ‘Sivri’ (Köksal *et al*., 2006) and about 5% in all studied cultivars by Müller *et al*., (2020). The main saturated fatty acids in the Western diet are palmitic and stearic acids found in plant and animal food products (Berry, 2009). According to Carta *et al* (2017), main common cooking oils contain high saturated fats. For instance, palmitic acid was a constituent of palm oil (44 %), cocoa butter (26%), and olive oil (8-20%). In addition, Fatima *et al*. (2019) have reported palmitic acid as a common fatty acid in the human diet that can cause several diseases, such as cardiovascular diseases, neurodegenerative diseases, and inflammation.

Balik (2021) reported the amount of Stearic acid between 1.93 % and 11.2 %, with the greatest value in the cultivar ‘Incekara’. Stearic acid is a saturated fatty acid that in contrast to other long-chain saturated fatty acids, does not raise plasma LDL cholesterol (Aro *et al*., 1997).

Overall, saturated fat is known to be harmful to health. Hence their recommended dietary intake is less than 10 % of the total daily fat consumption. Although stearic acid is a saturated fatty acid, its impact on health notably differs from palmitic acid (Crupkin & Zambelli, 2008). Compared with palmitic acid, stearic acid can lower low-density lipoprotein cholesterol, a serious risk factor in coronary heart disease (Rooijen & Mensink, 2020).

Because of the high ratio of unsaturated to saturated fatty acids in hazelnut, processed food containing this ingredient can be notably enriched (Bonvehi & Coll, 1993; Ebrahem *et al*., 1994).

Protein content ranged from 11.7 % to 20.8 % in hazelnut cultivars grown in Turkey (Köksal *et al*., 2006). According to Müller *et al*. (2020), in some hazelnut cultivars harvested in Germany, the highest crude protein content was in the cultivar Corabel (22.1 %) and the cultivar Cosford contained the lowest (10.2 %) protein content.

Protein has a variety of biological functions (e.g., kinetic and structural) in the body (Jahanbani et al., 2018; Hoffman & Falvo, 2004; Vasdev & Stuckless, 2010). The recommended daily intake of protein is 0.8 g per kg body weight for an individual (WHO, 2007). According to the results of this research and previous related studies, like other nuts, hazelnut is considered an important source of protein in a healthy diet (Brufau *et al*., 2006).

High animal protein intake can cause serious health problems, such as diabetes and cardiovascular diseases (Shu *et al*., 2015; Rosato *et al*., 2014). Accordingly, plant-based protein sources such as nuts are encouraged as alternatives to animal products to provide dietary protein needs.

Conclusions

This paper showed that hazelnuts have a high content of unsaturated fatty acids and contain comparably small amounts of saturated fatty acids. Based on the results obtained in this study, the major unsaturated fatty acids were oleic and linoleic, and the main saturated fatty acids were palmitic and stearic. Hazelnut kernel was found to be a considerable source of protein. The results of this research can be particularly notable for increasing the knowledge about the diversity of hazelnut germplasm and its nutritional value. In addition, the recorded data can be utilized in the food industry and breeding programs.

Conflict of interests

The authors declare no conflicts of interest with respect to the research, authorship, and publication of this paper.

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