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ORIGINAL ARTICLE

The Effectiveness of Hazelnut Cultivars and Genotypes on Sensory, Physical, and Chemical Properties of Chocolate Cream

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K E Y W O R D S

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A B S T R A C T

Chocolate is made from roasted and ground cocoa seeds and used on its own or as a flavoring to prepare various desserts. The high price of cocoa butter and the need for tempering operations have reduced the desire of chocolate manufacturers to use this product. As a result, high-quality, lower-priced substitutes for cocoa butter are increasingly being used in the preparation of chocolate. Hazelnut (*Corylus avellana* L.) is one of the most commonly used nuts as an additive in the preparation of sweets and chocolates, and its cultivation has increased in recent decades. In the present study, the paste of two varieties (Round de Peymon and Segrob hazelnuts) and two genotypes (Eshkevar 1 and Eshkevar 3 hazelnuts) of hazelnut was used instead of cocoa cream to prepare chocolate cream. After the preparation of this cream, its physicochemical (fat, protein, peroxide, sugar, moisture, acidity, ash, and viscosity) and sensory (color, taste, odor, texture, and overall acceptability) properties were evaluated. The results showed that the highest protein content, the lowest moisture content, and the highest overall acceptability were associated with Eshkevar 3 hazelnut. In conclusion, this variety is a promising approach for producing chocolate cream with reasonable quality and price. The cultivation of this hazelnut genotype is recommended to gardeners and growers.

Introduction

The hazelnut (*Corylus avellana* L.) from the family Betulaceae is one of the important nuts in the world, prized for its unique properties, including good taste and high nutritional value (Zare and Hazrati, 2025). This plant is mainly cultivated in regions with temperate climates (Zare and Hazrati, 2025). Worldwide, Turkey, Italy, and the United States are among the largest producers of hazelnuts. According to global statistics, Turkey is the largest producer of this product, producing more than 70% of the world's hazelnuts. With an annual production of about 25,000 tons of hazelnuts, Iran is one of the region’s important producers (FAO, 2022). The area under hazelnut cultivation in Iran is about 20,000 hectares, mostly including Ardabil, Eshkevarat, Navan, Tarom, Dinochal, Alamut, Goli Dagh, Guilan, Mazandaran, and Golestan provinces (Zare and Hazrati,

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2025).

The hazelnut fruit is inside a hard shell called involucre, which turns brown when ripe. Hazelnut harvesting usually ranges from late summer to early autumn (Mehlenbacher, 2018). Some varieties and genotypes of hazelnuts are native to Iran, others are imported. Pashmineh (with a thin skin and high brain content), Shastak (round shape and excellent taste), round (large and easy to break), Segrob, and Eshkevar hazelnuts are native and well-known varieties and genotypes in the northern mountainous regions of Iran, especially in Guilan province. Despite this diversity, some indigenous and old varieties of hazelnuts in Iran, such as the hazelnut Eshkevar, are at risk of extinction. The conservation and restoration of these varieties contribute both to the maintenance of genetic diversity and the development of native species in Iran (Sayadi *et al.*, 2012). Moreover, the revival of these native species can be very useful for improving the quality of hazelnuts and optimizing their nutritional and sensory quality (Mousadoost *et al.*, 2018; Ershadi & Farrokhi, 2022; Hassani *et al*., 2022; Bostan & Karakaya, 2024).

With scientific advances in chocolate processing technology and the development of the chocolate industry, it has become possible to produce new types of chocolate products containing hazelnuts. The unique characteristics of hazelnut in terms of chemical composition, technological properties, taste, and nutritional value have made it a key ingredient in the formulation of chocolate cream. Scientific research into the chemistry and physics of chocolate has made it possible to improve the technology of combining hazelnuts with chocolate. Also, the use of modern processing methods such as tempering and proper storage improved the quality and extended the lifespan of chocolate products containing hazelnuts (Król & Gantner, 2020; Yılmaz & Öz, 2024; Santagiuliana *et al*., 2018). During the 20th century, consumers' desire for natural and healthy products has increased, and chocolate products with hazelnuts have become more popular and diverse. The manufacturing of different varieties of hazelnut chocolate spreads, and the incorporation of hazelnuts in chocolate bars and chocolate confections has gained widespread popularity (Granato & Masson, 2010; Mahmood & Bozkurt, 2024).

Due to its high-fat content (50-60%), hazelnut is used as one of the main ingredients in the recipe of chocolate cream (Mehlenbacher, 2018). This fatty content causes the chocolate cream to easily melt in the mouth and create a pleasant sensation when consumed and also leads to thermal characteristics including the appropriate melting and freezing temperature in its processing (Jin *et al*., 2024; Król & Gantner, 2020; Yılmaz & Öz, 2024). Phenolic and antioxidant compounds such as tocopherol also contribute to oxidative stability and increase the shelf life of chocolate cream. In addition, hazelnuts contain various vitamins, minerals, and bioactive compounds that improve the nutritional value of this cream, and the flavorings in hazelnuts contribute to its desired taste and aroma. In addition, the natural pigments in hazelnuts create the desired appearance and color in chocolate cream (Mahmood & Bozkurt, 2024).

Iran has the potential to significantly influence the global hazelnut market due to its hazelnut varieties and favorable climatic conditions. Continuous research and development regarding the quality and performance of hazelnut varieties can increase the production and quality of this product. This improvement not only increases Iran's share of the world market and improves the economic situation of farmers, but will also lead to the sustainable development of hazelnut-growing areas.

The main objectives of this research were the selection of native hazelnut species with high nutritional value and the investigation of factors affecting the nutritional quality of chocolate cream produced with hazelnut cultivars. In this research, the qualitative characteristics of three indigenous and deep-rooted hazelnut varieties and genotypes in Iran (hazelnuts Segrob, Eshkevar 1, and Eshkevar 3) were investigated to preserve and revive them to maintain genetic diversity and nutritional value. This qualitative assessment of hazelnuts can improve formulation performance and production of chocolate cream with stable quality. It can be used as an innovative and valuable solution to improve physicochemical properties and bioactive and health-promoting compounds in the chocolate industry. In addition, this innovation can yield high-value products with strong competitiveness in the consumer market.

Materials and Methods

The hazelnut cultivars (Round de Peymon and Segrob) and genotypes (Eshkevar 1 and Eshkevar 3) used for this research (Fig. 1) were obtained from Eshkevarat Hazelnuts Research Station in Roudsar, Guilan, Iran in September 2022. This station is located at the coordinates of longitude 36° 48′ 94″ and latitude 50° 52′ 29″. Its altitude is 22 meters above sea level, its average rainfall is 1200 mm, and its average daily temperature is 15.8°C. The soil texture of the area is sandy with an acidity of 6.8. Hazelnuts Round de Peymon, Segrob, Eshkevar 1, and Eshkevar 3 are native to Italy, Spain, and Iran respectively. After harvesting, these fruits were transferred to the physiology and postharvest laboratory, Faculty of Agriculture, Zanjan University, Iran. The evaluation of their quantitative properties was done immediately after the preparation. Then 2 kg of each hazelnut variety were harvested and dried in an oven at 30°C in a dark place for 5 days. Then, they were put in plastic bags and stored in a dry place.

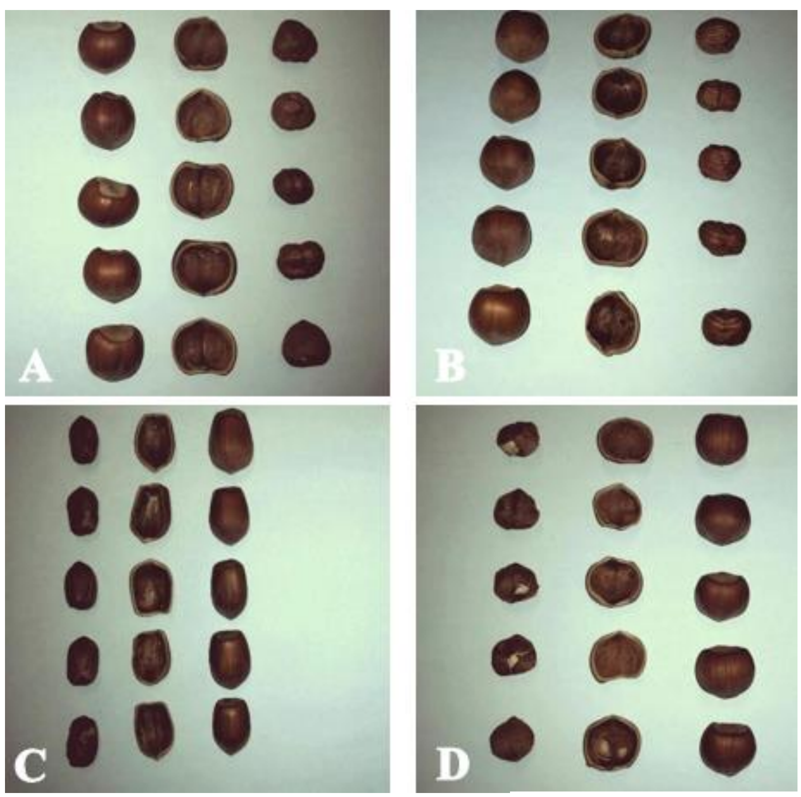

Fig. 1. Hazelnut varieties and genotypes used in the present research. (A) Hazelnuts Round de Peymon; (B) Segrob; (C) Eshkevar 1 and (D) Eshkevar

Measurement of some physicochemical characteristics in hazelnut fruit

Moisture based on fresh weight

After removing the green cover of the fruits and cleaning them, their fresh weight (immediately after harvesting) was measured by a scale. Then, they were transferred to an oven with a temperature of 45-50°C. Drying continued until no weight loss was observed in the fruits. According to the difference in weight of the samples before and after drying, their moisture based on fresh weight showed the initial moisture content (AOAC, 2005).

Dry matter

The total amount of nutrients without considering moisture is called dry matter. Dry matter includes protein, fat, raw fiber, and mineral elements. To measure the percentage of dry matter in the sample, the rate of obtained moisture was subtracted from 100 (AOAC, 2005).

Protein

The micro Kjeldahl method was used to determine the crude protein of hazelnuts (AOAC, 2005). This method includes two stages: distillation and titration. In the first stage, the nitrogen in the food is converted into ammonium sulfate using concentrated sulfuric acid and a catalyst. In the second stage, the desired solution was boiled and ammonia was released by adding 60-70% sodium hydroxide solution to the digested materials. In this stage, sulfuric acid was used to titrate ammonium. The crude protein content was obtained by calculating the amount of nitrogen in the coefficient of 6.25.

Crude fat

Crude fat is defined as an ethereal decomposition component. After dissolving the food material in an ether solvent, the dissolved fat in the sample in the balloon is obtained. Since fat contains a different group of organic substances regarding its solubility in ether, it has a common feature with -N-hexane, benzene, and other organic solutions. Soxhlet apparatus was used to measure crude fat (AOAC, 2005). First, the weight of the dried balloons (250 ml) was noted in the oven, then 3 g of powdered hazelnut kernels were put in a cover of filter paper and placed in the extracting part of the Soxhlet device inside the device cartridge. After connecting the balloon to the device, two-thirds of the balloon volume was filled with ether solvent, and the temperature was set to 60°C. The fat extraction process lasted for 8 hours. First, the balloon was put in the rotary device for half an hour, then the remaining solvent was separated from the fat and weighed again. The difference between the secondary and initial weight of the balloon was calculated to determine the amount of extracted fat.

Preparation of chocolate specimens

First, the prepared hazelnuts were crushed by a mill (RM-100 model, Higao Tech. Co. Ltd. China). This process continued until the ground hazelnuts turned into paste. Different cultivars and genotypes were used to prepare samples of hazelnut chocolate cream. A sample without hazelnuts was considered as a control group. At first, the oil was melted in a warm house at 60°C, and then cocoa powder, dry milk, sugar, and vanillin were added. All the raw materials were weighed by a scale with an accuracy of 0.01 g and the obtained mixture was kneaded by a mixer designed in the laboratory at a speed of 85 rpm for 3 h at a temperature of 45°C. To better mix the ingredients and improve the kneading process, several stainless and anti-wear balls with a diameter of 8 mm were added to the above mixture. 10 g of oil and 5 g of lecithin were added in the last 30 min of kneading. The prepared samples were kept in a warm house with a temperature of 50°C for 12 h. Then, the samples were transferred to molds and kept in them. The control sample was prepared similarly, with the difference that hazelnuts were not used in the composition (Afoakwa, 2016).

Measurement of some physicochemical characteristics in chocolate

Moisture

A certain amount of the sample was weighed and placed in an oven at 105°C until reaching a constant weight (AOAC, 2005). Then, it was placed in a desiccator to be cooled and weighed.

Acidity

Acidity was measured by ethanol, phenolphthalein indicator solution, concentrated potassium hydroxide, and titration method (AOAC, 2005).

Fat

To measure fat about 3 g of the sample was placed in a 300 ml beaker, and to prepare a uniform suspension, 45 ml of boiling distilled water was added while stirring the sample (AOAC, 2005). Then, 55 ml of 8 N hydrochloric acid and a few fat-free baking stones were added to the suspension. This mixture was placed on an electric stove, heated slowly to reach the boiling point, and kept at a gentle boil for 15 min. Then, the digested suspension was passed through the filter paper and the filter was transferred to the fat-free extraction ring (cartridge) and dried in the oven at 100°C for 2 h. Then, the cartridge containing the dried sample was placed in the machine. A cartridge containing the dried specimen was placed in Soxhlet, washed with petroleum ether solvent, and refluxed for 8 to 16 hours. After the evaporation of the solvent, the fat percentage was calculated (AOAC, 2005).

Sugar

The amount of sugar was measured and calculated using Fehling's solution and Lane-Eynon Table (Shakerardekani, 2013).

Viscosity

The viscosity of breakfast chocolate samples was determined using a Spanish Fungilab viscometer device. 200 ml of chocolate was poured into the bowl and after weighing, it was liquefied in a bain-marie at 42.5°C. Then, the viscosity of the samples was determined with 4 spindles, 12 rpm speed, and 85.7% torque (McGill and Hartel, 2018).

Protein

To measure the protein in chocolate, 0.35 g of selenium oxide was poured into a balloon and 100 ml of concentrated sulfuric acid was added to it. The resulting black solution was heated to 330°C with rotation. The heating process continued until it became colorless. Then, the decolorized solution was cooled and 2.7 g of salicylic acid was added. After adding acid, the solution turned into a yellow solution. Then, about 0.3 g of the chocolate cream sample was poured into the tubes of the Kjeldahl device and 2.5 ml of the produced yellow solution was added. The resulting mixture was kept overnight. After this period, the existing solution was placed in the digestion block heated to 100°C and then cooled. Then, 3 ml of hydrogen peroxide (H_2O_2) was added and heated to 330°C until the sample became colorless. After cooling, 48.3 ml of concentrated sulfuric acid was added to them and stirred. The resulting solution was filtered, and the passing solution was poured into a container and kept in the refrigerator. The next day, the sample was placed in the Kjeldahl device (model 1030, Sweden), and its corresponding number was read. To calculate the protein in cocoa powder, the obtained nitrogen number was multiplied by 9.75 and then the obtained number was multiplied by 6.25. The resulting number was reported as the chocolate protein percentage (AOAC, 2005).

Sensory assessment

The taste panel experiment involved 10 trained evaluators between the ages of 25 and 45, comprising both males and females. They were presented with chocolate samples labeled with random 3-digit codes. They were then asked to rate various qualitative aspects of the chocolate, such as color, aroma, smell, taste, sweetness, hardness, melting sensation, and texture. The rating was given on a scale from 1 to 5, with 5 indicating the highest quality and 1 indicating the lowest quality. The duration of the test was not specified in the search findings. The results suggest that the experiment aimed to minimize variables by melting the chocolates and shaping them uniformly to avoid any bias based on appearance. Furthermore, the evaluators were unaware of participating in an experiment and were informed that it was a chocolate-tasting session.

Experimental design and statistical analysis

The experiment was conducted in a completely randomized block design in 3 replications for 2 cultivars and 2 genotypes of hazelnuts. Fruits in the ripening stage (when 30% of their color changed to brown) were picked manually and randomly from all sides of the tree. The statistical population was chocolate produced in the laboratory. The volume of samples was equal to 15 according to the 5 existing treatments (including the control treatment) and 3 repetitions for each treatment. The tests were performed on the prepared samples immediately after the production of chocolate cream. Means were compared with Duncan's multi-range test at a significance level of 99%. Data analysis was done using SPSS (ver. 19) software and graphs were drawn with EXCEL software.

Results

Nutritional value of hazelnut varieties and genotypes

Table 1 compares the amount of moisture, dry matter, protein percentage, and crude fat of the studied varieties and genotypes. Analysis of variance of the obtained data confirmed the effect of cultivar and genotype on the level of average values of the measured parameters (moisture, dry matter, protein, and crude fat percentage) ($p < 0.01$) (data not shown). The mean comparison of the data showed that the highest content of moisture (3.1%) and dry matter (96.81%) was related to Eshkevar 1 hazelnut. The protein percentage of Eshkevar 3 hazelnut (10) was the highest. Eshkevar 1 Hazelnut also had a high protein content (9.4%) compared to the two cultivars studied (8.03 and 6.33% for Round de Peymon and Segrob hazelnuts, respectively). On the other hand, the crude fat of the two cultivars of hazelnuts Round de Peymon and Segrob was higher than that of Eshkevar 1 and Eshkevar 3 genotypes hazelnuts (Table 1). The highest crude fat content (71.34 g) was obtained from Round de Peymon hazelnut. The amount of crude fat in Eshkevar 1 hazelnut (66.16 g) was lower than those of Eshkevar 3 (69.00 g), Round de Peymon and Segrob (69.84 g) species.

Table 1. Mean comparison of the amount of some chemical compounds in varieties and genotypes of hazelnut kernel.

Treatments (hazelnut type)	Moisture (%)	Dry matter (%)	Protein (%)	Crude fat (g)
Round de Peymon	2.6 ± 0.19^{bc}	96.63 ± 2.47^{bc}	8.03 ± 0.39^{b}	71.34 ± 0.6^{a}
Segrob	2.5 ± 0.21^{c}	97.74 ± 2.10^{ab}	6.33 ± 0.41^{c}	69.84 ± 1.4^{b}
Eshkevar 1	3.1 ± 0.23^{a}	96.81 ± 2.30^{a}	9.40 ± 0.83^{ab}	66.16 ± 0.2^{c}
Eshkevar 3	2.0 ± 0.24^{b}	96.00 ± 4.20^{b}	10.00 ± 0.64^{a}	69.00 ± 1.7^{bc}

Means ± standard error with different letters in the same column are significantly different (p<0.01) based on Duncan's multi-range test.

Nutritional and biochemical parameters of chocolate cream enriched with hazelnut

Table 2 presents the parameters of hazelnut-enriched chocolate cream. Analysis of variance showed a statistically significant effect by cultivar and genotype on protein, peroxide, ash, and viscosity of chocolate cream ($p < 0.01$). This effect was insignificant on sugar, crude fat, and acidity (data not shown). Enrichment of chocolate cream with both cultivars and hazelnut genotypes resulted in a significant increase in protein content and a non-significant increase in crude fat compared to the control. This increase in acidity and viscosity was also observed, although the difference in acidity in hazelnut cultivars and genotypes was not significant. The effect of cultivar and genotype on the amount of sugar in hazelnut-enriched chocolate cream was insignificant. A mean comparison revealed that the highest amount of sugar (47.20 g 100 g^{-1}) and ash (0.30 g 100 g^{-1}) was extracted from the control hazelnut. The highest percentage of protein (5.79) and viscosity (4.28) was obtained in Eshkevar 1 hazelnut. Control hazelnut had the lowest amount of protein (4.75 g 100 g^{-1}), crude fat (36.39 g 100 g^{-1})) and viscosity (4.02 cp). Comparison between chocolate creams enriched with different cultivars and genotypes of hazelnuts showed that Eshkevar 3 hazelnut had the lowest sugar (45.00 g 100 g^{-1}), protein (5.00 g 100 g^{-1}), crude fat (36.66 g 100 g^{-1}) and peroxide content (1.00%). The highest crude fat (37.25 g), acidity (0.33), and peroxide (1.46) were observed in Segrob hazelnut (Table 2).

Qualitative parameters of chocolate cream enriched with hazelnut

The variance of the data analysis showed that the difference between the color and texture of chocolate cream enriched with different varieties and genotypes at the probability level of 95% ($p < 0.05$) and between the taste, smell, and overall acceptance at the probability level of 99% ($p < 0.01$) was significant (data not shown). Table 3 shows that the overall acceptance of Eshkevar 3 hazelnut (4.3) was higher than others (3.5, 3.0, 3.0, and 2.8 in Eshkevar 1, Round de Peymon, control, and Segrob hazelnuts, respectively). This genotype ranked first in terms of taste (4.3), texture (3.9), and smell (4.4). Segrob Hazelnut had the highest desire of consumers in terms of color (4.2). In general, the genotypes were superior to cultivars in terms of acceptability of taste, texture, smell, and overall acceptance of chocolate cream (Table 3).

Table 2. Mean comparison of the amount of some chemical compounds in chocolate cream enriched with hazelnut kernel.

Treatments (hazelnut type)	Sugar (g 100 g^{-1})	Protein (g 100 g^{-1})	Crude fat (g 100 g^{-1})	Acidity (%)	Peroxide (%)	Ash (g 100 g^{-1})	Viscosity (cp)
Control	47.20 ± 0.53^{a}	4.75 ± 0.66^{b}	36.39 ± 0.26^{a}	0.30 ± 0.02^{a}	1.29 ± 0.21^{b}	0.30 ± 0.00^{a}	4.02 ± 0.52^{e}
Round de Peymon	45.56 ± 0.46^{a}	5.60 ± 0.19^{a}	37.06 ± 0.85^{a}	0.31 ± 0.05^{a}	1.26 ± 0.47^{b}	0.12 ± 0.00^{b}	4.16 ± 0.52^{c}
Segrob	47.16 ± 2.29^{a}	5.61 ± 0.21^{a}	37.25 ± 0.59^{a}	0.33 ± 0.02^{a}	1.46 ± 0.11^{a}	0.13 ± 0.01^{b}	4.06 ± 0.52^{d}
Eshkevar 1	45.54 ± 0.52^{a}	5.79 ± 0.23^{a}	37.07 ± 0.32^{a}	0.32 ± 0.02^{a}	1.35 ± 0.83^{ab}	0.13 ± 0.01^{b}	4.28 ± 0.52^{a}
Eshkevar 3	45.00 ± 3.70^{a}	5.00 ± 0.24^{a}	36.66 ± 0.36^{a}	0.32 ± 0.01^{a}	1.00 ± 0.11^{b}	0.12 ± 0.01^{b}	4.21 ± 0.37^{ab}

Means ± standard error with different letters in the same column are significantly different ($p<0.01$) based on Duncan's multi-range test.

Table 3. Mean comparison of some qualitative traits in chocolate cream enriched with hazelnut kernel.

Treatments (hazelnut type)	Color	Taste	Texture	Smell	Overall acceptance
Control	3.0 ± 0.60^{b}	2.0 ± 0.88^{bc}	2.3 ± 0.95^{b}	3.0 ± 0.45^{bc}	3.0 ± 0.45^{b}
Round de Peymon	3.1 ± 1.28^{b}	2.6 ± 1.26^{bc}	2.6 ± 1.70^{b}	3.0 ± 0.41^{bc}	3.0 ± 0.82^{b}
Segrob	4.2 ± 0.79^{a}	1.8 ± 0.79^{c}	1.9 ± 0.88^{b}	2.5 ± 0.71^{c}	2.8 ± 0.63^{b}
Eshkevar 1	3.6 ± 0.52^{ab}	3.4 ± 1.07^{ab}	3.0 ± 1.15^{ab}	3.7 ± 0.95^{ab}	3.5 ± 0.53^{ab}
Eshkevar 3	3.8 ± 0.63^{ab}	4.3 ± 0.68^{a}	3.9 ± 0.88^{a}	4.4 ± 0.52^{a}	4.3 ± 0.67^{a}

Means ± standard error with different letters in the same column are significantly different ($p<0.01$) based on Duncan's multi-range test.

Discussion

Survey on nutritional and biochemical parameters of hazelnut-enriched chocolate cream

Hazelnut is widely used as an additive to prepare all kinds of sweets and chocolate and its cultivation has increased in recent decades. In the present study, two varieties (Round de Peymon and Segrob hazelnuts) and two genotypes (Eshkevar 1 and Eshkevar 3) of hazelnut were used instead of cocoa cream to prepare chocolate cream. A comparison was made between the biochemical characteristics of these cultivars and genotypes, revealing variations in both the quantity of chemical compounds and physical attributes. The results showed that the protein content of Eshkevar 1 and Eshkevar 3 hazelnuts was higher than those of Round de Peymon and Segrob varieties. Similar results have been reported regarding the higher content of hazelnut protein in Iranian genotypes compared to imported varieties (Hosseinpour *et al*., 2013; Król & Gantner, 2020). This difference between the protein and oil of imported hazelnut varieties is also observed (Köse *et al*., 2017). The variance in the amount of protein in different types of hazelnuts can affect the texture and rheological properties of chocolate. The difference in the protein pattern of hazelnut species, cultivars, and genotypes can affect the emulsifying properties and viscosity of the resulting paste, so that species with higher protein content may create a stiffer paste texture (Köse *et al*., 2017; Fan *et al*., 2020; Pollon, *et al*., 2024). This is in agreement with similar results in pistachio (Roozban *et al.*, 2006)

In the present study, the amount of crude fat of Round de Peymon and Segrob hazelnuts was higher than Eshkevar 1 and Eshkevar 3. Studies have shown that the composition of fatty acids, antioxidants, and volatile compounds in hazelnut varieties is different, and these variances affect the sensory and physical properties of chocolate (Ollani *et al*., 2024; Fan *et al*., 2020). Some species of hazelnuts, such as *Corylus avellana*, have higher oleic acid content, which improves the oxidation stability of the resulting paste. Also, hazelnuts of different species have different amounts of vitamin E. For example, *C. avellana* usually has higher vitamin E content than *C. maxima* (Fan *et al*., 2020). Fat is one of the most important parameters affecting sensory properties. Due to the fat content of hazelnuts, a type of vegetable fat causes a better mouthfeel. Some reports also showed that chocolate creams containing hazelnuts taste more favorable than control samples without hazelnuts (Köse *et al*., 2017; Martini, 2013; Fan *et al*., 2020; Pollon *et al*., 2024). Some studies showed that the percentage of fat in wild hazelnuts (*C. heterophylla*) is equal to that of fat in *C. avellana* (Fan *et al*., 2020). Among other nutrients, the average protein content, soluble sugar, starch, and ash of these two types of hazelnuts were different. The variances observed can be attributed to the disparities in the growth of the respective environment.

In the present study, Eshkevar 3 hazelnut was selected as the best variety and had a higher nutritional value and quality. There are many differences in the composition of nutrients between different types of native hazelnuts, which can be used to select suitable cultivars and improve the quality of future products.

Adding hazelnuts reduces the sugar content of chocolate cream. None of the studied hazelnut genotypes and cultivars affected the sugar content and sensory properties (sweetness) of chocolate cream. Adding hazelnuts (which have low sugar content) to the chocolate cream lowers the total sugar content. Adding chestnuts to the formulation of chocolate cream increases sugar, fat, and protein in chocolate, resulting in a fundamental change in physical, chemical, and sensory properties (Doğan & Yilmaz, 2023). On the contrary, adding hazelnuts to the formulation of chocolate cream reduces the sugar in the chocolate and, as a result, reduces the sweet taste.

Some studies revealed that hazelnuts are a rich source of protein, healthy fats (including polyunsaturated fatty acids and polyunsaturated fatty acids omega-3 and omega-6), fiber, vitamins (including vitamin E and vitamin B), and minerals (including magnesium, phosphorus, and potassium) (Köse *et al*., 2017; Silveira *et al*., 2024). The present research showed that adding hazelnuts to chocolate cream caused a significant change in the content of moisture, peroxide, and ash.

Due to their specific physical and chemical characteristics, some species and varieties of hazelnuts may have better compatibility with other ingredients used in chocolate production, such as cocoa and sugar, and thus improve the final quality of the product (Helmstetter *et al*., 2020; Bursa *et al*., 2021). Viscosity changes are visible in treatments that change the moisture content. The increase of moisture in the chocolate cream leads to swelling of the chocolate and its hardness. To some extent, adding emulsifiers solves the problem, but moisture content above 3% will cause sensory changes in chocolate (Jin *et al*., 2024). Adding iron (Fe) and B-group vitamins decreased the hardness of chocolate cream (Ieggli *et al*., 2024). The Round de Peymon hazelnut variety has a higher percentage of Fe than the Segrob variety and Eshkevar 1 and Eshkevar 3 genotypes. So, it absorbs more moisture and as a result, increases chocolate cream hardness.

Survey on sensory properties of hazelnut-enriched chocolate cream

Adding hazelnuts improved the sensory properties (color, texture, smell, and general acceptability) of the chocolate cream. In this connection, Eshkevar 3 hazelnut had the best performance. Some studies showed that the ratio of adding hazelnuts to cocoa in the production stage of chocolate cream can affect its characteristics. For example, increasing the ratio of hazelnut to cocoa increased fat content, improved rheological properties, and increased consumers' sensory acceptance (Yılmaz & Öz, 2024). Hazelnut processing and preparation methods (such as roasting, grinding, etc.) can also affect the properties of the chocolate cream. For example, roasted hazelnuts cause special color and flavor in chocolate cream. Conversely, crushed hazelnuts raised the level of suspended particles and imparted a more delicate consistency to the item (Pollon *et al*., 2024; Bostan & Karakaya, 2024). Recent studies have shown that the type of hazelnut used can affect the characteristics of chocolate cream. For example, the addition of Turkish hazelnut (*C. color*) increased the fat content and the texture of the product, whereas using Lambert hazelnut (*C. Americana*) led to an increase in the protein content and antioxidant compounds in chocolate cream (Król & Gantner, 2020; Santagiuliana *et al*., 2018). Similar results of various sensory and nutritional properties in varieties has been reported in walnut (Pakrah et al., 2021 and 2022)

Conclusions

Finally, the results of this research showed that the physicochemical (fat, protein, peroxide, sugar, moisture, acidity, ash, and viscosity) and sensory (color, taste, smell, texture, and overall acceptance) characteristics among the four genotypes and varieties of hazelnuts were different. The Eshkevar 3 hazelnut genotype added to the chocolate cream resulted in the highest protein content, the lowest moisture content, and the highest overall acceptance compared to other hazelnut varieties and genotypes. This finding indicates promising potential for producing high-quality and affordable chocolate cream products. However, further comparative analysis is necessary to fully assess the overall acceptance of Eshkevar 3 chocolate cream compared to other commercially available products and industry standards. Our research also suggests that organizations responsible for managing agricultural resources should consider promoting the cultivation of this hazelnut genotype in suitable areas to benefit both procedures and consumers by providing a high-quality and cost-effective product option.

Conflict of interests

The authors declare that there is no conflict of interest.

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