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Original Article

Determination of volatile aroma composition of some hazelnut varieties grown in Akçakoca conditions

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Abstract

Türkiye is leading country for hazelnut production and hazelnut orchards are widely established in Black Sea belt. Akçakoca district belongs to Duzce province is accepted as one of the most important production areas. In this research, volatile aroma components in nuts (kernels) of Çakıldak, Kara, Sarı (Mincane), Tombul and Yomra hazelnut varieties grown in Akçakoca district were determined by SPME/GC-MS. The analysis revealed the presence a total of 55 different volatile aroma components. These analyzes identified the presence of 39 descriptive volatile aroma compounds with significant differences between varieties. Çakıldak variety differed from the other varieties in terms of Isopentyl alcohol and Ethyl acetate components. At the same time, some volatile aroma compounds are commonly detected among the all varieties. This study has shown that the climate and soil conditions of Akçakoca cause the emergence of unique taste profiles through the effect of hazelnut varieties on volatile aroma components. The findings emphasize that regional diversity and local ecosystem factors play a critical role in determining flavor in hazelnut kernels. This study also emphasizes that variety selection is a critical factor in ensuring sustainability in hazelnut cultivation and that determining volatile aroma components is an important indicator in this selection.

Keywords: Hazelnut, Akçakoca, Aroma, Volatile compounds, Diversity.

1. Introduction

Türkiye is leading position in world hazelnut production and export. In 2021, while 1.077.117 tons of hazelnuts were produced in an area of 1.039.147 hectares worldwide, Türkiye met 65-70% of this production with 684.000 tons in an area of 7.389.201 hectares. This success emphasizes the country's leadership in hazelnut production, and 765.000 tons of hazelnuts were produced in 7.440.473 hectares of land in 2022 [1, 2]. Although there is hazelnut production in many countries around the world, the world hazelnut production approximately 72% of its area is located in Türkiye. Among other countries; Türkiye is followed by Italy with 8%, Azerbaijan with 4%, Iran with 2%, USA with 2%, Chile with 2% and Georgia with 1% production area.

Producing approximately 65-70% of the world hazelnut production and export, Türkiye is the leading country in the world hazelnut market. Considering exports, Turkey's share reaches 80%. Hazelnuts, which are among Turkey's traditional export products, are worth 2 billion providing foreign exchange inflow close to USD, and supporting around 400 thousand producers and directly or indirectly concerns the family's livelihood. In addition to providing a source of employment, it has an important place in the Turkish economy due to socioeconomic reasons such as the added value created [3, 4].

Hazelnut is a fruit that stands out with its high vitamin E and unsaturated fatty acids. It also contains nutritious nutrients such as niacin, vitamins B1, B2, B6, ascorbic acid, folic acid, retinol and tocopherol. Hazelnuts also offer a rich profile in terms of mineral substances such as K, Mn, Mg, Ca, Fe, Zn, Na and Cu [5-7]. Hazelnuts are also rich in phenolic compounds and antioxidants, and these components also affect the flavor of hazelnuts [8-10].

It is well known that the taste of fruit is determined

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not only by acid and sugar content but also by volatile aromatic components. Aroma is an important criterion for the quality of fruit, and determining aroma components as well as chemical properties plays a critical role in quality control [11-16].

Volatile compounds found in hazelnut kernels vary depending on factors such as variety, soil structure, climate, harvest time, cultivation method, drying method, season, geographical origin, environmental factors, storage and maturity [9]. It is of great importance to select the most suitable variety to ensure sustainability in hazelnut cultivation, and in this selection, volatile aroma components are considered a basic indicator to determine the desired taste quality of hazelnuts [12]. Alasalvar et al. [8] compared natural and roasted Tombul hazelnut variety, detected 39 different volatile aromatic compounds in natural hazelnuts and 71 different volatile aromatic compounds in roasted hazelnuts. These results show that the roasting process plays an important role in increase flavor of hazelnuts. Additionally, Alasalvar et al. [10] detected 46 volatile compounds in Turkish hazelnut varieties by the GC-MS method, and 31 of them were positively identified in all hazelnuts. Different volatile substance contents were determined among the varieties, especially Çakıldak variety had the highest total volatile substance content, followed by Palaz, Mincane, Fosa and Tombul varieties. Artik et al. [12] stated that hazelnut varieties showed significant differences in terms of aromatic components, and in their study, they found that both natural and roasted forms of Turkish hazelnut varieties contained a greater number and variety of aromatic compounds. In natural varieties, nonanal, heptanol and octanal; In roasted varieties, nonanal, hexanal and heptanol were identified as the dominant components.

In light of this information, it can be seen that the climatic conditions of the region where hazelnuts grow have a significant impact on the distribution of volatile aroma components of the varieties and ultimately on the taste of the hazelnut.

In this context, this study evaluates the regional differences and aromatic profiles of the varieties by determining the volatile aroma components of Çakıldak, Kara, Sarı, Tombul and Yomra hazelnut varieties grown in Akçakoca district of Düzce province and comparing the results obtained with other studies.

2. Materials and Methods

2.1. Plant Material

The material of the study consists of nut samples taken from trees belonging to Çakıldak, Kara, Sarı (Mincane), Tombul and Yomra hazelnut varieties growing in the Akçakoca district of Düzce province.

2.2. Aroma Analysis

Hazelnut samples taken during the 2021 harvest period were separated from their husks, dried at room temperature and stored at +4 ºC until the analysis. Using the solid phase micro-extraction (SPME) method, 5 g of hazelnut kernel samples were taken and ground. The homogeneous samples were placed in 20 ml vials, the lids were closed and mixed in the vortex for 2 seconds. Fiber (2 cm, DVB/CAR/PDMS, Supelco, Bellefonte, PA, USA), previously conditioned for GC-MS at 200 °C for 20 min, was attached to the vial for 30 min at 55 °C. At the end of the period, the fiber was automatically injected into the GC-MS and analyses were performed. Aroma analysis was performed using Shimadzu, model AOC-6000 GC-MS. A Restek RTX-5MS (30m x 0.25mm x 0.25µm) column was used in the device and were modified depending on the intertwining of the peaks. The following parameters were used for analysis: injection temperature: 250 °C, pressure: 90.0 kPa, column flow rate: 1.61 mL/min, column temperature 1: 40 °C, dwell time: 3 min, ramp rate: 4 °C/min, column temperature 2: 240 °C, hold time at final temperature: 5 min, total flow 20.7 mL/min, split ratio: 1/10. C7-C30 alkane series were injected into the device by the specified method and RI calculation was made. To identify peaks, peaks were identified in the FFNSC (natural and synthetic aroma and fragrance components) library. Volatile aroma compounds in hazelnut samples were determined from the library with 90% or more similarity. The areas of the identified peaks were determined as a percentage of the total area.

3. Results

SPME/GC-MS analyses performed on different hazelnut varieties grown in the unique climatic conditions of Akçakoca revealed the presence of a total of 55 different volatile aroma components. These analyses identified the presence of 39 descriptive volatile aroma compounds with significant differences between varieties, these results are presented in detail in Table 1.

In the Çakıldak hazelnut variety, a total of 15 variety-specific volatile aroma components were determined. These components include Ethyl acetate, Isopentyl alcohol, Ethyl Isobutyrate, Ethyl Lactate, n-Hexanol, Isoamyl acetate, Ethyl hexanoate, Phenethyl alcohol, Diethyl succinate, Ethyl octanoate, Cyclomyral, Anethole, Ethyl decanoate, Ethyl dodecanoate and Ethyl palmitate (Figure 1). In the Kara hazelnut variety, a total of 9 volatile aroma components were identified, including Ethyl oleate and Ethyl phenylacetate, specific to the variety (Figure 1). In the Sarı (Mincane) hazelnut variety, a total of 10 volatile

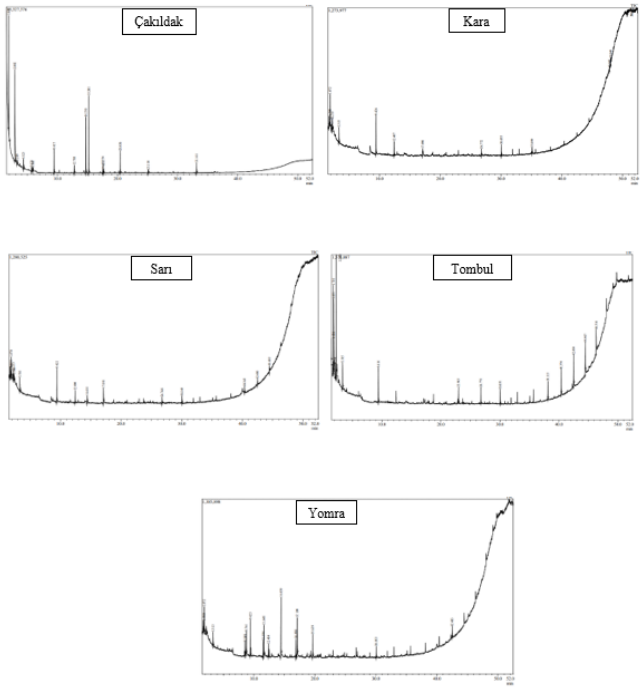

Fig. 1. GC-MS aroma chromatograms of the hazelnut varieties examined.

Table 1. Distribution of aroma components based on hazelnut varieties.

Aroma components	Çakıldak	Kara	Sarı	Tombul	Yomra
Ethyl acetate	27.73	-	-	-	-
Isopentyl alcohol	27.99	-	-	-	-
Ethyl Isobutyrate	0.54	-	-	-	-
Ethyl Lactate	2.05	-	-	-	-
n-Hexanol	0.72	-	-	-	-
Isoamyl acetate	0.60	-	-	-	-
Ethyl hexanoate	4.44	-	-	-	-
Phenethyl alcohol	1.54	-	-	-	-
Diethyl succinate	10.47	-	-	-	-
Ethyl octanoate	14.70	-	-	-	-
Cyclomyral	1.62	-	-	-	-
Anethole	0.61	-	-	-	-
Ethyl decanoate	4.28	-	-	-	-
Ethyl dodecanoate	0.59	-	-	-	-
Ethyl palmitate	2.12	-	-	-	-
Ethanoic acid	-	5.98	8.26	10.08	2.91
tert-butyl methyl Ether	-	18.57	-	22.69	6.40
Ethyl phenylacetate	-	9.13	-	-	-
Fructone	-	9.10	8.69	8.96	3.89
n-Decane	-	18.93	18.34	6.98	9.67
n-Undecane	-	6.59	6.34	-	3.09
Nonanoic acid	-	3.11	8.64	-	11.54
Ethyl oleate	-	3.45	-	-	-
Butanone	-	-	4.16	-	-
Diethyl acetal	-	-	10.84	-	-
Benzyl salicylate	-	-	9.40	-	-
Methyl isobutyrate	-	-	3.79	-	-
n-Octanoic acid	-	-	3.85	-	21.44
Lactic acid	-	-	-	1.33	-
Benzyl phenylacetate	-	-	-	14.06	-
Decamethylcyclopentasiloxane	-	-	-	2.80	-
n-Heptanol	-	-	-	-	3.22
Hexanoic acid	-	-	-	-	7.17
n-Octanol	-	-	-	-	3.96
n-Heptanoic acid	-	-	-	-	9.99
Gamma Octalactone	-	-	-	-	4.79
Gamma Decalactone	-	-	-	-	6.00

aroma compounds were identified, such as Butanone, Diethyl acetal, Benzyl salicylate, Methyl isobutyrate, n-Octanoic acid, which are specific to the variety (Figure 1). In the Tombul hazelnut variety, 8 volatile aroma compounds were identified, including Lactic acid, Benzyl phenylacetate, and Decamethylcyclopentasiloxane, specific to the variety (Figure 1). In the Yomra hazelnut variety, 13 volatile aroma compounds were identified, including n-Heptanol, Hexanoic acid, n-Octanol, n-Heptanoic acid, Gamma Octalactone and Gamma Decalactone, which are specific to the variety (Figure 1).

Ethanoic acid, Fructone and n-Decane components were found in other hazelnut varieties examined (Kara, Sarı, Tombul, Yomra) except Çakıldak; n-Undecane and Nonanoic acid components are found in Kara, Sarı and Yomra varieties; tert-butyl methyl Ether detected in Kara, Tombul and Yomra varieties; n-Octanoic acid was seen as a common component in Sarı and Yomra varieties (Table 1).

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In the evaluations made among the varieties, the highest values were determined for Isopentyl alcohol (27.99%) and Ethyl acetate (27.73%) in the Çakıldak variety. This value was followed by the n-Decane component in the Kara (18.93%) and Sarı (18.34%) varieties. The lowest values were determined as Ethyl Isobutyrate (0.54%), Ethyl dodecanoate (0.59%), Anethole (0.61%) and n-Hexanol (0.72%) in the Çakıldak variety (Table 1)

The volatile aroma components common to the hazelnut varieties examined and the characteristic features of these components are given below:

-Ethanoic acid, detected in Kara, Sarı, Tombul and Yomra varieties, has a strong and sharp vinegar odor. Fructone is another ingredient found in these varieties, it is a clear colorless liquid and carries a strong fruity apple green sweet woody aroma.

-Nonanoic acid, which is common in Kara, Sarı and Yomra varieties, has a slightly oily and pungent aroma.

-Tert-butyl methyl Ether (Tert-butyl methyl ether), found in Kara, Tombul and Yomra varieties, has a rather unpleasant taste and a strong turpentine-like aroma.

-n-Octanoic acid, detected in Sarı and Yomra varieties, is a colorless, oily liquid and carries a mild, unpleasant aroma.

3. Discussion

The volatile compounds of hazelnuts (*Corylus avellana* L.) encrypts information about phenotype expression as a function of cultivar/origin, post-harvest practices, and their impact on primary metabolome, storage conditions and shelf-life, spoilage, and quality deterioration. Moreover, within the bulk of detectable volatiles, just a few of them play a key role in defining distinctive aroma and conferring characteristic hedonic profile. In particular, in raw hazelnuts, key-odorants as defined by sensory are: 2,3-diethyl-5-methylpyrazine (musty and nutty); 2- acetyl-1,4,5,6-tetrahydropyridine (caramel); 2-acetyl-1-pyrroline (popcorn-like); 2-acetyl3,4,5,6-tetrahydropyridine (roasted, caramel); 3-(methylthio)-propanal (cooked potato); 3-(methylthio)propionaldehyde (musty, earthy); 3,7-dimethylocta-1,6-dien-3-ol/linalool (citrus, floral); 3-methyl-4-heptanone (fruity, nutty); and 5-methyl-(E)-2-hepten-4-one (nutty, fruity) [17].

When the findings are evaluated in general, quite different volatile compound profiles and differences depending on the variety were observed in the nut (kernel) samples of the hazelnut varieties examined. Researchers have stated that aroma-active compounds are decisive in the taste of the variety. It has also been stated that the volatile aroma compounds of hazelnuts vary significantly depending on ecological conditions and maturity stage [9, 12, 17].

Alasalvar et al. [18], in their study examining the aroma profiles of 18 hazelnut varieties obtained from Giresun Hazelnut Research Institute, detected 11 volatile aroma components in Çakıldak hazelnut variety, 18 in Black hazelnut, 11 in Yellow hazelnut, 12 in Tombul hazelnut and 10 in Yomra. Çakıldak, Kara, Sarı, Tombul and Yomra hazelnut varieties grown in the Akçakoca region contain 2-methylbutanal, 2,5-dimethylfuran, toluene, (E)-3-penten-2-one, (E)-2-pentenal and 5-methyl-(E)-2-hepten-4-one compounds were detected. Although these volatile aroma components are found in different concentrations in each variety, they are generally determined to be common to all varieties. These findings indicate that similar volatile aroma profiles exist among hazelnut varieties.

The characteristic aromatic properties of the identified volatile aroma components are as follows:

- 2-Methylbutanal: Fruity, hazelnut and chocolatey aroma,
- 2,5-dimethylfuran: Etheric, chemical aroma,
- Toluene: Burnt aroma,
- (E)-3-Penten-2-one: Fruity aroma in roasted hazelnuts,
- (E)-2-pentenal: Green floral aroma,
- 5-Methyl-(E)-2-hepten-4-one: Nutty aroma.

Artik et al. [12] focused on hazelnut varieties obtained from Giresun Hazelnut Research Institute in the 2019 harvest period. The hazelnut varieties used in the study are Çakıldak, Foşa, Kara, Yomra, Tombul and Mincane. The volatile components Acetic acid, 2-Heptanol, Heptanal, 6-Methyl-5-hepten-2-one, 1-Octanol, Nonanal and Hexanal were detected in all mentioned varieties. These components are found in common across different varieties, indicating that the hazelnut flavor profile has a wide range of varying characteristics. The characteristic aromatic properties of the identified volatile aroma components are as follows:

- Acetic acid: Sharp, dominant vinegar aroma,
- 2-Heptanol: Colorless, lemony and grass-like aroma,
- Heptanal: Strong, pungent, oily aroma,
- 6-Methyl-5-hepten-2-one: Strong oily, green citrus-like aroma,
- 1-Octanol: Colorless, liquid/pungent oily-citrus aroma,
- Nonanal: Citrus, citrus, oily aroma,
- Hexanal: Herbal, grassy aroma.

In this study, volatile aroma components of Çakıldak, Kara, Sarı, Tombul and Yomra hazelnut varieties grown in Akçakoca ecological conditions were analyzed. The findings are compared with other studies to reveal regional differences and determine the effects of these differences on nut (kernel) taste. The volatile aroma components of the examined varieties differ from studies conducted in other regions in Türkiye even on the same varieties used. This shows that the special climate and soil conditions of Akçakoca affect the aroma profiles of hazelnut varieties, resulting in the emergence of unique taste profiles. The results emphasize that regional diversity and local ecosystem factors may play a critical role in determining palatability in hazelnut production.

Previous studies have also indicated that horticultural crops differ from each other for biochemical composition even in genotypes and cultivars of the same species [19-22]. differences and aroma are strongly cultivar dependent in horticultural crops [23-30].

This research analyzed in detail the volatile aroma components of Çakıldak, Kara, Sarı, Tombul and Yomra hazelnut varieties grown in Akçakoca ecological conditions. Comprehensive analyses reveal that the volatile aroma component distributions of the examined varieties differ significantly from studies conducted in other regions. These differences have shown that Akçakoca's unique climate and soil conditions are critical factors in determining the aroma profiles of hazelnut varieties.

The results obtained emphasize that regional diversity and local ecosystem factors are effective in determining the taste of hazelnut production. In this context, it is of great importance to take into account the unique conditions of Akçakoca in future studies on quality control and variety development in the hazelnut industry.

The diversity of hazelnut's volatile aroma components and the impact of these components on kernel taste reveals its potential to offer consumers more diverse and rich flavor profiles. The results of this research aim to focus on variety selection and cultivation methods to contribute to future research aimed at improving product quality in the hazelnut industry and offering consumers a variety of fla-

vor experiences.

4. Conclusion

From the present study, valuable information on the aroma characterisation of five important hazelnut cultivars namely Çakıldak, Kara, Sarı (Mincane), Tombul and Yomra was unveiled. Our findings indicate a total of 55 different volatile aroma components. These analyses identified the presence of 39 descriptive volatile aroma compounds with significant differences between varieties. These results indicate that the Çakıldak variety may be the more favourable option for the development of value-added food products by using hazelnut kernels. It has been revealed that in the hazelnut industry, it is necessary to focus on variety selection and cultivation methods in order to increase product quality and offer various aroma experiences to consumers.

Conflict of interests

The author has no conflicts with any step of the article preparation.

Consent for publications

The author read and approved the final manuscript for publication.

Ethics approval and consent to participate

No human or animals were used in the present research.

Informed consent

The authors declare not to use any patients in this research.

Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request

Authors' contributions

Hulya Unver, Yalcin Gucer, and Ozan Haliscelik did all the steps in the research work, and Ebru Sakar, Zeynep Mujde Sakar and Sezai Ercisli made significant contributions to planning the study and writing the draft paper.

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