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# Investigation of aroma components obtained by HS-SPME (Headspace-solid phase microextraction) method of wild strawberry (*Fragaria vesca* L.) and strawberry (*Fragaria x ananassa* Duch.) fruits

*Dağ çileği (Fragaria vesca L.) ve çilek (Fragaria x ananassa Duch.) meyvelerinin HS-SPME (Tepe boşluğu katı faz mikro ekstraksiyonu) yöntemi ile elde edilen aroma bileşenlerin araştırılması*

**Mehmet ÖZ*[1], Cemalettin BALTACI[2], Muhammed Said FİDAN[3]**

[1]*Gümüşhane University, Gümüşhane Vocational School, Department of Forestry, 29100, Gümüşhane*

[2]*Gümüşhane University, Faculty of Engineering and Natural Sciences, Department of Food Engineering, 29100, Gümüşhane*

[3]*Bursa Technical University, Faculty of Forestry, Department of Forest Industry Engineering, 16310, Bursa*

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**Abstract**

Wild strawberries (*Fragaria vesca*) are in the category of non-wood forest products due to their unique fragrance, aroma, and natural ability to grow. In this study, aroma components of wild strawberry (*Fragaria vesca*) and strawberry (*Fragaria x ananassa*) fruits were determined by Headspace-Solid Phase Micro-Extraction technique combined with Gas Chromatography-Mass Spectrometry (HS-SPME/GC-MS). In addition, it aimed to compare the results of both fruits with each other by chemical classification of the aroma components determined from wild strawberry and strawberry fruits. As a result of the HS-SPME/GC-MS analysis; 50 and 76 aroma components were determined in wild strawberry and strawberry fruits, respectively. The structure of aroma components was defined as 97.63% of wild strawberries and 98.26% of strawberries. The main components in the aroma compounds are 2-undecanone (10.38%), *γ*-decalactone (8.81%), and eugenol (7.14%) in wild strawberry fruit; nerolidol (29.44%), *γ*-decalactone (26.36%) and bisabolol oxide II (4.23%) were found in strawberry fruits. In addition, chemical classes of identified aroma compounds were determined as ester, terpene or terpenoid, fatty acids, aldehyde, and ketone classes in *Fragaria vesca* and *Fragaria x ananassa* fruits. When the results are examined, it is seen that strawberry fruits are found to be higher than wild strawberry fruits in terms of percentage of aroma components, number of aroma components, and percentage of dominant components.

**Keywords:** Fruit, HS-SPME/GC-MS, Aroma components, Wild strawberry

***Öz***

*Dağ çileği (Fragaria vesca) kendine özgü hoş koku ve aroması, doğal olarak yetiştiğinden dolayı odun dışı orman ürünleri sınıfinda yer almaktadır. Bu çalışma kapsamında dağ çileği (Fragaria vesca) ve çilek (Fragaria x ananassa) meyvelerinin aroma bileşenleri Gaz Kromatografisi-Kütle Spektrometresi ile kombine edilmiş Tepe Boşluğu-Katı Faz Mikro Ekstraksiyon (HS-SPME/GC-MS) tekniği ile belirlenmiştir. Ayrıca dağ çileği ve çilek meyvelerinden tespit edilen aroma bileşenlerinin kimyasal sınıflandırmaları yapılarak her iki meyvenin sonuçları birbirleri ile karşılaştırılması amaçlanmıştır. Yapılan HS-SPME/GC-MS analizi sonucunda; dağ çileği ve çilek meyvelerinde sırasıyla 50 adet ve 76 adet aroma bileşen tespit edilmiştir. Dağ çileği aroma bileşenlerin %97.63'ünün, çilek aroma bileşenlerinin ise %98.26'sının yapısı tanımlanmıştır. Aroma bileşikler içerisinde bulunan ana bileşenlerin dağ çileği meyvesinde 2-undecanone (%10,38), γ-decalactone (%8,81) ve eugenol (%7,14); çilek meyvelerinde ise nerolidol (%29,44), γ-decalactone (%26,36) ve bisabolol oxide II (%4,23) olduğu saptanmıştır. Ayrıca, tanımlanan aroma bileşiklerinin kimyasal sınıfları olarak Fragaria vesca ve Fragaria x ananassa meyvelerinde ester, terpen veya terpenoid, yağ asitleri, aldehit ve keton sınıfları olarak tespit edilmiştir. Sonuçlar incelendiğinde aroma bileşenlerin yüzdesi, aroma bileşen sayısı ve ana bileşen yüzdeleri bakımından çilek meyvelerinin, dağ çileği meyvelerine göre daha fazla bulunduğu görülmektedir.*

**Anahtar kelimeler**: *Meyve, HS-SPME/GC-MS, Aroma bileşenler, Dağ çileği*

*Mehmet ÖZ; mehmetoz@gumushane.edu.tr

## 1. Introduction

Plants constitute the basic raw material sources of industries such as food, medicine, cosmetics and pharmacy. Medicinal plants are used to treat human and animal diseases with therapeutic activity due to their rich bioactive substance content. Aromatic plants are defined as plants with a pleasant smell and taste. Medicinal and aromatic plants have been used in traditional and modern medicine to treat diseases and as medicines since ancient times, thanks to the important compounds they contain (Boztaş et al., 2021; Avan, 2021; Öz, 2022a). Aromatic extracts and essential oils (essences, essential oils) are used as starting materials for the production of nature-identical and semi-synthetic useful aroma chemicals or as a source of aroma chemicals (Sarıkaya & Fakir, 2017).

Strawberry belongs to the *Fragaria* genus of the Rosaceae family of the Rosales order. *Fragaria vesca* L. (Mountain, Forest strawberry), and *Fragaria x ananassa* Duch. (cultivated strawberry) is among the species of strawberry. Cultivated strawberry (*F. x ananassa* Duch.) was produced in the mid-18th century as a result of natural hybridization of *F. chiloensis* L., and *F. virginiana* Duch. These strawberries can be grown very successfully in different ecologies in places with temperate climates and are one of the most important members of the berry group that many people consume with pleasure (Akın, 2014).

*Fragaria* species are represented in Turkey by three different species: *F. x ananassa* Duchesne., *F. vesca* L., and *F. viridis* Duchesne. *F. vesca* L. species is known as Mountain strawberry, Forest strawberry, and Wild strawberry in our country (Yıldırım Birinci, 2012). It is a perennial herbaceous plant with a creeping stem that can grow up to 30-40 cm tall. Basal leaves rosette, trifoliate; leaflets 1-6 cm, ovate, obovate or rhomboid shaped, saw-toothed, grey-hairy below, and sparsely hairy above. Its flowers are 2-7 in number and the petals are white, 4-5 mm, opposite ovate or round. The fruit is red, hairless (naked), and 1 cm in diameter. It grows in humid places, especially in forests, at an altitude of 200-2450 m (Davis, 1985). Wild strawberries have a more pleasant smell and taste than cultivated strawberries. It prefers to grow in a sheltered location, such as under a forest, and since its fruits are very small, it is difficult and troublesome to collect them (Yıldırım Birinci, 2012). Wild strawberry (*F. vesca* L.) plant is used by the people of the Ordu (Korgan) region against diabetes, to strengthen body resistance, against cardiovascular diseases, as a blood purifier, against skin, nerve, kidney, mouth, and gum diseases, against rheumatism, blood pressure, and cholesterol (Sarıkaya & Karaevli, 2019). It has been stated that in Rize province, *Fragaria vesca* L. fruits are used for diabetes and the fruits are consumed by making jam and syrup (Saraç et al., 2013). Mountain (forest) strawberry spreads naturally in Trabzon, Ordu, Samsun, Sinop, Bolu, Bitlis, Kastamonu, Kars, Yozgat, Hatay, Kütahya, Istanbul, Çanakkale, and Kırklareli (Tübives, 2023). Figure 1 shows the distribution of *F. vesca* L. in our country.

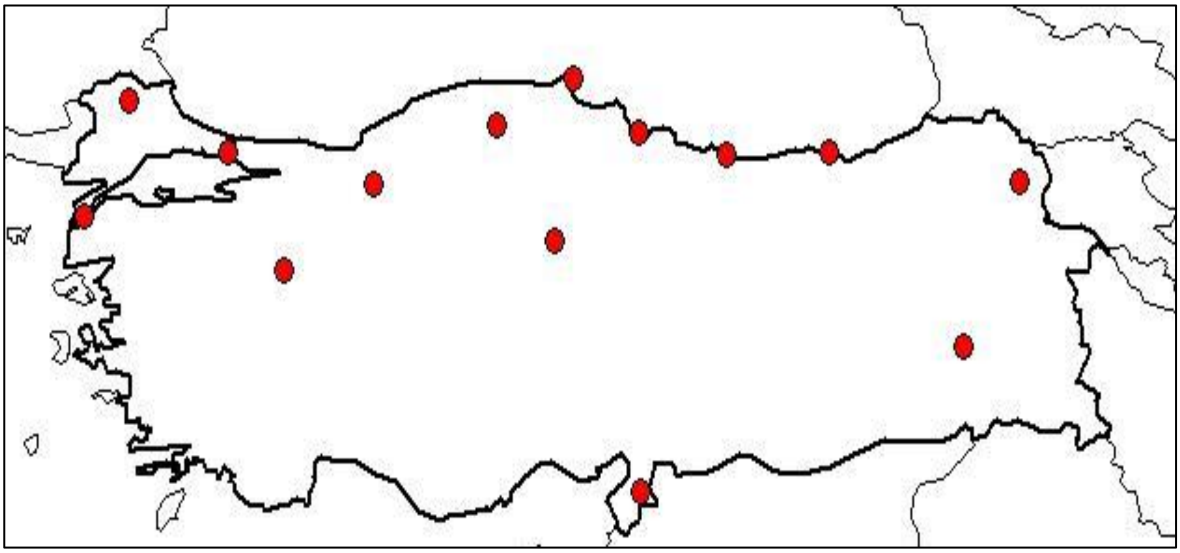

**Figure 1.** Distribution of *Fragaria vesca* L. in our country (Tübives, 2023)

Aromatic extracts and essential oils are used in large quantities in the production of food, perfume, cleaning materials, cosmetics, and medicines, and in the production of nature-identical and semi-synthetic useful aroma chemicals. SPME and GC/MS technique, which is a cheap and highly sensitive method. They combine sample

preparation, extraction, and concentration stages in a single solvent-free step. Moreover, they are obtained successful results in determining aroma compounds, especially for fruits with complex aromas (such as; strawberry, banana, mango, raspberry, and blackberry) (Kafkas et al., 2002; Sarıkaya, 2020).
The scope of this study, the aroma components of *F. vesca* (wild strawberry), and *F. x ananassa* (strawberry) were aimed to determine the results of both HS-SPME/GC-MS technical of fruits and by chemical classification of the detected aroma components.

## 2. Material and method

### 2.1. Material

*Fragaria vesca* (wild strawberry) fruits were collected in July 2022 from Gümüşhane province, Torul district, Zigana Mountain (40°39'03"N, 39°24'36"E, Altitude: 2050 m). Plant material was identified by Prof. Dr. Salih Terzioğlu and registered in the Karadeniz Technical University, Faculty of Forestry Herbarium with the herbarium number KATO 19453. *Fragaria x ananassa* (strawberry) fruits were purchased from a greengrocer in Gümüşhane province.

### 2.2. Methods

#### 2.2.1. Determination of aroma components by HS-SPME/GC-MS analysis

Aroma (volatile, odor) components of *F. vesca* (wild strawberry), and *F. x ananassa* (strawberry) fruits combined with Gas chromatography/mass spectrometry (GC-MS) with Headspace-solid phase microextraction (HS-SPME) technique Kang et al. (2019) method. For extraction, 5 grams of fruit samples were taken, mixed in a homogenizer, transferred to headspace vials, and 2 grams of salt (NaCl) was added. The vials were kept at 70 ºC for 45 minutes, and aroma compounds were collected in the headspace with 75 µm thin Carboxene/Polydimethylsiloxane (CAR/PDMS) coated fused silica fiber. Aroma compounds collected in the headspace were injected into GC/MS (Agilent 7890A GC-5975MSD) and the separation of aroma substances was carried out using an HP-5 MS apolar capillary column (30 m x 250 µm x 0.5 µm). The injector temperature was 220 °C, the detector temperature was 250 °C, and the column temperature was increased by 2 °C per minute to 220 °C, and then by 3 °C per minute to 245 °C, after waiting for 3 minutes at 50 °C. The temperature was adjusted to remain constant for 20 minutes. Helium was used as the carrier gas and the flow rate of helium was set at 1 mL/min and the detector and injector temperatures were set at 250 °C in 1:10 split mode. As a result of the analysis, RI (Retention Indices) values were calculated with the help of a series of $C_6$-$C_{27}$ saturated n-alkane standards (Sigma-Aldrich Chemical Co. USA), and Wiley, Nist libraries and using Adams (2007) data were used to identify the compounds. HS-SPME method and GC-MS analysis are shown in Figure 2.

**Figure 2.** Headspace-solid phase microextraction (HS-SPME) method and GC-MS analysis

## 3. Results and discussion

### 3.1. Results of aroma components with HS-SPME/GC-MS analysis

The aroma components of the obtained wild strawberry, and strawberry fruit samples were determined by the HS-SPME/GC-MS analysis technique. The aroma components showed high coupling rates (at least 80%) and their chemical structures were identified by comparing their retention times. 50 out of 52 different components have been identified in wild strawberries, and 76 out of 79 different components in strawberries have been identified. In the aroma component analysis, 97.61% of the compounds in wild strawberries and 98.85% of strawberry fruits were determined (unidentified compounds rates were excluded). HS-SPME/GC-MS analysis results of aroma compounds determined in *F. vesca* and *F. x ananassa* fruits are given in Table 1.

**Table 1.** HS-SPME/GC-MS analysis results of aroma compounds determined in *F. vesca* and *F. x ananassa* fruits

| No | ***F. vesca*** **% area** | ***F. x ananassa*** **% area** | **Compound class** | **Compounds** | **Kovats index** | **Literature kovats index** |
|---|---|---|---|---|---|---|
| 1 | 1.13 | | Ketone | 2-Pentanone | 655 | 653 |
| 2 | 0.50 | | Ketone | 3-Methyl-2-butanone | 660 | 658 |
| 3 | | 0.20 | Ester | Methyl butanoate | 698 | 698 |
| 4 | | 0.20 | Ester | Ethyl butanoate | 798 | 798 |
| 5 | | 0.02 | Aldehyde | Hexanal | 822 | 820 |
| 6 | | **3.61** | **Aldehyde** | **(*E*)-2-Hexenal** | 855 | 855 |
| 7 | | 0.11 | Alcohol | (*E*)-2-Hexen-1-ol | 868 | 868 |
| 8 | | 0.23 | Alcohol | 1-Hexanol | 870 | 870 |
| 9 | 1.99 | | Ketone | 2-Heptanone | 891 | 891 |
| 10 | | 2.55 | Ester | Methyl hexanoate | 927 | 927 |
| 11 | | 0.48 | Aldehyde | Benzaldehyde | 964 | 964 |
| 12 | 0.91 | | Phenol | Phenol | 985 | 984 |
| 13 | | 2.86 | Fatty acid | Hexanoic acid | 997 | 997 |
| 14 | | 0.78 | Ester | Hexyl ethanoate | 1016 | 1016 |
| 15 | | 0.59 | Ester | (*E*)-2-Hexenyl acetate | 1018 | 1017 |
| 16 | 0.92 | 0.12 | Monoterpene | Limonene | 1033 | 1033 |
| 17 | | 0.09 | Monoterpene | (*E*)-$\beta$-Ocimene | 1052 | 1052 |
| 18 | | 0.08 | Aldehyde | (*E*)-2-Octenal | 1062 | 1062 |
| 19 | | 0.31 | Other | Mesifurane | 1065 | 1065 |
| 20 | 2.87 | 0.20 | Alcohol | 1-Octanol | 1072 | 1072 |
| 21 | | 0.24 | Monoterpenoid | *(Z)*-Linalool oxide | 1078 | 1078 |
| 22 | 2.20 | | Ketone | 2-Nonanone | 1092 | 1092 |
| 23 | | 0.31 | Monoterpene | $\alpha$-Terpinolene | 1093 | 1093 |
| 24 | 0.72 | | Alcohol | 2-Nonanol | 1100 | 1100 |
| 25 | | **3.02** | **Monoterpenoid** | **Linalool** | 1103 | 1103 |
| 26 | 1.01 | 0.14 | Aldehyde | Nonanal | 1107 | 1107 |
| 27 | 0.27 | 0.20 | Ester | Methyl caprylate | 1126 | 1126 |
| 28 | | 0.04 | Monoterpene | Allo-Ocimene | 1132 | 1132 |
| 29 | | 0.05 | Aldehyde | (*E*)-2-Nonenal | 1163 | 1163 |
| 30 | | 0.29 | Ester | Benzyl acetate | 1169 | 1169 |
| 31 | 1.68 | 0.61 | Fatty acid | Octanoic acid | 1174 | 1174 |
| 32 | 1.25 | | Monoterpenoid | Hexahydrothymol (Menthol) | 1178 | 1178 |
| 33 | | 0.11 | Monoterpenoid | Carvomenthenal | 1184 | 1191 |

***Table 1. Continued***

| | | | | | | |
|---|---|---|---|---|---|---|
| 34 | 0.82 | | Other | Ethanol, 1-(2-butoxyethoxy)- | 1189 | 1187 |
| 35 | | 0.16 | Ester | Hexyl butanoate | 1193 | 1193 |
| 36 | 1.02 | 1.63 | Monoterpenoid | *α*-Terpineol | 1198 | 1198 |
| 37 | | 0.15 | Ester | Methyl salicylate | 1202 | 1201 |
| 38 | 1.09 | | Monoterpenoid | Myrtenol | 1202 | 1202 |
| 39 | 0.72 | 0.08 | Aldehyde | Decanal | 1208 | 1208 |
| 40 | 0.64 | 0.57 | Ester | Caprylyl acetate | 1211 | 1211 |
| 41 | 2.56 | | Hydrocarbon | (*E*)-2-Dodecene | 1212 | 1205 |
| 42 | | 0.28 | Monoterpenoid | 1-p-Menthen-9-al, isomer 1 | 1224 | 1221 |
| 43 | | 0.25 | Monoterpenoid | 1-p-Menthen-9-al, isomer 2 | 1226 | 1223 |
| 44 | | 0.17 | Monoterpenoid | *(Z)*-Geraniol | 1233 | 1233 |
| 45 | 1.81 | | Other | Benzothiazole | 1234 | 1234 |
| 46 | 2.55 | | Ester | Dimethyl 2-methylhexanedioate | 1245 | 1245 |
| 47 | 1.23 | 0.51 | Monoterpenoid | (*E*)-Geraniol | 1253 | 1253 |
| 48 | | 0.05 | Ester | Phenethyl acetate | 1262 | 1261 |
| 49 | **5.21** | 0.11 | **Aldehyde** | **Undecanal** | 1271 | 1274 |
| 50 | 1.68 | 0.05 | Alcohol | 1-Decanol | 1279 | 1279 |
| 51 | 0.61 | | Aldehyde | 10-Undecenal | 1287 | 1288 |
| 52 | **10.13** | | **Ketone** | **2-Undecanone** | 1292 | 1292 |
| 53 | 1.30 | | Alcohol | 2-Undecanol | 1298 | 1303 |
| 54 | | 0.08 | Ester | Octyl propionate | 1302 | 1301 |
| 55 | 0.74 | 0.20 | Other | Dibutylformamide | 1309 | 1319 |
| 56 | 0.25 | 0.06 | Aldehyde | (*E*,*E*)-2,4-Decadienal | 1320 | 1320 |
| 57 | | 0.11 | Ester | Methyl caprinate | 1324 | 1324 |
| 58 | | 0.13 | Terpene-related | Phenol, 4-(1-methylpropyl)- | 1326 | 1317 |
| 59 | 0.59 | | Terpene-related | Myrtenyl acetate | 1329 | 1328 |
| 60 | **5.30** | | **Ester** | **Methyl anthranilate** | 1349 | 1347 |
| 61 | **7.14** | | **Phenol** | **Eugenol** | 1361 | 1361 |
| 62 | | 0.15 | Phenol | Chavibetol | 1366 | 1362 |
| 63 | | 0.09 | Ester | Hexyl hexanoate | 1385 | 1385 |
| 64 | | 1.52 | Ester | Octyl butanoate | 1389 | 1394 |
| 65 | | 0.05 | Monoterpenoid | (*E*)-*β*-Damascenone | 1394 | 1394 |
| 66 | 0.77 | | Hydrocarbon | Tetradecane | 1394 | 1400 |
| 67 | 1.48 | | Aldehyde | Vanillin | 1403 | 1403 |
| 68 | | 0.29 | Ester | Decyl acetate | 1408 | 1408 |
| 69 | 0.70 | | Alcohol | 1-Dodecanol | 1425 | 1430 |
| 70 | | 1.36 | Ester | Octyl isovalerate | 1434 | 1434 |
| 71 | 0.63 | | Hydrocarbon | 2-Methyl-tetradecane | 1446 | 1454 |
| 72 | | 0.07 | Ester | Cinnamyl acetate | 1451 | 1455 |
| 73 | 0.60 | | Hydrocarbon | 4-Methyl-tetradecane | 1451 | 1457 |
| 74 | | 0.14 | Monoterpenoid | (*E*)-Geranylacetone | 1456 | 1456 |
| 75 | | 1.53 | Sesquiterpene | (*E*)-*β*-Famesene | 1460 | 1460 |
| 76 | 2.15 | | Terpene-related | 2,6-Di-tert-butylbenzoquinone | 1472 | 1472 |
| 77 | **8.81** | **26.36** | **Ester** | ***γ*-Decalactone** | 1489 | 1490 |

***Table 1. Continued***

| | | | | | | |
|---|---|---|---|---|---|---|
| 78 | 3.85 | 0.58 | Hydrocarbon | 1-Pentadecene | 1492 | 1492 |
| 79 | 1.53 | 0.25 | Hydrocarbon | Pentadecane | 1500 | 1500 |
| 80 | | 0.21 | Ester | *δ*-Decalactone | 1508 | 1509 |
| 81 | | 0.45 | Sesquiterpene | *α*-Farnesene | 1512 | 1512 |
| 82 | 2.05 | | Sesquiterpenoid | Butylated Hydroxytoluene | 1516 | 1516 |
| 83 | | 1.76 | Terpene-related | 2,5-Di-tert-butylphenol | 1517 | 1514 |
| 84 | | 0.13 | Ester | Methyl dodecanoate | 1525 | 1525 |
| 85 | | 0.20 | Sesquiterpene | *α*-Bisabolene | 1552 | 1544 |
| 86 | | **29.44** | **Sesquiterpenoid** | **Nerolidol** | 1579 | 1577 |
| 87 | 2.88 | 2.20 | Ester | Octyl hexanoate | 1587 | 1575 |
| 88 | | 0.40 | Ester | Decyl butyrate | 1591 | 1590 |
| 89 | 1.26 | | Hydrocarbon | 1-Hexadecene | 1593 | 1593 |
| 90 | 1.47 | 0.68 | Hydrocarbon | Hexadecane | 1599 | 1600 |
| 91 | | 0.25 | Sesquiterpenoid | Caryophyllene oxide | 1624 | 1625 |
| 92 | | 0.33 | Sesquiterpenoid | Viridiflorol | 1631 | 1636 |
| 93 | | **4.23** | **Sesquiterpenoid** | **Bisabolol oxide II** | 1679 | 1676 |
| 94 | 0.67 | | Hydrocarbon | 1-Heptadecene | 1695 | 1694 |
| 95 | | 1.50 | Ester | *γ*-Dodecalactone | 1696 | 1695 |
| 96 | | 0.65 | Sesquiterpenoid | *α*-Bisabolol | 1703 | 1704 |
| 97 | 0.98 | 0.60 | Ester | Ethylhexyl benzoate | 1719 | 1735 |
| 98 | | 0.31 | Ester | *δ*-Dodecalactone | 1724 | 1725 |
| 99 | | 0.13 | Ester | Methyl myristate | 1728 | 1728 |
| 100 | 3.07 | 0.42 | Ester | Hexyl decanoate | 1787 | 1784 |
| 101 | 2.85 | 0.14 | Ester | Methyl pentadecanoate | 1821 | 1820 |
| 102 | 0.42 | | Ester | Diisobutyl phthalate | 1873 | 1873 |
| 103 | | 0.28 | Ester | Methyl hexadecanoate | 1940 | 1939 |
| 104 | 0.60 | | Fatty acid | Hexadecanoic acid | 1963 | 1963 |
| 105 | | 0.12 | Ester | Methyl linoleate | 2120 | 2107 |

The main components of wild strawberry aroma were determined as 2-undecanone (ketone) with 10.13%, *γ*-decalactone (ester) with 8.81%, eugenol (terpene-related) with 7.14%, methyl anthranilate (ester) with 5.30% and undecanal (aldehyde) with 5.21%. The main components of strawberry aroma were detected nerolidol (sesquiterpenoid) with 29.44%, *γ*-decalactone (ester) with 26.36%, bisabolol oxide II (sesquiterpenoid) with 4.23%, (*E*)-2-hexenal (aldehyde) with 3.64% and linalool with 3.02% (monoterpenoid). It is seen that the main components differ in both fruits, and 21 compounds are common in both fruits (Table 1).

In HS-SPME/GC-MS analysis three different *F. vesca* genotypes were identified as eugenol, *γ*-octalactone and *δ*-decalactone, and mesifurane as characteristic aroma (Zheng et al., 2023). Li et al. (2017) identified 97 volatile compounds in *F. x ananassa*. They were demonstrated as the highest concentrations of the characteristic aroma compounds such as *γ*-decalactone, ethyl butanoate (butanoic acid, ethyl ester), methyl hexanoate (hexanoic acid, methyl ester), *γ*-dodecalactone and ethyl caproate (hexanoic acid, ethyl ester). Kafkas et al. (2002) in the analysis of aroma substances determined in the apolar column by SPME-GC/MS in fresh and frozen fruits of Ottoman strawberries are the main components as methyl hexanoate, ethyl hexanoate (hexanoic acid, ethyl ester), ethyl octanoate (octanoic acid, ethyl ester), hexyl hexanoate (hexanoic acid, hexyl ester). As a result of the analysis of the aroma components of white strawberry (*Fragaria chiloensis*), 50 compounds were detected by HS-SPME. The identified components were classified as esters, alcohols, aldehydes and ketones, acids, norisoprenoids and terpenes, as well as lactones and furanones (Prat et al., 2014).

The chemical classification, number of compounds, and percentage amounts of main components determined in *F. vesca* and *F. x ananassa* fruits are shown in Table 2.

**Table 2.** The percentage amount of main components, number of compounds, and chemical classification of aroma compounds determined in *F. vesca* and *F. x ananassa* fruits

| Constituents Composition | Compound Number | Main Compound | Ratio % | Compound Number | Main Compound | Ratio % |
|---|---|---|---|---|---|---|
| | Wild strawberry (*Fragaria vesca*) | | | Strawberry (*Fragaria x ananassa*) | | |
| Aldehydes | 6 | Undecanal | 9.28 | 9 | Hexanal | 4.63 |
| Alcohols | 5 | 1-Octanol | 7.27 | 4 | 1-Hexanol | 0.59 |
| Esters | 10 | $\gamma$-Decalactone | 27.77 | 31 | $\gamma$-Decalactone | 42.06 |
| Hydrocarbons | 9 | 1-Pentadecene | 13.34 | 3 | Hexadecane | 1.51 |
| Ketones | 5 | 2-Undecanone | 15.95 | | | |
| Monoterpenes | 1 | Limonene | 0.92 | 4 | $\alpha$-Terpinolene | 0.56 |
| Monoterpenoids | 4 | Hexahydrothymol | 4.59 | 10 | Linalool | 6.40 |
| Sesquiterpenes | | | | 3 | (*E*)-$\beta$-Famesene | 2.18 |
| Sesquiterpenoids | 1 | Butylated Hydroxytoluene | 2.05 | 5 | Nerolidol | 34.90 |
| Terpene-related Compounds | 3 | Eugenol | 9.88 | 3 | 2,5-Di-tert-butylphenol | 2.04 |
| Fatty Acids | 2 | Octanoic acid | 2.28 | 2 | Hexanoic acid | 3.47 |
| Phenols | 1 | Phenol | 0.91 | | | |
| Others | 3 | Benzothiazole | 3.37 | 2 | Mesifurane | 0.51 |
| Unidentified Compounds | 2 | | 2.39 | 3 | | 1.15 |
| **Total** | **52** | | **100** | **79** | | **100** |

When examined in Table 2, according to the chemical classification results of aroma compounds obtained from *F. vesca* fruits, it can be seen that 50 compounds whose structures were defined were divided into 12 groups (excluding unidentified compounds), while 76 compounds (excluding unidentified compounds) in *F. x ananassa* fruits were distributed into 11 groups.

When the chemical component classes determined in aroma compounds were evaluated, it was determined that the most abundant compound class in *F. vesca* fruits in terms of percentage was esters with 27.77%, and the main component was $\gamma$-decalactone. In other compound classes, respectively, it was found that ketones were 15.95%, the main component was 2-undecanone, hydrocarbons were 13.34% and the main component was 1-pentadecene, terpene-related compounds were 9.88%, the main component was eugenol and aldehydes were 9.28% and the main component was undecanal. In terms of the number of compounds determined in these classes, it was determined that the most abundant compound classes were esters 10, hydrocarbons 9, aldehydes 6, alcohols, and ketones 5 each. It can be seen that there are 9 compounds in total and 17.44% of terpene or terpenoid class compounds (Table 2).

When the chemical component classes determined in the aroma compounds of *F. x ananassa* fruits were examined, it was found that the most abundant compound class in terms of percentage was esters with 42.06% and the main component was $\gamma$-decalactone. In other compound classes, it was determined that sesquiterpenoids were 34.90%, and their main component was nerolidol, monoterpenoids were 6.40% and their main component was linalool, and aldehydes were 4.63% and their main component was hexanal. In terms of the number of compounds determined in these classes, the most abundant compound classes were determined to be esters 31, monoterpenoids 10, aldehydes 9, and sesquiterpenoids 5, respectively. It is understood that there are 25 compounds in total, comprising 46.08% of terpene or terpenoid class compounds (Table 2). When the chemical classes of aroma compounds detected from wild strawberry and strawberry fruits are compared, it is seen that the major chemical class in both fruits in terms of percentage amount and number of compounds was esters. While similar groups exist in other chemical classes, there are differences in the percentage amount and number of compounds of these groups.

Song et al. (2017) reported that, as a result of their research with wild strawberry HS-SPME/GC-MS analysis, 78 aroma compounds were determined, including 25 esters, 25 alcohols, 9 terpenes, 5 phenols, 5 ketones, 4 aldehydes, 4 fatty acids, and 1 styrene.

Bianchi et al. (2014), in their study using the HS-SPME technique with strawberries of different genotypes, stated that nerolidol is dominant in the terpenoid class in *F. x ananassa* fruits, and the monoterpene class is mostly in wild species. Ester and terpene concentrations are significant among the analyzed genotypes. Methyl and ethyl esters are the compounds that most significantly contribute to strawberry (*F. x ananassa*) aroma (Cozzolino et al., 2022). As a result of SPME/GC-MS aroma analysis of commercial varieties of *Fragaria ananassa* (strawberry), it was reported that esters, which generally give a fruity fragrance, were observed to be the active ingredient in all strawberries (Görgüc et al., 2019).

It appears that the compounds and chemical classes obtained in our study are generally compatible with the data found in the literature. It can be said that some differences between the percentage amounts and chemical classification of the detected components are due to the differences in the investigated species, growing places, climatic conditions, collection times, storage conditions, and analysis parameters (Öz, 2022b).

## 4. Conclusions

This research was conducted on the fruit aroma (volatile, odor) components of wild strawberry (*Fragaria vesca*) and strawberry (*Fragaria x ananassa*) by HS-SPME technique combined with GC-MS. As a result of the aroma analysis obtained by HS-SPME/GC-MS within the scope of the study, the structures of 50 compounds in wild strawberry fruits and 76 compounds in strawberry fruits were identified. The main components of wild strawberries were detected to be 2-undecanone, *γ*-decalactone, and eugenol. The major constituents of strawberry were determined to be nerolidol, *γ*-decalactone, and bisabolol oxide II. Esters were the major chemical class in terms of percentage amount and number of compounds in both fruits. Differences in percentage amounts and number of compounds were found in other chemical classes. The data obtained at the end of the study is expected to be useful in fields such as food, perfumery, medicine, and cosmetics and will contribute to further studies.

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**Author contribution**

MO: Supervision, manuscript design, helped in plant collection, preparation of the manuscript, and editing. CB: Supervision, experimental process, and laboratory analyses. MSF: Supervision, the preparation of the manuscript, interpretation of the results, and revised the draft.

**Declaration of ethical code**

The authors of this article declare that the materials and methods used in this study do not require ethics committee approval, and/or legal-special permission.

**Conflicts of interest**

The authors declare that there is no conflict of interest.

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