JFBE 6(2): 48-55, 2023

Journal of Food and Bioprocess Engineering

Journal homepage: https://jfabe.ut.ac.ir

Original research

Quantitative Changes in Essential Oils Contents of Parsley (*Petroselinum crispum*) Harvested in Three Consecutive Months of Spring

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A B S T R A C T

Essential oils, such as sweets and juice flavorings, are widely used in the perfume, fragrance, and food industries. In addition, they are used as components of pharmaceuticals, antiseptics, and aromatherapy products. In this research, parsley essential oils from the Apiaceae family were investigated. Parsley was harvested in three consecutive months of spring and after each harvest, was carefully transported to the laboratory. After drying at ambient temperature and extraction of the essential oils of parsley by clevenger, its essential oils were analyzed by GC/MS. The family of chemical compounds was specified precisely. The results indicated that more compounds were detected in the third harvest. Parsley indicator compounds were present in all three harvests. The most identified compound from the first to the third harvest was Myristcin in the first and second harvests and 1,3,8-p-Menthatriene in the third. The amounts of these compounds would be various due to the different conditions of the product's surrounding circumstances (such as light or temperature).

Keywords: Parsley (*Petroselinum crispum*); Essential oils; GC-MS; Food Analysis; Food Chemistry

Received 12 Sep 2023; Revised 28 Nov 2023; Accepted 02 Dec 2023

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1. Introduction

Parsley (belonging to the *Apiaceae* family) is a plant, formerly *Umbelliferae*, which scientists and researchers consider to be the birthplace of Southern Europe, the Mediterranean region, and especially Greece (Morris, 2012; Farzaei et al., 2013; Stephens, 2018; Mirmohammadmakki et al., 2022). This plant can be considered from a group of green leaves with a unique aroma. (Navazio, 2012). Plant extract emulsions are used as the best tool to understand the vast benefits of essential oils in the preservation and safety of food and are used for different purposes. Therefore, paying attention to these compounds can be a helpful factor in their correct use (Anash Herman et al., 2019). The parsley leaves are interchangeably set and separated into two to three leaflets. In tropical locations, parsley can grow more than one meter long, but it only blooms every two years in temperate areas. Water stress is especially hard on parsley (Najla et al., 2012; Petropoulos et al., 2006) .Parsley grows in sunny areas with suitable environmental conditions and moist soil with pH=5.3-7.3; its height reaches 60-50 cm. This plant is grown outdoors and harvested seasonally (Mirmohammadmakki et al., 2023; Navazio, 2012). Parsley is considered home and a source and powerhouse of nutrition. Parsley has vitamin B, C, β -carotene, and zinc. Parsley is one of the important components in the diet to strengthen bones due to its high content of boron and fluorine. Parsley also contains iron and calcium in an absorbable form (Aćimović, 2019) . Parsley can be used fresh or not processed until consumption (Mirmohammadmakki et al., 2023). Essential oils significantly affect the food, pharmaceutical, cosmetic, and perfume industries. They can be used alternately or simultaneously with other compounds (Ivania et al., 2016). Essential oils and their active components are continually studied and investigated due to their wide range of antioxidant, antifungal, and antibacterial properties and their potential use as preservatives. (Amorati et al., 2013; Maurya et al., 2021). Essential oils can be used

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https://doi.org/10.22059/JFABE.2023.365275.1154

for active packaging and food coatings; therefore, their use in the food industry is growing (Sharma et al., 2021). Also, the bioactive compounds in essential oils can be used for medicinal and cosmetic applications (Diniz do Nascimento et al., 2020). 0.04-0.4% of the volatile oil in parsley leaves is composed of apiol, myristicin, elemicin, α -pinene, β-pinene, and 2,3,4,5-tetra methoxy-allylbenzene (Charles, 2004). The fragrance of parsley is due to terpenes, which are toxic to many insects. Myristin is a chemical compound (phenylpropene/acyl benzene) (also known as 5-methoxy safrole). It has properties that are used as psychotherapeutic compounds at high levels (Hallstrom & Thuvander, 1997). Parsley seeds contain 2-8% volatile oil and 13-22% non-volatile oil, similar to the compounds found in the leaves of this plant (Charles, 2004). Parsley roots contain 0.2-0.75% oil, whose main compounds are Terpinolene, Apiol, which constitutes 0.2-0.6% of the root, and Myristicin Parsley roots contain 0.2-0.75% oil, whose main compounds are Terpinolene, Apiol, which constitutes 0.2-0.6% of the root, and Myristicin (Orav et al., 2003). Parsley plant phenols have many health properties, including antioxidant, anti-inflammatory, antimicrobial, anti-tumor, and protective activity (Middleton Jr et al., 2000; Hinneburg et al., 2006; Lin et al., 2016). Parsley is one of the plants used to treat diabetic patients in Turkey, and the results showed that it significantly reduces blood glucose levels (Sener et al., 2003). Phenolic has anti-inflammatory, diuretic, and hypoglycemic properties (Aćimović, 2019). The use of parsley seed powder and parsley fruit juice has been reported to stimulate hair growth and treat and prevent insect bites (Charles, 2004). Farouk et al. stated in 2017 that the composition of essential oils of parsley is affected by the conditions in which the plant grows. The environment influences these substances' concentrations, notably the season in which the plant is growing (Farouk et al., 2017).

There are many different ways to extract essential oils, and by doing so, their bioactive and beneficial actions are improved. The principal effective methods used in these extraction forms include solidifying drying, rotating vanishing, steam refining, hydrolyzation, and GC chromatography tests, among others (Jaimand et al., 2018; Safaee et al., 2016; Richter & Schellenberg, 2007). Therefore, the GC-MS method has been employed in this study to identify the essential oils in parsley. Therefore, in this investigation, we looked at the variations in essential oils over three consecutive months in the spring (May, June, and July 2021).

2. Material and Methods

2.1. Sample Collection and Cultivation of Parsley Seed

Parsley seeds (*Petroselinum crispum*) were procured from the Ministry of Agriculture, Department of Beans, Vegetables and Seeds Production in Tehran. The desired soil for parsley cultivation was prepared from Tehran province, Tehran city. The soil type was sandy-clay, and its pH was 6.5. The soil was passed through a 2 mm sieve, and then the suitable pots for growing vegetables that were prepared in advance were filled with that soil. Parsley seeds were planted in the mentioned pots in the first week of March. Regular watering was carried out to prevent any water stress and to guarantee the best possible growth of plants. Three times in April, May, and June, the aerial sections of parsley were plucked and taken to the lab to measure its essential oils. After being collected, the samples were dried at room temperature before being ground.

2.2. Extraction of Essential Oil

The essential oil of dried parsley leaves was extracted in three replicates using a Clevenger machine. 40 g of dried parsley leaves were weighed. The extraction process took 4 h. To find the most suitable thermal planning of the column, in order to achieve the best separation, the essential oils were diluted with 50 mL of normal hexane (Merck, Germany). The obtained essential oils were filtered through Whatman filter paper and dried over a tiny amount of anhydrous Na_2SO_4 (Merck, Germany) to remove any moisture. Before being injected into the GC-MS, the extracts were kept at four degrees Celsius in sealed vials (Ertl, 1997, AOAC, 2007.01).

2.3. GC-MS Analyses

Analysis of the Parsley's essential oil was performed using a GC-MS with a HP-5 capillary column (30 m × 0.25 mm, film thickness 0.25 µm) (Agilent Technologies, United States). Helium was used as the carrier gas, and its flow rate was 0.9 mL/min. The temperature of the GC oven was set to 50 °C for 2 min before rising to 260 °C at a rate of 5 °C/m^{-1}. The temperature was maintained at 260 °C for 10 min. The mass spectra were taken at a scan range of 40–5000 m/z, a transfer line temperature of 260 °C, and an ion source temperature of 230 °C. The compounds of essential oils were identified by calculating the retention indices for the compounds of essential oils on an HP-5 column under temperature-programmed conditions for (C6 - C26) n-alkanes (Kovats indices).

2.4. Qualitative and Quantitative Analysis of Essential Oils

Mass spectra and retention indices were used to identify specific chemicals by comparing them to the NIST 98 and Wiley 7 libraries, and to other works of literature or mass spectra. Without utilizing correction factors, component relative concentrations were determined based on GC peak regions (Bhuiyan et al., 2009; De Figueiredo et al., 2004; Adams, 2007).

The identity of the compounds was taken from the available standards. Under the same operating conditions, the Kovats Index was calculated in reference to a homologous sequence of n-alkanes (C6-C26). The data was statistically assessed on duplicated test data using SPSS version 24. Analysis of variance was performed by SS Type 3.

3. Results and Discussion

In Parsley's essential oils petroselinum crispum is a pale-yellow essential oil with a pleasant smell. Table 1 shows a list of compounds in parsley harvested in three consecutive months, determined by GC/MS.

In this regard, it is recommended to read the article by Bianchi et al., which was published in 2007. In this study, researchers used a CP3800 gas chromatograph outfitted with a Saturn 2000 IT mass selective detector and a TRACE GC 2000 gas chromatograph outfitted with a Finnigan TRACE MS mass spectrometer to examine the volatile fraction of various foods (cheese and bread). Then they checked the accuracy and precision of the data obtained from each device (Bianchi et al., 2007). Paying attention to the content of this article can be a breakthrough in the field of research.

The total amount of essential oils detected in the first, second, and third harvests was 30, 38, and 58 compounds, respectively. Table 1 lists parsley's three consecutive months' essential oil chemical compositions.

Mass spectra were determined for the parsley compounds (Fig 1). Hallstrom and Thuvander in 1997 and Charles in 2004 reported 0.4-0.04% of volatile oil in parsley leaves, the primary and significant part of which is α-pinene, β-pinene, myristicin, elemicin, and apiol.

As mentioned earlier, the aroma of parsley is due to the presence of terpenes, which are toxic to many insects (Charles, 2004; Hallstrom & Thuvander, 1997). On the other hand, terpenes (pinene, myrcene, limonene, terpinene, p-cymene) are characterized as compounds with simple structures. Among all the chemical components of essential oils, terpenes have been comprehensively studied and reported to play critical roles in human health. Terpenes have been reported to exert antimicrobial activities against antibiotic-susceptible and antibiotic-resistant bacteria, mainly via their ability to promote cell rupture and inhibit protein and DNA synthesis (Masyita et al., 2022). According to the findings, terpene content in parsley grew from 2.91% at the time of the first harvest to 10.22% (an increase of about 4.5 times) before reaching 26.92% in the third harvest (With an increase of almost 14 times from the first harvest). Table 1 lists the aforementioned essential oils. It can be seen that the percentage of most compounds identified in the first to the third harvest of the plant has increased (Figs 3 and 4).

According to the data of Figs 3 and 4, hydrocarbons have a significant percentage of identified compounds in all three harvests. The highest amount of hydrocarbon, with more than 60%, belonged to the second harvest. It was mentioned in the paper that the presence of polycyclic aromatic hydrocarbons could be produced during incomplete combustions due to non-optimal temperature and oxygen content and high moisture (Paris et al., 2018). Of course, hydrocarbons have been talked about here in general, and its essential oils changes can be due to the increase in temperature and the transition from relatively cold weather in early spring to warm weather in late spring. Gruszecki et al. have also considered the changes in plant essential oils influenced by many factors, including genetic changes and environmental conditions. Their research observed that the essential oil content of parsley had changed significantly due to weather conditions in the studied growing seasons (Gruszecki & Walasek-Janusz, 2022).

The amounts of these hydrocarbons can vary depending on the desired product's surrounding environment. The content of some of these compounds, like polycyclic aromatic hydrocarbons, is usually higher for crops grown near roads or in urban areas than in rural areas. In the present study, the samples were grown in urban conditions. According to Paris et al. (2018), polycyclic aromatic hydrocarbons, including naphthalene, acenaphthylene, and acenaphthene, may be present in relatively high concentrations in some items like vegetables (Paris et al., 2018). Naphthalene was discovered in the third harvest of this investigation and the amount of it, was about 0.51%.

It should also be noted that in the third harvest, the lowest chemical compounds were aldehydes, sulfur compounds, and ketones.

According to Fig 3, carboxylic acid compounds were not found in the second harvest, and their amount was negligible in the third harvest.

Similarly, amide compounds were not present in the third harvest, while it was more than 18% in the first harvest (Fig 2).

Likewise, aldehyde compounds, ketones, furans, and amine compounds were not found in the first harvest, possibly due to temperature changes during the spring.

According to Table 1, as the year's warm season approaches, the index compounds of parsley essential oils increased, and this amount for compounds such as α-pinene, β -pinene, myrcene, and sabinene was 2.77%, 1.91%, 7.28% and, 0.22% respectively. While these amounts in the same compounds in the second harvest were 0.33%, 1.91%, 3.21%, and 5.2%, respectively, except for sabinen, the amount of all mentioned compounds increased.

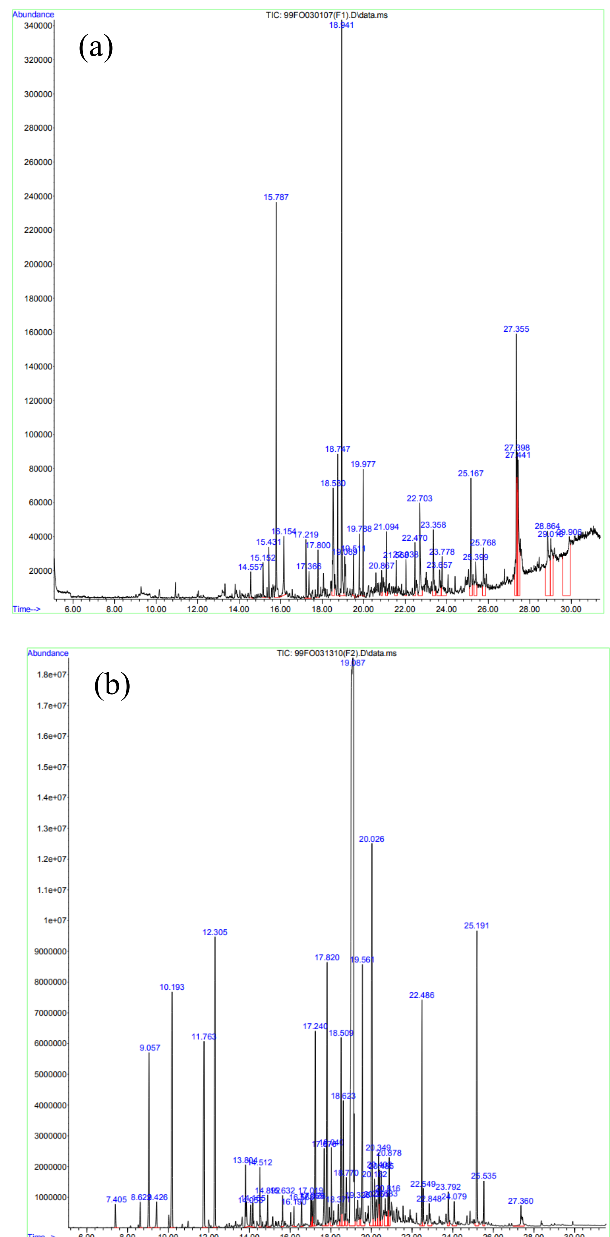

Figure 1. The GC-MS total chromatograms of essential oils in parsley, (*Petroselinum crispum.*) (a. spectrum of compounds in the first harvest b. spectrum of compounds in the second harvest).

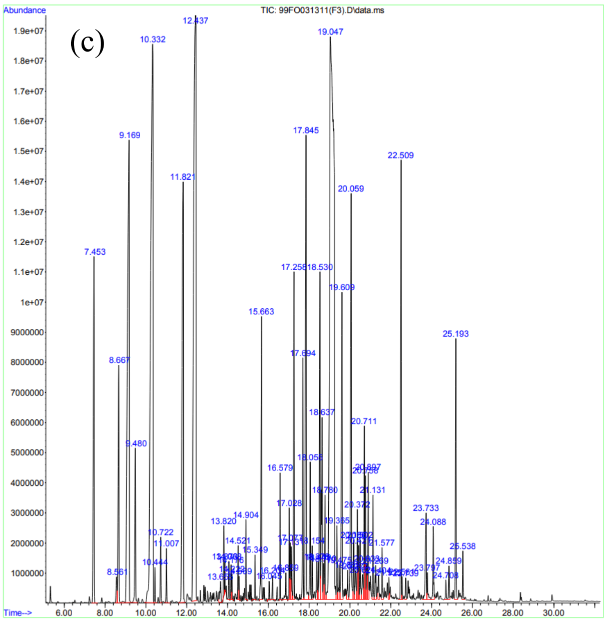

Fig. 1. Continuation. c. spectrum of compounds in the third harvest.

According to Table 1, the main components of the essential oil of parsley leaves were identified in all three samples (A, B, and C). As mentioned above, one of the most significant compounds identified among the above compounds was myristicin, which is a phenylpropanoid whose amount was significant in parsley leaves. Myristin is a chemical compound with properties that are used as psychotherapeutic compounds at high levels (Charles, 2004).

Moreover, in a study conducted by Farouk et al. on Egyptian parsley in 2017, thirty-nine essential oils were identified in Egyptian parsley's hydraulically distilled (HD) essential oil, constituting 97.87% of the total oil. Also, they conducted a study on solid-phase microextraction (HS-SPME), revealing that 16 components constituted 96.54% of the volatile material from the total extracted oil. In their study, myristicin, β-phellandrene, and myrecene were the main components identified among the total identified components.

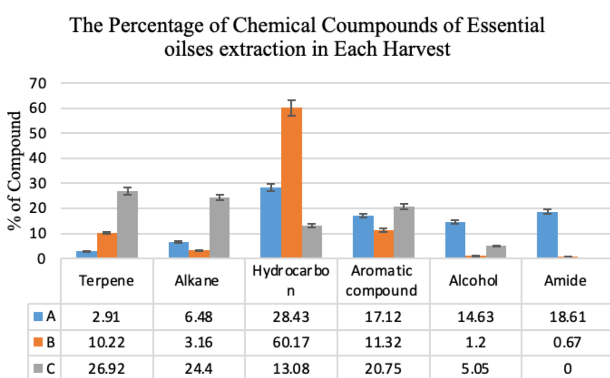

Fig. 2. The comparison of the chemical composition of essential oils in parsley, (*Petroselinum crispum.*) in the first, second and third harvest (for Terpene, Alkane, Hydrocarbon, Aromatic compound, Alcohol, Amide).

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In the first harvest, the most identified compound was assigned to myristicin, with 12.41%. After myristcin, p-Cymen-2-ol, with 8.22%, was the most identified compound. In the second harvest, the most identified compound was assigned to myristcin, with an amount of 35.63%, which is a hydrocarbon. In the third harvest, the highest amount detected was the alkene compound croweacin, with 21.6%, followed by the aromatic compound 1,3,8-p-menthatriene, with an amount of 12.68%. As mentioned in much literature, non-polar organic compounds are naturally present in the unsaponifiable fraction of vegetable oil, also a saturated aliphatic hydrocarbon made up of carbon and hydrogen, and with a linear carbon chain named n - Alkanes. Plants and their other living organisms distribute n-alkanes widely. With additional components of the wax fraction, its action forms the external cuticle of the plant, epiderm, as a moisture barrier (Srbinovska et al., 2020).

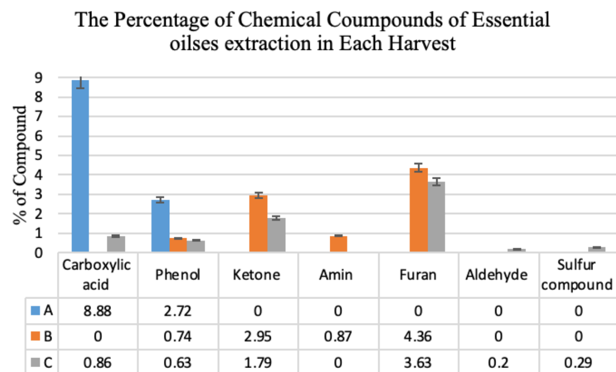

Fig. 3. The comparison of chemical composition of essential oils in parsley, (*Petroselinum crispum.*) in the first, second and the third harvest (for Carboxylic acid, Phenol, Ketone, Amin, Furan, Aldehyde, Sulfur compound).

Finally, the terpene compound, β.-phellandrene, with 12.15%, was one of the most identified compounds in the third harvest (Table 1).

According to a study done in 2017, the researchers stated that the characteristics of the flavoring compounds of parsley are affected by the location of the plant in which it grows, agricultural practices, and environmental conditions, all of which have a significant effect on the composition of its sensory compounds, and it is possible Even responsible for the disappearance of many of these components (Farouk et al., 2017). As in the present study, in the research of Gruszecki et al., the GC/MS technique was used to analyze the composition of essential oils. In 2022, Gruszecki et al. measured the essential oils of parsley in both leaves and roots. This experiment compared the content and composition of essential oil of fifteen parsley cultivars in two growing seasons in roots and leaves. The leaf essential oils output was higher than the roots, which shows that parsley leaves are a valuable spice. They observed that apiol was the predominant component of essential oils obtained from the root of all cultivars. However, in the case of essential oils obtained from the leaves, the main compounds were myristicin, β-pinene, Z-falcarinol, and β-phellandrene. However, like the present study, their content differed depending on the weather conditions in the growing months analyzed (Gruszecki & Walasek-Janusz, 2022).

Table 1. The GC-MS total chromatograms of essential oils in parsley, (*Petroselinum crispum.*) (A. Identified compounds in the first harvest B. Identified compounds in the second harvest C. Identified compounds in the third harvest).

Row	Name	KI [a] EXPERIMENTAL	Area %		
			A	B	C
1	Camphene	909	2.91	0.28	---
2	α -Pinen	938	---	0.33	2.77
3	Sabinene	978	---	5.2	0.22
4	β- Pinen	980	---	0.39	1.91
5	Myrcene	994	---	3.21	7.28
6	Phellandrene	1007	---	0.43	---
7	α.-Phellandrene	1010	---	---	1.03
8	β.-Phellandrene	1047	---	---	12.15
9	β. -trans- Ocymene	1052	---	---	0.18
10	β. Ocimene	1069	---	0.38	0.34
11	γ.-Terpinene	1075	---	---	0.29
12	p- Cymenyl	1103	---	3.58	---
13	p - α -Dimethylstyrene	1106	---	---	4.98
14	1,3,8- p -Menthatriene	1127	---	4.86	12.68
15	Phellandral	1180	---	---	0.21
16	4-Methylacetophenone	1186	---	1.2	0.33
17	L- Cryptone	1188	---	---	0.12
18	6-n-Propyl-m-cresol	1195	---	0.33	0.18
19	Iso pseudocumenol	1199	---	---	0.15
20	p-cymene	1202	---	---	0.11
21	Hydrazine	1222	---	0.87	---
22	cis-2-Methyl-5-n-propenyl furan	1223	---	---	0.25
23	β –Citronellol	1226	---	---	0.09
24	Thymol	1248	---	0.41	0.35
25	Benzoic acid	1264	0.86	---	---
26	Cinnamaldehyde	1277	---	---	0.2
27	Octadecan	1282	0.95	---	---
28	p -Cymen-3-ol	1296	---	0.46	1.66
29	p -Cymen-2-ol	1305	8.22	---	---
30	Chrysomelidial	1323	---	---	0.07
31	Morphinan-6-ol	1331	1.9	---	---
32	α.-Hydroxytoluene	1333	---	0.28	---
33	α.-Terpinolene	1359	---	---	0.54
34	Piperitenone oxide	1378	---	---	0.14
35	α.-Copaene	1389	---	0.36	0.43
36	5-phenyl- Thiazole	1392	---	---	0.29
37	levo-.β.-Elemene	1395	---	0.42	---
38	Elemol	1395	---	---	0.32
39	Tebacon	1401	1.9	---	---
40	β. Elemene	1404	---	2.59	1.89
41	Tetradecane	1414	1.31	---	---
42	β.-Caryophyllene	1440	---	1.18	1.38
43	γ.-Elemene	1450	0.98	---	3.2
44	Elixene	1451	---	3.53	---
45	α.-Farnesene	1459	---	0.98	0.25
46	β.-Farnesene	1470	---	---	0.68
47	α-Humulene	1478	---	---	0.28
48	Germacrene -D	1496	---	0.37	0.21
49	Croweacin	1497	---	---	21.6
50	α.-Curcumen	1502	---	---	0.2

Row	Name	KI [a] EXPERIMENTAL	Area %		
			A	B	C
51	γ.-Cadinene	909	1.96	2.43	---
52	dodecamethyl- Dodecamethylpentasiloxane	938	---	---	3.9
53	2,4,4-Trimethyl-3-(3-methylbutyl)cyclohex-2-enone	978	---	1.75	---
54	Dehydrocostusl actone	980	1.34	---	---
55	α.-Gurjunene	994	0.21	---	---
56	2,4-bis(1,1-dimethylethyl)phenol	1007	---	---	2.72
57	β-Bisabolene	1010	0.63	0.74	---
58	Myristcin	1047	---	35.63	12.41
59	Hexadecane	1052	---	---	1.11
60	Elemicin	1069	0.07	0.56	---
61	Pentacosane	1075	---	---	1.35
62	β -Agarofuran	1103	2.11	4.36	---
63	Caryophyllene oxide	1106	0.19	---	---
64	Carotol	1127	2.83	6.03	2.33
65	Gurjunene	1180	---	0.76	---
66	Valencene	1186	---	0.76	---
67	Viridiflorene	1188	0.26	---	---
68	l-Calamenene	1195	---	1.03	---
69	Naphthalene	1680	0.51	---	---
70	α.-Cadinol	1695	---	0.81	---
71	γ.-Cadinene	1697	0.33	---	---
72	1,2,3 Trimethylbenzene	1713	0.92	---	---
73	β. Tumerone	1711	---	0.9	---
74	Camphor	1725	---	0.89	---
75	Tricosane	1740	---	---	1.49
76	α.-Tumerone	1742	0.52	---	---
77	Apiol	1746	0.7	---	0.5
78	Docosane	1772	---	---	0.96
79	3 N Buthyl Phthalide	1773	0.27	---	---
80	p-Cymen-7-ol	1795	0.12	---	---
81	Neophytadiene	1848	0.11	2.74	1.1
82	Nonahexacontanoic acid	1845	---	---	1.44
83	Heptacosane	1846	---	---	1.8
84	2-Hexadecen-1-o	1851	2.43	---	---
85	Caffeine	1870	---	---	3.39
86	Hexadecanoic acid	1973	0.75	---	---
87	Benzofuran	2091	0.19	---	---
88	Phytol	2127	1.33	3.96	3.18
89	Tetratetracontane	2151	---	---	1.63
90	Oleyl amide	2191	---	---	2.06
91	Crodamide O	2359	---	0.67	7.27
92	Oleamide	2362	---	---	3.65
93	9-Octadecenamide	2366	---	---	5.63
94	1,2-Benzenedicarboxylic acid	2528	---	---	6.58
95	5-Methyl-2-phenylindole	2544	---	---	4.51
96	Gibberllin	2635	---	---	11.74
97	Total (100%)		96.74	95.66	99.78

KI[a]: Kovat's index on a DB5 column (Adams, 2007).

The results of the present study indicate that the number of identified compounds increases with moving toward the warmer months of the year (Fig 1 and Table 1).

Also, a study titled extraction of thymol compound from thymus vulgaris L. oil was conducted by Jannati et al. In this study, just like the present study, after extracting the leaves and aerial parts of Thyme vulgaris, the chemical compounds of the essential oils of this plant were identified using GC/MS. They continued to refine thymol as the main ingredient with hot water or microwave and then determined the yield and purity of the extracted thymol. The results showed that the extraction efficiency of essential leaf oil is higher than that of aerial parts, and thymol is the main ingredient of both essential oils (Jannati et al., 2021).

In 2016, Marín et al. studied the chemical composition of essential oils of spices widely grown and used organically in Spain, namely foeniculum vulgare, petroselinum crispum, and lavandula officinalis. In addition to their chemical compounds, they also conducted studies on total phenolic compounds, the antioxidant activity of the mentioned plants, and the effect of essential oils on the inhibition of listeria innocua CECT 910 and pseudomonas fluorescens CECT 844. Their studies showed great diversity in the composition of essential oils of the mentioned plants. Their studies on parsley showed that it has the highest phenolic content and, in general, has the best antioxidant profile due to the highest percentage of DPPH radical inhibition (64.28%) and FRAP (0.93 mmol/L Trolox). Their studies showed that the most identified compound in parsley was myristicin, with a rate of 36.15%, followed by apiole, with a rate of 20.97%. α-pinene and β-pinene, with amounts of 15.47% and 10.43%, respectively, were the third and fourth identified compounds of parsley in their studies. Also, the good inhibitory activity of parsley essential oils on listeria innocua and pseudomonas fluorescens was observed (Marín et al., 2016).

4. Conclusion

GC/MS analyzed parsley essential oils for three consecutive months from spring. The results indicated that the GC/MS device could be a helpful tool in the field of plant analysis in order to obtain compounds and identify them more precisely**.** Essential oils, are compounds that have been researched and investigated in various industries. Their presence largely combats food pathogens and other microorganisms; however, there is still a need for research on more diverse essential oils. Also, the extract of plants is used widely as the most suitable natural matter to understand the extended benefits of essential oils for different purposes. Therefore, paying attention to these compounds can be helpful to in their correct use. It has always clearly known that plants are important sources of essential oils used in various industries. In addition, familiarity with the changes of these compounds in plants can be a good guide for the consumption of foods for their nutritional value. The aerial components of parsley were investigated in this study. The significant identified compounds were hydrocarbons in the first and second harvests and terpenes in the third harvest, respectively, from the first to the third harvest. Every three months, changes in the indicated chemicals were noticed. Diffrences in chemical compounds could be due to the difference in environmental conditions in the three months the study was conducted. Also, the primary identified compounds from the first to the third harvest were myristcin in the first and second harvests and 1,3,8-p-Menthatriene in the third harvest. The compounds contained monoterpene hydrocarbons such myrcene, phellandrene, p-cymen-3-ol, α-pinen, and β-pinen. It assumes that the essential oils compounds of plants are affected by the plant's location, agricultural practices, and environmental conditions, all of which significantly affect the composition of its sensory compounds. It is likely responsible for the disappearance of many of these components. The environmental, climatic, and geographical differences and different conditions between the cultivation areas have likely led to changes in the compositions observed in the studies.

In this regard, careful examination of factors such as climatic conditions, weather conditions, temperature, the intensity of light radiation, duration of receiving light, providing suitable conditions for metabolic activities of the plant and plant species, and changes in the effective ingredients of parsley is recommended.

Acknowledgment

Authors gratefully express their sincere thanks to Razi Laboratory Complex, Science and Research Branch, Islamic Azad University, Tehran, Iran.

Conflict of interest

The authors declare that there is no conflict of interest.

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