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Original Article

Preliminary Comparative Analysis of Essential Oil Composition of *Kelussia odoratissima* Mozaff. Under Field and Natural Habitat Conditions

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Abstract

Introduction: *Kelussia odoratissima* Mozaff., as one of the most valuable and endemic species of the Zagros region, is of particular importance for its aromatic and bioactive compounds. This research aimed to evaluate the content and composition of *K. odoratissima* essential oil (EO) from a natural habitat (Doorak, Fereydunshahr County) and field cultivation (Gavkhoft, Koohrang County).

Methods: EOs were obtained using a Clevenger-type apparatus and then chemically characterized by gas chromatography (GC) and GC with mass spectrometry methods.

Results: A total of 20 components were identified in the EO samples from both the natural habitat and the field. Z-ligustilide was the predominant compound in both environments, accounting for 71.29% and 70.74% of the oil in the wild-collected samples and cultivated plants, respectively. Other major compounds included terpinolene, E-butylidenephthalide, and (E)-ligustilide. In the field samples, the corresponding amounts were 8.44%, 6.81%, and 2.79%, respectively, while in the habitat samples, they were 6.74%, 8.96%, and 2.10%, respectively.

Conclusion: The results of this preliminary study revealed that the EO of *K. odoratissima* was characterized by a phthalide-dominant profile, with (Z)-ligustilide as the major constituent. Moreover, the same 20 compounds were detected in both wild and cultivated samples, while some quantitative differences were observed among individual constituents. Overall, the EO composition appeared largely preserved under field conditions. Nonetheless, further studies with larger sample sizes are required to confirm these findings.

Keywords: *Kelussia odoratissima* Mozaff, Essential oil, Gas chromatography–Mass spectrometry, Z-ligustilide

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Introduction

Medicinal plants have been an important part of the human diet for centuries and have long been used to improve the taste, color, and aroma of food products (1). In addition to enhancing flavor, herbs and spices possess preservative effects and exhibit antioxidant, anti-inflammatory, antitumor, and anticancer properties (2). Moreover, secondary metabolites are key sources of protective pharmaceutical compounds, synthesized by medicinal plants in response to biotic and abiotic stresses. Their production and profile depend on multiple factors, including species and genotypic differences, growth stages, and environmental conditions. Across many plant species, environmental changes alter not only the concentration but also the type and accumulation pattern of secondary metabolites, thereby positioning environmental factors as the crucial regulators of biosynthetic pathways and metabolite levels (3).

Kelussia odoratissima Mozaff. is a perennial, aromatic endemic of Iran in the Apiaceae family, predominantly found in the western Zagros Mountains. Furthermore, it is used in traditional medicine, and its essential oil (EO) is a valuable source of bioactive compounds (4-6). Phytochemically, *K. odoratissima* is rich in phthalides, the dominant components of its EO (7). In addition to its nutritional value, the medicinal properties of *K. odoratissima* EO, including sedative (8) and anti-inflammatory and analgesic effects (9), have been confirmed as well. Several studies have investigated the EO composition of *K. odoratissima* from different Iranian regions. Omidbaigi et al (7) reported an extremely higher Z-ligustilide content (87.6%) in fresh bud leaves from Fereydunshahr, Isfahan.

Additionally, Salimi et al (10) analyzed three ecotypes (i.e., Koohrang, Bazoft, and Doab-e-Samsami) and concluded that Z-ligustilide and butylidenephthalide averaged 39.5%

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and 19.1%, respectively, together comprising 58.7% of the oil. Overall, phthalide derivatives accounted for 68.6% of the plant's chemical composition. Likewise, Rabbani et al (8) identified 3-butylidene-4,5-dihydrophthalide as the major constituent in leaves with an oil yield of just 0.4%. Similarly, Pirbalouti et al (11) examined wild and cultivated populations from Isfahan and Chaharmahal and Bakhtiari provinces, indicating oil yields between 0.3% and 0.35% and identifying 3-n-butyl phthalide (34.1–45.6%) and neophytadiene (42.2–68.2%) as key compounds. Vatandoost et al (12) also found Z-ligustilide (77.73%), 2-octen-1-ol (6.27%), and E-ligustilide (2.27%) as the main components. In contrast, Sajjadi et al (13) reported Z-ligustilide (29.2%) alongside significant amounts of germacrone-B (15.9%) and germacrone-D (15.5%) in samples from Zardkooh, whereas Mahmoudi et al (14) identified α-caryophyllene and α-humulene as the major compounds from the same region. Ghasemi and Kiani (15) demonstrated Z-ligustilide (64.3%) and 2-octen-1-ol acetate (12%) from the Biregan habitat in Koohrang County. Akbarian et al (16) also compared populations from Fereydunshahr, Kelusse (Isfahan), and Dishmok (Kohgiluyeh & Boyer-Ahmad), finding oil yields of 1.16–1.19% and Z-ligustilide contents ranging from 51.34% to 58.74%, along with thymol (4.46–8.76%) and carvacrol (2.85–7.84%). In addition, the Dishmok population exhibited the highest Z-ligustilide levels. However, to the best of our knowledge, a limited body of research has so far compared the EO composition of *K. odoratissima* under natural habitat versus controlled field conditions, particularly with respect to the stability of Z-ligustilide as the major bioactive compound.

Therefore, this study aims to identify the chemical composition of the *K. odoratissima* EO using GC-MS and compare the percentage of its predominant compound, Z-ligustilide, between a natural habitat and field conditions.

Materials and Methods

Seeds of *K. odoratissima* were cultivated in a field located in Gavkhoft, Koohrang region (32° 31' 57 " N, 50° 8' 7" E, elevation 2446 m) in 2019. The natural habitat serving as the source of wild-growing *K. odoratissima* was the Doorak region in Fereydunshahr County (32° 41' 16" N, 49° 55' 10" E, elevation 2120 m). The aerial parts of both field-grown and wild plants were collected from each site in March 2024. Moreover, a voucher specimen of *K. odoratissima* was deposited in the Herbarium of the Chaharmahal and Bakhtiari Agricultural and Natural Resources Research Center under voucher number 7766 (Figure 1).

Extraction of Essential Oil

EOs were extracted from the shade-dried aerial parts (50 g), which were subjected to hydrodistillation using a Clevenger-type apparatus for 3 hours. The resulting EO was separated from the aqueous phase and dehydrated with anhydrous sodium sulfate. Then, the oil was stored at 4°C in sealed vials until analysis.



Figure 1. *K. odoratissima* Plants Collected From Different Sources: Wild Habitat (Left) and Cultivated Field (Right)
Note. *K. odoratissima*: *Kelussia odoratissima*

Gas Chromatography Analysis

The chemical composition of the EOs was analyzed on a ThermoQuest-Finnigan Trace GC-flame ionization detector system using a DB-5 capillary column (30 m × 0.25 mm ID, 0.25 μm film thickness). The oven temperature was ramped from 60°C to 250°C at 5°C/min and held for 10 minutes. In addition, helium was the carrier gas at 1.1 mL/min.

Gas Chromatography-Mass Spectrometry Analysis

GC-MS analysis was performed using a ThermoQuest-Finnigan gas chromatograph coupled with a ion trap detector (Trace Mass, Manchester, UK), equipped with the same DB-5 capillary column (30 m × 0.25 mm i.d., 0.25 μm film thickness). The oven temperature was programmed from 60°C to 250°C at a rate of 5°C/min and held isothermally at 250°C for 10 minutes. Further, helium served as the carrier gas, and the ionization voltage was set at 70 eV. Additionally, the ion source and interface temperatures were maintained at 200°C and 250°C, respectively, and the mass scan range was 40–460 m/z. Moreover, chromatographic peaks were identified by comparing their Kovats retention indices with those of authentic standards. Kovats indices were also calculated using the linear interpolation of the retention times of a homologous series of n-alkanes (C7–C24, Sigma). Furthermore, the compounds were determined by comparing their experimental mass spectra with those available in the Wiley 7.0 and Adams libraries, as well as their calculated retention indices with the corresponding values reported in the NIST Chemistry WebBook.

Results

General Composition of Essential Oils

GC–MS analysis of the EOs of *K. odoratissima* identified 20 compounds in both samples, accounting for 96.44% and 96.23% of the total chemical composition of the habitat and field samples, respectively (Table 1).

The GC–MS total ion chromatogram of the habitat sample and the corresponding GC chromatograms of the habitat and field samples are displayed in Supplmentary file, Figures S1–S3.

Individual Major Compounds

The EOs of *K. odoratissima* were predominantly composed of phthalide derivatives, particularly (Z)-ligustilide. This

Table 1. Essential Oil Composition of *Kelussia odoratissima* in the Field and Habitat

Component	RI*	RI**	Content (%)	
			Field	Habitat
Propylbenzene	951	950.5	0.1	0.40
4-Octanone	967	977	0.12	0.17
2-Pentylfuran	988	989	1.31	0.39
D-Limonene	1027	1031	0.57	0.78
Terpinolene	1087	1090	8.44	6.74
1,1-Diethoxyhexane	1089	1092	0.46	0.57
5-Pentylcyclohexa-1,3-diene	1157		0.33	0.24
2-Methoxy-4-vinylphenol	1314	1314	0.30	0.35
Phenyl-1-pentanone-1	1356		0.30	0.39
α-Copaene	1378	1374	0.27	0.41
Germacrene D	1483	1481	0.54	0.60
Cuparene	1508	1505	0.34	0.35
(Z)-γ-Bisabolene	1515	1515	0.38	0.36
δ-Cadinene	1524	1524	0.79	1.22
Kessane	1531	1530	0.99	0.37
3-Butylisobenzofuran-1(3H)-one	1654		0.20	0.28
(Z)-Butylidene phthalide	1677	1666	0.45	0.47
(E)-Butylidene phthalide	1722	1707	6.81	8.96
(Z)-Ligustilide	1748	1741	70.74	71.29
(E)-Ligustilide	1802	1797	2.79	2.10
Monoterpene hydrocarbons			9.01	7.52
Sesquiterpene hydrocarbons			2.32	2.94
Oxygenated sesquiterpenes			0.99	0.37
Phthalides and ligustilides			80.99	83.10
Other compounds			2.92	2.79
Total			96.23	96.44

Note. *RI: Retention indices calculated using n-alkanes (C7–C24) on a DB-5 capillary column. **RI: Retention indices reported in the NIST Chemistry WebBook

compound represented the major constituent of both oils, accounting for 71.29% of the habitat sample and 70.74% of the field sample. Moreover, the second most abundant compound was (E)-butylidene phthalide, which accounted for 8.96% and 6.81% of the habitat and field EOs, respectively. Compared with (Z)-ligustilide, which showed only a slight decrease of 0.55% points under cultivation, (E)-butylidene phthalide exhibited a more pronounced decrease of 2.15% points. Likewise, other notable compounds included terpinolene, (E)-ligustilide, δ-cadinene, 2-pentylfuran, and kessane. Terpinolene, a monoterpene hydrocarbon, increased from 6.74% in the habitat oil to 8.44% in the field oil; similarly, (E)-ligustilide increased from 2.10% to 2.79%. However, δ-cadinene, a sesquiterpene hydrocarbon, decreased from 1.22% to 0.79%; on the other hand, 2-pentylfuran increased approximately 3.4-fold from 0.39% to 1.31%. In addition, kessane, an oxygenated sesquiterpene, increased from 0.37% to 0.99%. The remaining compounds occurred at minor levels, each accounting for less than 1.0% of the total EO. These included propylbenzene, 4-octanone, D-limonene, 1,1-diethoxyhexane, 5-pentylcyclohexa-1,3-diene, 2-methoxy-4-vinylphenol, 1-phenylpentan-1-one, α-copaene, germacrene D, cuparene, (Z)-γ-bisabolene, 3-butylisobenzofuran-1(3H)-one, and (Z)-butylidene phthalide.

Classification of Compounds by Chemical Groups

To provide a clearer understanding of the chemical architecture of the EO, the 20 identified compounds were categorized into five distinct chemical classes based on their biosynthetic origin and functional groups: (1) Monoterpene hydrocarbons (MH), (2) sesquiterpene hydrocarbons (SH), (3) oxygenated sesquiterpenes (OS), (4) phthalides and ligustilides (PL), and (5) other compounds (i.e., Aromatic hydrocarbons, aliphatic and aromatic ketones, furan derivatives, acetals, phenolic compounds, and other cyclic hydrocarbons). This classification is particularly important because it isolates the phthalide derivatives, which are the most characteristic and bioactive constituents of *K. odoratissima*.

Phthalides and Ligustilides

This class was dominant in both EO samples, comprising 83.10% of the habitat EO and 80.99% of the field EO. Five phthalide derivatives were identified in this class: (Z)-ligustilide (71.29% and 70.74%), (E)-butylidene phthalide (8.96% and 6.81%), (E)-ligustilide (2.10% and 2.79%), and (Z)-butylidene phthalide (0.47% and 0.45%) and 3-butylisobenzofuran-1(3H)-one (0.28 and 0.20%) for the habitat and field samples, respectively.

Monoterpene Hydrocarbons

MH represented the second largest chemical group, accounting for 7.52% of the habitat EO and 9.01% of the field EO. Two compounds, terpinolene (6.74% and 8.44%) and D-limonene (0.78% and 0.57%), were identified in this class for the habitat and field samples, respectively.

Sesquiterpene Hydrocarbons

SH accounted for 2.94% of the habitat oil and 2.32% of the field oil, showing minimal variation between the two samples. In addition, five compounds were identified in this class, with percentages for wild-grown versus field-grown plants, respectively: δ-cadinene (1.22, 0.79), germacrene D (0.60, 0.54), α-copaene (0.41, 0.27), (Z)-γ-bisabolene (0.36, 0.38), cuparene (0.35, 0.34). δ-cadinene, and α-copaene were higher in the habitat sample.

Oxygenated Sesquiterpenes

This class accounted for 0.37% of the habitat oil and 0.99% of the field oil, representing an increase of 0.62% points under cultivation. Kessane was the only compound identified in this class, occurring at 0.37% and 0.99% in the habitat and field oils, respectively.

Other Compounds

This category comprised seven compounds with diverse chemical structures, accounting for 2.51% of the habitat

EO and 2.92% of the field-grown EO. The identified compounds were 2-pentylfuran (0.39% and 1.31%), propylbenzene (0.40% and 0.10%), 1-phenylpentan-1-one (0.39% and 0.30%), 2-methoxy-4-vinylphenol (0.35% and 0.30%), 5-pentylcyclohexa-1,3-diene (0.24% and 0.33%), 4-octanone (0.17% and 0.12%), and 1,1-diethoxyhexane (0.57 and 0.46%) in the habitat and field samples, respectively. Among these compounds, 2-pentylfuran exhibited the most pronounced increase under cultivation, rising from 0.39% in the habitat oil to 1.31% in the field oil.

Discussion

The Z-ligustilide content observed in the present study (71.29–70.74%) is generally comparable to those reported by Omidbaigi et al (7) from Fereydunshahr (87.6%) and Vatandoost et al (12) (77.73%). Likewise, Ghasemi and Kiani (15) found Z-ligustilide (64.3%) from the Biregan habitat in Koohrang County, which is also relatively close to our findings. However, our values are higher than those reported by Salimi et al (10) from Koohrang, Bazoft, and Doab-e-Samsami, observing an average Z-ligustilide of only 39.5% and total phthalides of 68.6%. Similarly, Akbarian et al (16) indicated that Z-ligustilide contents ranged from 51.34% to 58.74% across populations from Fereydunshahr, Kelusse, and Dishmok. These discrepancies may reflect intraspecific chemovariability, differences in plant part, phenological stage, or microclimatic variation even within the same general region. Notably, some previous studies reported completely different chemotypes. Pirbalouti et al (11) identified 3-n-butyl phthalide (34.1–45.6%) and neophytadiene (42.2–68.2%) as major compounds, while Sajjadi et al (13) found germacrone-B (15.9%) and germacrone-D (15.5%) alongside only 29.2% Z-ligustilide from Zardkooh. Moreover, Mahmoudi et al (14) even observed that α-caryophyllene and α-humulene were the major constituents from the same Zardkooh region.

Differences in the EO composition of different ecotypes of a plant across studies may be due to plant material, phenological stage, ecological conditions, and analytical methodologies (17-19). Our preliminary study, along with those of Omidbaigi et al (7), Vatandoost et al (12), Ghasemi and Kiani (15), and Akbarian et al (16), suggests a phthalide-dominant chemotype for *K. odoratissima*. A key observation from this preliminary comparison is that field cultivation did not markedly alter the qualitative chemical profile of the EO, as the same 20 compounds were identified in both the wild and cultivated samples. However, quantitative differences were found for several constituents. Notably, (E)-butylidene phthalide decreased from 8.96% in the wild sample to 6.81% in the cultivated sample, whereas terpinolene increased from 6.74% to 8.44%. In addition, 2-pentylfuran increased approximately 3.4-fold (from 0.39% to 1.31%).

Conclusion

The findings of this preliminary study demonstrated that the EO of *K. odoratissima* is likely rich in phthalide compounds and predominantly characterized by (Z)-ligustilide, which is generally consistent with previous reports. Although some variations in chemical composition were observed compared to earlier studies, these differences may be associated with ecological conditions, phenological stages, and inherent chemovariability within the species. In this preliminary comparison, field cultivation did not appear to influence the qualitative composition of the EO, as an identical set of 20 compounds was detected in both wild and cultivated samples. Moreover, quantitative differences were noted for several constituents, and the overall chemical profile appeared generally preserved under field conditions. Overall, these results should be interpreted cautiously, and it is recommended that further studies be conducted with larger sample sizes and additional environmental replicates to confirm these observations. Therefore, while the results are promising, the potential of field cultivation as a sustainable strategy for conservation and utilization should be considered preliminary pending more extensive research.

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Authors' Contribution

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Competing Interests

None.

Ethical Approval

Wild *K. odoratissima* sample collection and experimental procedures were conducted in accordance with institutional and national guidelines for plant research. It should be noted that wild samples were collected with appropriate permits where necessary.

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Supplementary Files

Supplmentary file contains Figures S1–S3

References

1. Gokhale JS, Lele SS, Ananthanarayan L. Indian traditional foods and diets: combining traditional wisdom with modern science of nutraceuticals and functional foods. In: Rattan SI, Kaur G, eds. Nutrition, Food and Diet in Ageing and Longevity. Cham: Springer International Publishing; 2021. p. 357-92. doi:10.1007/978-3-030-83017-5_18
2. Muzolf-Panek M, Stuper-Szablewska K. Comprehensive study on the antioxidant capacity and phenolic profiles of black

seed and other spices and herbs: effect of solvent and time of extraction. J Food Meas Charact 2021;15(5):4561-74. doi:10.1007/s11694-021-01028-z
3. Kaptan B, Sivri GT. Utilization of medicinal and aromatic plants in dairy products. J Adv Plant Sci 2018;1(2):205.
4. Mozaffarian V. Two new genera of Iranian Umbelliferae. Bot Zh 2003;88(2):88-94.
5. Shojaee Asadieh Z, Ebrahimi A, Salimi M. Chemical composition of three ecotypes of wild celery (*Kelussia odoratissima*). J Herbs Spices Med Plants 2011;17(1):62-8. doi:10.1080/10496475.2011.560089
6. Mozaffarian V. A Dictionary of Iranian Plant Names. Tehran: Farahang Moaser; 1996. p. 522.
7. Omidbaigi R, Sefidkon F, Saeedi K. Essential oil content and composition of *Kelussia odoratissima* Mozaff. as an Iranian endemic plant. J Essent Oil Bear Plants 2008;11(6):594-7. doi :10.1080/0972060X.2008.10643672
8. Rabbani M, Sajjadi SE, Izadi A. Alleviation of morphine withdrawal signs but not tolerance by the essential oil of *Kelussia odoratissima* Mozaff. Evid Based Complement Alternat Med 2012;2012:847096. doi:10.1155/2012/847096
9. Shafaroodi H, Soltanmoradi A, Asgarpanah J. The essential oil from *Kelussia odoratissima* Mozaff. fruits exerting potent analgesic and anti-inflammatory effects. Bol Latinoam Caribe Plantas Med Aromat 2023;22(1):59-67. doi:10.37360/blacpma.23.22.1.5
10. Salimi M, Ebrahimi A, Shojaee Asadieh Z, Saei Dehkordi SS. Essential oil copmposition of *Kelussia odoratissima* Mozaff. Iran J Med Aromat Plants Res 2010;26(2):147-56. doi:10.22092/ijmapr.2010.6837
11. Ghasemi Pirbalouti A, Aghaee K, Kashi A, Malekpoor F. Chemical composition of the essential oil of wild and cultivated plant populations of *Kelussia odoratissima* Mozaff. J Med Plants Res 2012;6(3):449-54. doi:10.5897/jmpr11.1162
12. Vatandoost H, Sanei Dehkordi A, Sadeghi SM, Davari B, Karimian F, Abai MR, et al. Identification of chemical constituents and larvicidal activity of *Kelussia odoratissima* Mozaffarian essential oil against two mosquito vectors *Anopheles stephensi* and *Culex pipiens* (Diptera: Culicidae). Exp Parasitol 2012;132(4):470-4. doi:10.1016/j.exppara.2012.09.010
13. Sajjadi SE, Shokoohinia Y, Mehramiri P. Isolation and characterization of steroids, phthalide and essential oil of the fruits of *Kelussia odoratissima* Mozaff., an endemic mountain celery. Res Pharm Sci 2013;8(1):35-41.
14. Mahmoudi R, Kosari M, Zare P, Barati S. *Kelussia odoratissima* essential oil: biochemical analysis and antibacterial properties against pathogenic and probiotic bacteria. J Agroaliment Process Technol 2014;20(1):109-5.
15. Ghasemi M, Kaini S. The essential oil composition of wild celery (*Kelussia odoratissima* Mozaff.): an Iranian endemic plant. Adv Herb Med 2016;2(2):21-7.
16. Akbarian A, Rahimmalek M, Sabzalian MR, Sarfaraz D. Variation in essential oil composition, phenolic, flavonoid and antioxidant activity of *Kelussia odoratissima* Mozaff based on three model systems. J Appl Res Med Aromat Plants 2019;13:100208. doi:10.1016/j.jarmap.2019.10020
17. Saeidi K, Moosavi M, Lorigooini Z, Maggi F. Chemical characterization of the essential oil compositions and antioxidant activity from Iranian populations of *Achillea wilhelmsii* K.Koch. Ind Crops Prod 2018;112:274-80. doi:10.1016/j.indcrop.2017.12.007
18. Askari F, Mirza M, Golipour M, Fekri Qomi S. Essential oil compositions of wild and cultivated *Achillea millefolium* L. subsp. *elbursensis*. Iran J Med Aromat Plants 2019;35(1):1-11. doi:10.22092/ijmapr.2019.122699.2361
19. Vahedi E, Saeidi K, Lorigooini Z, Kiani M. Chemometric mapping reveals chemical, phenolic, and antioxidant profiles in *Tanacetum polycephalum* essential oils from Southwest Iran. Sci Rep 2025;15(1):41850. doi:10.1038/s41598-025-25861-0