

ХІМІЧНИЙ СКЛАД ЕФІРНИХ ОЛІЙ У ГЕНОТИПАХ *MENTHA LONGIFOLIA* VAR. *ASIATICA* (BORISS.) RECH.F. (LAMIACEAE) РІЗНОГО ГЕОГРАФІЧНОГО ПОХОДЖЕННЯ**Ковтун-Водяницька С.,**

Кандидат біологічних наук

Національний ботанічний сад імені М.М. Гришка НАН України

Рахметов Д.,

Доктор с.-г. наук, Професор

Національний ботанічний сад імені М.М. Гришка НАН України

Левчук І.,

Доктор технічних наук,

Науково-дослідний центр випробувань продукції,

ДП «УКРМЕТРТЕСТСТАНДАРТ»

Голубець О.,

Кандидат с.-г. наук,

Науково-дослідний центр випробувань продукції,

ДП «УКРМЕТРТЕСТСТАНДАРТ»

CHEMICAL COMPOSITION OF ESSENTIAL OILS IN GENOTYPES OF *MENTHA LONGIFOLIA* VAR. *ASIATICA* (BORISS.) RECH.F. (LAMIACEAE) OF DIFFERENT GEOGRAPHICAL ORIGIN**Kovtun-Vodyanytska S.,**

PhD of Botany,

M.M. Gryshko National Botanical Garden of the NAS of Ukraine

Rakhmetov D.,

Prof (D) of Agricultural Sciences,

M.M. Gryshko National Botanical Garden of the NAS of Ukraine

Levchuk I.,

D of Engineering

Scientific and Research Center for Products Testing, State Enterprise «UkrMetrTestStandart»

Golubets O.

PhD of Agricultural Sciences

Scientific and Research Center for Products Testing, State Enterprise «UkrMetrTestStandart»

Анотація

Величезна кількість досліджень присвячена роду *Mentha* L. (Lamiaceae). Однак *Mentha longifolia* var. *asiatica* (Boriss.) Rech.f. з Середньої Азії залишається досить слабо вивченим як джерело ефірної олії. В Україні *M. longifolia* var. *asiatica* вперше була інтродукована у Національному ботанічному саду імені М.М. Гришка НАН України. У колекції нетрадиційних ефірних рослин сорт представлений двома генотипами різного географічного походження. Нашою метою було встановити здатність рослин синтезувати ефірну олію в нових умовах зростання, визначити її якісний та кількісний склад. Методом гідродистиляції встановлено, що зразки *M. longifolia* var. *asiatica* містять: $2,36 \pm 0,63\%$ ефірної олії у зразку з Азербайджану та $1,49 \pm 0,29\%$ з Молдови. За допомогою ГХ-МС були ідентифіковані складові сполуки та визначено їх співвідношення. Домінуюче положення займають карвон оксид (45,98-60,39%), піперитон оксид (10,79-25,33%), а також метил евгенол (9,36%), піперитенон (4,06%), β -фарнезен (Z) (3,63%). Огляд літератури щодо фармакологічних та економічно цінних властивостей цих сполук дозволяє вважати ефірні олії зразків *M. longifolia* var. *asiatica* досить перспективними об'єктами для медичної практики, косметології та харчової промисловості України

Abstract

A huge amount of research is devoted to the genus *Mentha* L. (Lamiaceae). However, *Mentha longifolia* var. *asiatica* (Boriss.) Rech.f. from Central Asia remains rather poorly studied as a source of essential oil. In Ukraine, *M. longifolia* var. *asiatica* was first introduced in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine. In the collection of Non-Traditional Essential Plants, the variety is represented by two genotypes of different geographical origins. Our goal was to establish the ability of plants to synthesize essential oil in new growth conditions, to determine its qualitative and quantitative composition. Using the hydrodistillation method, it was established that samples of *M. longifolia* var. *asiatica* contain: $2.36 \pm 0.63\%$ essential oil in the sample from Azerbaijan and $1.49 \pm 0.29\%$ from Moldova. By using to GC-MS, the constituent compounds were identified and their ratios were determined. The dominant position is occupied by carvonoxide (45.98-60.39%), piperitonoxide (10.79-25.33%), as well as methyl eugenol (9.36%), piperithenon (4.06%), β -farnesene (Z) (3.63%). A review of the literature on the pharmacological and economically valuable properties of these compounds allows us to consider

the essential oils of samples of *M. longifolia* var. *asiatica* as fairly promising objects for medical practice, cosmetology and the food industry of Ukraine.

Ключові слова: *Mentha longifolia* var. *asiatica*, ефірні олії, ГХ-МС аналіз, практичне значення.

Keywords: *Mentha longifolia* var. *asiatica*, essential oils, GC-MS analysis, practical significance.

Introduction

The genus *Mentha* L. (Lamiaceae) is widely known and studied, primarily for such species as *Mentha* × *piperita* L., *M. pulegium* L., *M. spicata* L. [1-11]. However, studies of *M. longifolia* var. *asiatica* (Boriss.) Rech.f. today are quite sporadic and fragmentary [12-13].

M. longifolia var. *asiatica* is a perennial herb 70-150 cm tall, has a creeping rhizome, thanks to which it is vegetatively mobile. The entire aerial part has pubescence to one degree or another. The leaves are grayish, softly pubescent, elongated elliptic or egg-lanceolate, slightly bent downwards. Inflorescences are dense, spike-cylindrical, pointed subtly towards the apex; corolla of lilac color. The seeds are tiny. The natural area of plants of this variety covers Central Asia (Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan and Uzbekistan) and Western Asia (Afghanistan, Iran and Iraq) and China (South-Central China, Tibet and Xinjiang). Plants grow in full sun or partial shade, prefer moist soils [14].

At one time *M. longifolia* var. *asiatica* was considered as a separate species – *M. vegans* or as *M. asiatica*. The variety was first described as *M. asiatica* in 1954 by A. Borysova, but in the same year Karl Heinz Rechinger revised the taxonomy for these plants and shortened the species name to a variety. The species has several synonyms: *M. arvensiaquatica* f. *asperata* Timb.-Lagr., *M. asiatica* Boriss., *M. asperata* (Timb.-Lagr.) Pérard, *M. kopetdaghensis* Boriss., *M. vagans* Boriss. Their use still occurs in modern scientific works [15-16].

The aerial part of *M. longifolia* var. *asiatica* has a pleasant taste and aroma due to the content of essential oil. According to literary sources, the main components of the essential oil are piperitone, isomentone, cis-piperitone, as well as carvone and pulegone – in plants of Iranian origin [17], plants from Uzbekistan in the experiment contained trans-piperitone oxide, piperitone oxide, thymol, spatulenol [18-19], from China – was the main compound piperitone oxide, and were also dominant sabinene, limonene, piperitone oxide, piperitone, thymol, etc. [20-21], from Tajikistan – limonene, eucalyptol, menthone, pulegone, carvone and other compounds [22].

In the aerial part of *M. longifolia* var. *asiatica* revealed a protein – (E)- β -farnesene synthase 1 and amino acids. Protein identifier (protein Id) – AEA49038.1 [23-24]. β -farnesene has one natural isomer – isomer E. Its aroma is citrus-green. This protein occurs in the essential oil of some plant species and is catalyzed by E β F synthase. Also, (E)- β -farnesene (E β F) as a pheromone-protein plays the role of a natural repellent. The experimental work carried out by scientists from China suggests that the E β F synthase gene of *M. longifolia* var. *asiatica* can be a potential object in genetic engineering of important agricultural crops [25-26].

In Ukraine, as we know today, *M. longifolia* var. *asiatica* was introduced only in one scientific institution – M.M. Gryshko National Botanical Garden of the NAS of Ukraine (NBG). The plants have high rates of resistance and viability in the proposed growing conditions. Therefore, the issue of a comprehensive study of plants of this variety, in particular its essential oil potential in the conditions of Ukraine is of high scientific and practical relevance due to insufficient study both in the world and in our country.

Materials and Methods

Origin of plant material. Plants used in the experiments were *M. longifolia* var. *asiatica* from the collection of Non-Traditional Essential Plants of the Department of Cultural Flora of NBG. The variety is represented in the collection by samples of genotypes of different geographical origins. They were obtained in 2012 planting material (plant cuttings) from Azerbaijan (Lerik, natural population) and Moldova (Chisinau, introduced population).

Preparation of plant raw materials. Harvesting of raw materials – aerial parts of plants was carried out in the phase of the beginning of their flowering. The fresh aerial part of the plants was chopped into 1–1.5 cm fragments and left to wither for 24 hours in room conditions. The raw materials were then dried to an air-dry state using an Eridri ULTRA FD1000 dryer.

Isolation of the essential oils. The EOs were obtained by hydro distillation using an apparatus with a Clevenger nozzle. The samples were weighed on a VLKT-500 g-M scale. The weight of one sample was 40 g. The volume of water in the flask was 500 mL. The experiments were performed in triplicate. The exposure time – 90 min (from the moment the water boils). Data is presented as average + standard deviation.

Gas chromatography – Mass spectrometry analysis (GC-MS). The chromatographic profile was established on an Agilent Technologies 7890 gas chromatograph using a vf-5ms (5%-phenyl)-methylpolysiloxane) capillary column (0.25 mm×25.0 m). Experiment conditions: gas velocity-carrier – 1.0 mL/min, flow split ratio – 1:20, evaporator temperature – 250 °C, detector temperature (DEP) – 280 °C, column temperature regime – gradual heating from 60 °C to 185 °C.

The component composition of the EOs was determined on a gas chromatograph with a mass spectrometric detector HP 6890. Mass spectrometric detector 1.6–800 a.o.m., EI ionization, Scan Mode & SIM Mode, «Hewlett Packard», USA. Chromatographic column – capillary HP-5ms (0.25 mm×30.0 m). Carrier gas – helium. Carrier gas velocity 1.2 mL/min. Sample injection heater temperature – 180 °C. Oven temperature programmable from 62 to 165 °C at a rate of 5 deg/min. Sample injection (1 μ L) without flow split.

Identification of the EO components was performed using the NIST Mass Spectral Database mass

spectrum library in conjunction with programs for identification by time AMDIS.

Results and Discussions

M. longifolia var. *asiatica* was introduced for the first time in Ukraine. It has been experimentally confirmed that under the proposed growing conditions, plants have high rates of essential oil synthesis. Quantitative content of essential oil in the aerial parts of plants in two genotypically different samples of *M. longifolia* var. *asiatica* was: the sample from Azerbaijan (A) contained $2.36 \pm 0.63\%$ oil, and from Moldova (M) – $1.49 \pm 0.29\%$ in terms of absolutely dry weight. Both oil samples are slightly yellowish in color,

but differ in aroma. Sample (A) is characterized by a pleasant, complex aroma, while sample (M) is somewhat herbal-sharp with an unpleasant undertone.

The quantitative and qualitative composition of essential oils, as well as the share of each component, was established. In the essential oil of *M. longifolia* var. *asiatica*, sample A was identified by GC–MS of 39 volatile aromatic compounds. The main odorants are carvone oxide (45.98%) and piperitone oxide (25.33%). piperitenon (4.06%), nepetalactone (3.62%), linalool (3.22%) also occupy important positions in terms of quantitative content (tab. 1; fig. 1).

Table 1.

Chemical constituents of essential oil *Mentha longifolia* var. *asiatica* (Azerbaijani origin)

No	Compounds	RetTime, min	Content index, %
1.	3-Octanol	14.547	0.651
2.	1.8-Cineol	17.193	1.349
3.	β -Ocimene (E)	18.209	0.137
4.	cis -Linalool oxide (furanoid)	19.984	0.212
5.	trans-Linalool oxide (furanoid)	21.060	0.135
6.	Terpinolene	21.294	0.193
7.	Linalool	21.955	3.224
8.	Lavandulol	25.723	0.097
9.	Terpinen-4-ol	26.228	0.227
10.	α -Terpineol	26.738	0.114
11.	Menthol	26.900	0.593
12.	Hexyl butyrate	27.104	0.126
13.	Piperiton	28.603	0.103
14.	Geraniol	28.838	0.583
15.	Carvone oxide	29.292	45.981
16.	Chrysanthenyl acetate	29.546	0.192
17.	Geranial	29.764	0.262
18.	Bornyl acetate	29.926	0.115
19.	Lavandulyl acetate	30.247	0.305
20.	Geranyl formate	30.521	0.334
21.	Menthyl acetate	30.677	2.366
22.	Piperitenon	30.914	4.063
23.	α -Terpinyl acetate	31.167	0.100
24.	α -Cubebene	32.007	0.523
25.	Eugenol	32.532	0.215
26.	Piperitone oxide	32.761	25.332
27.	Nepetalactone	32.943	3.620
28.	α -Ylangene	33.106	0.739
29.	β -Bourbonene	33.646	1.601
30.	β -Cububene	33.752	1.295
31.	β -Elemene	33.965	0.184
32.	Methyl eugenol	34.345	0.466
33.	Caryophyllene (Z)	34.623	0.050
34.	α -Bergamotene	35.046	2.019
35.	Caryophyllene (E)	35.390	0.066
36.	β -Farnesene(Z)	36.008	0.235
37.	β -Farnesene(E)	36.414	0.414
38.	Germacrene D	37.253	1.7149
39.	Caryophyllene oxide	38.639	0.064
Total identified		100.00	

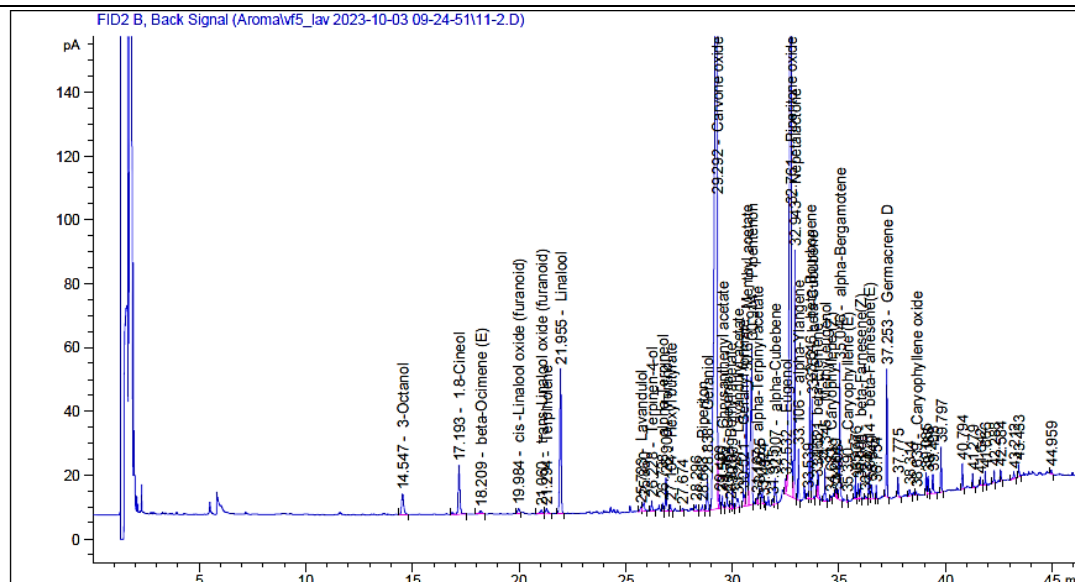


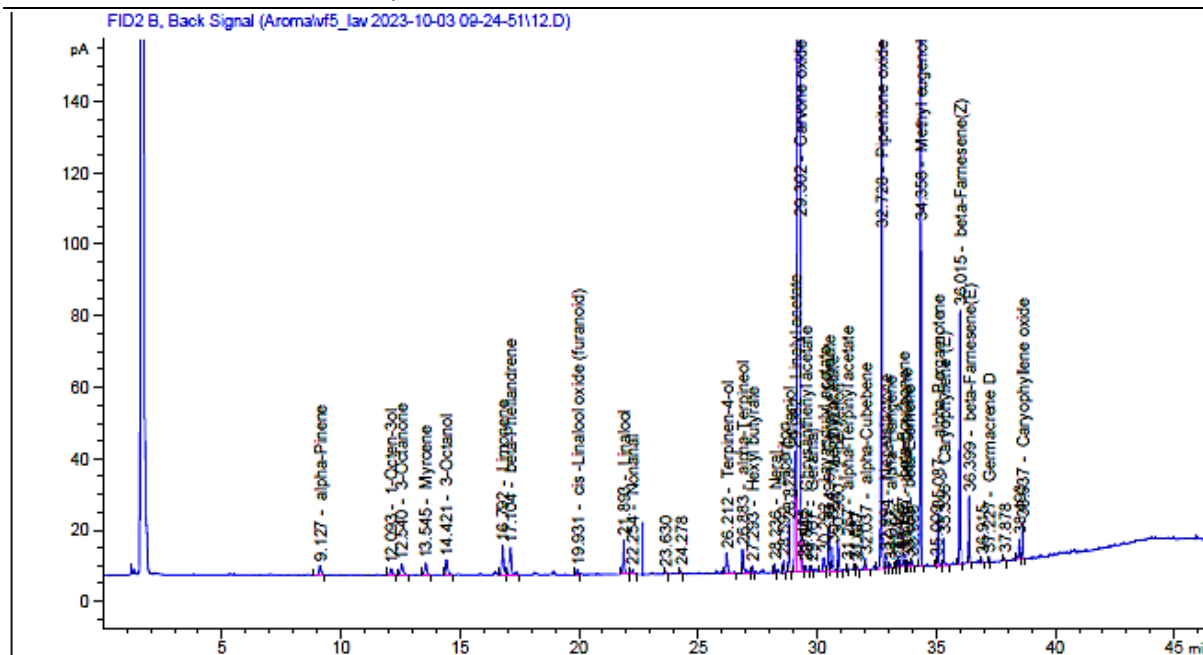
Figure 1. GS-MS Chromatogram of essential oil *Mentha longifolia* var. *asiatica* (Azerbaijani origin)

In the sample (M) *M. longifolia* var. *asiatica*, 37 compounds were discovered and identified, of which the main positions in terms of quantitative content belong to carvone oxide (60.39%) and piperitone oxide (10.79). methyl eugenol (9.36%), β -farnesene(Z) (3.63%), linalyl acetate (2.71%) also influence the formation of aroma (tab.2; fig. 2).

Table 2.

Chemical constituents of essential oil *Mentha longifolia* var. *asiatica* (Moldovan origin)

No	Compounds	RetTime, min	Content index, %
1.	3-Octanone	12.540	0.438
2.	Myrcene	13.545	0.414
3.	3-Octanol	14.421	0.534
4.	Limonene	16.792	0.592
5.	β -Phellandrene	17.104	0.866
6.	cis -Linalool oxide (furanoid)	19.931	0.119
7.	Linalool	21.893	0.859
8.	Nonanal	22.254	0.125
9.	Terpinen-4-ol	26.212	0.562
10.	α -Terpineol	26.883	0.560
11.	Hexyl butyrate	27.293	0.127
12.	Neral	28.236	0.172
13.	Piperiton	28.592	0.208
14.	Geraniol	28.828	0.839
15.	Linalyl acetate	29.082	2.715
16.	Carvone oxide	29.302	60.388
17.	Chrysanthenyl acetate	29.542	0.131
18.	Geranial	29.767	0.106
19.	Lavandulyl acetate	30.292	0.356
20.	Geranyl formate	30.496	0.630
21.	Menthyl acetate	30.662	0.450
22.	Piperitenon	30.900	0.467
23.	α -Terpinyl acetate	31.267	0.089
24.	α -Cubebene	32.037	0.184
25.	Piperitone oxide	32.728	10.788
26.	Nepetalactone	32.894	0.205
27.	α -Ylangene	33.077	0.089
28.	β -Bourbonene	33.607	0.234
29.	β -Cubebene	33.739	0.177
30.	β -Elemene	33.855	0.118
31.	Methyl eugenol	34.358	9.355
32.	α -Bergamotene	35.087	0.828
33.	Caryophyllene (E)	35.336	0.444
34.	β -Farnesene(Z)	36.015	3.630
35.	β -Farnesene(E)	36.399	0.922
36.	Germacrene D	37.227	0.086
37.	Caryophyllene oxide	38.637	0.627
Total identified		100.00	



with linalool can lead to allergies, eczema, psoriasis, irritation of the mucous membrane of the eyes, depression, impaired muscle coordination, disorders in the work of the nervous system, cancer of the breast and organs of the reproductive system [38-39]. Linalool's aroma is also why it is widely used in the manufacture of food products (candy, cookies, ice cream, cakes), as well as in personal care products, for cleaning, home care, detergents and as a fumigant for grain storage and as a pest repellent [40-42].

β -Farnesene has wide applications in industrial and agricultural production of pesticides, lubricants, surfactants, cosmetics, and biofuels [43]. Recently, β -farnesene has been used for the synthesis of vitamin E [44].

Linalyl acetate is moderately toxic to humans. It has a floral sweet-lemon aroma, sometimes described as a combination of bergamot and lavender complemented by a green spicy note with a clean woody tart nuance, and sometimes as aroma mint and slightly cumini. It has an inhibitory effect on microorganisms, including bacteria, viruses, fungi and protozoa [45-46]. It has an anti-inflammatory effect on the human body, is an effective antioxidant, does not have genotoxic, phototoxic, or photoallergenic properties. Can be used as a food additive to improve the taste and aroma of food [46-47].

Menthol is a widely known organic compound that is used by humans in a huge number of over-the-counter medicines. But despite this, there is still an incomplete understanding of its clinical pharmacology today. Known for its analgesic properties: reduces sensory hypersensitivity in pain types such as visceral pain, inflammatory pain, and neuropathic pain [48]. In dermatology – as a cooling, antiseptic, antipruritic agent [49]. It easily dissolves in human blood and actively reacts as an antioxidant [50].

Therefore, the practical use of essential oils of the investigated chemotypes of *M. longifolia* var. *asiatica*, given their chemical composition, is possible in medical practice, pharmacy, cosmetic and food industries.

Conclusion

Hence, according to the results we obtained in laboratory conditions, it is established high potential the synthesis of essential oil of *M. longifolia* var. *asiatica* during the introduction of plants into the NBG. This variety of *M. longifolia* was introduced for the first time in Ukraine. Two genotypically different plant samples of origin were tested – from natural conditions of Azerbaijan (A) and from Moldova (M); the rate of essential oil yield was $2.36 \pm 0.63\%$ and $1.49 \pm 0.29\%$, respectively. It was determined that the dominant compounds are carvone oxide, piperitone oxide, methyl eugenol, piperitenon, nepetalactone, linalool, β -farnesene(Z) and linalyl acetate, which directly or indirectly form the aroma and determine certain pharmacological properties. This experimental material proves the perspective of further comprehensive introduction, selection and pharmacological studies of *M. longifolia* var. *asiatica* precisely as an essential oil plant.

Compliance with ethical standards

The authors declare that the research was conducted in the absence of any commercial relationships that could be construed as a potential conflict of interest.

The research, analysis of the results and presentation of them in the form of a manuscript constitute original work. The article is being submitted for consideration for the first time.

Authors' contributions

Each author of the work contributed his share in the implementation of the research, which overall contributed to the successful experiment and writing of the work.

References

1. Şarer E., Toprak S.Y., Otlı, B., et al. Composition and Antimicrobial Activity of the Essential Oil from *Mentha spicata* L. subsp. *spicata*. J. Essent. Oil Res. 2011 23(1), 105-108. <http://dx.doi.org/10.1080/10412905.2011.9700435>
2. Bouazza F., Gherdaoui D., Ben miri Y., et al. Parametric and kinetic modeling, chemical composition, and comparative analyses of Algerian *Mentha pulegium* L. essential oil extracted from flowers and leaves by hydrodistillation. Not Sci Biol. 2022 14(4), 11292. <https://doi.org/10.55779/nsb14411292>
3. Teixeira B., Marquesa A., Ramos C., et al. European pennyroyal (*Mentha pulegium*) from Portugal: Chemical composition of essential oil and antioxidant and antimicrobial properties of extracts and essential oil. Ind Crops Prod. 2012 36, 81-87.
4. Andrianov K.V. Porivnjal'ne farmakognostychnye vyvchennja poshyrenyh sortiv m'jaty percevoi': dys. ... kand. farm. nauk: 15. 00. 02. NFU MOZ Ukrai'ny, Harkiv, 2016.
5. El-Ghorab A.H. The Chemical Composition of the *Mentha pulegium* L. Essential Oil from Egypt and its Antioxidant Activity. J. Essent. Oil-Bear. Plants. 2006 9(2), 183-195. <https://doi.org/10.1080/0972060X.2006.10643491>
6. Fidan H., Stankov S., Iliev S., et al. Chemical composition of essential oils from different *Mentha* spp.; 8th Intern. Conf. on EE&AE, Ruse, Bulgaria, 2022, 1-4. <http://dx.doi.org/10.1109/EEAE53789.2022.9831198>
7. Andrianov K.V., Fedchenkova Yu.A., Khvorost O.P. Accumulating Dynamics of Essential Oil in a Leaf of Widespread Sorts of Peppermint. Up-ravlinnya, Ekonomika ta Zabezpechennya Yakosti u Farmatsiyi. 2014 5(37), 16-18.
8. Abedinpour F., Ghanbariasad N., Taghinezhad A., et al. Preparation of Nanoemulsions of *Mentha piperita* Essential Oil and Investigation of Their Cytotoxic Effect on Human Breast Cancer Lines. BioNanoSci. 2021 11, 428-436. <https://doi.org/10.1007/s12668-021-00827-4>
9. Bindu N. Final Report on the Safety Assessment of *Mentha piperita* (Peppermint) Oil, *Mentha piperita* (Peppermint) Leaf Extract, *Mentha piperita* (Peppermint) Leaf, and *Mentha piperita* (Peppermint)

Leaf Water. IJT. 2001 20(3), 61-73. <https://journals.sagepub.com/doi/pdf/10.1080/10915810152902592>

10. El Hassani F.Z. Characterization, activities, and ethnobotanical uses of *Mentha* species in Morocco. *Heliyon*. 2020 9 6(11). <https://doi.org/10.1016/j.heliyon.2020.e05480>

11. Tafrihi M., Imran M., Tufail T., et. al. The Wonderful Activities of the Genus *Mentha*: Not Only Antioxidant Properties. *Molecules* 2021 26, 1118. <https://doi.org/10.3390/molecules26041118>

12. Eisenman S.W., Zaurov D.E., Struwe L. Medicinal Plants of Central Asia: Uzbekistan and Kyrgyzstan. SSBM, 2012, 340 p.

13. Aoken Aimila, Xueping Ma, Numonov Sodik, et al. Separation and Qualitative Study of *Mentha asiatica* Boriss. Essential Oil Components by prep-GC, GC-QTOF-MS, NMR and Prediction of Bioactive Compounds. *Chem. Biodivers.* 2023 20(3). <https://doi.org/10.1002/cbdv.202200566>

14. Kew Royal Botanic Gardens. Plants on the world online. Retrieved from <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:921177-1>

15. *Mentha longifolia* var. *asiatica* (Boriss.) Rech.f. Retrieved from https://en.wikipedia.org/wiki/Mentha_longifolia_var._asiatica

16. WFO. The World Flora Online. Retrieved from <https://www.worldfloraonline.org/taxon/wfo-0000240922>

17. Jaimand K., Rezaee M.B. Chemical Constituents of Essential Oils from *Mentha longifolia* (L.) Hudson var. *asiatica* (Boriss.) Rech. F. from Iran. *J. Essent. Oil Res.* 2002 14(2), 107-108. <https://doi.org/10.1080/10412905.2002.9699786>

18. Mamadalieva N.Z., Akramov D.K., Ovidi E., et al. Aromatic Medicinal Plants of the Lamiaceae Family from Uzbekistan: Ethnopharmacology, Essential Oils Composition, and Biological Activities. *Medicines (Basel)*. 2017 4(1), 8. <https://doi.org/10.3390/medicines4010008>

19. Baser K.H.C., Nuriddinov K.H.R., Nigmatullaev A.M., Aripov K.H.N. Essential oil of *Mentha asiatica* Boriss. from Uzbekistan. *J. Essent. Oil Res.* 1997 9, 453-454. <https://doi.org/10.1080/10412905.1997.9700747>

20. Okun A., Tao W., Xiaohui B., Maitinur M. Comparative study on the chemical components and biological activities of four kinds of mint volatile oils in Xinjiang analyzed by GC-MS. *Food Research and Development*. 2021 41(8), 127-131.

21. Aimila A., Ma X., Sodik N., et al. Separation and Qualitative Study of *Mentha asiatica* Boriss. Essential Oil Components by prep – GC, GC-QTOF-MS, NMR and Prediction of Bioactive Compounds. *Chem. Biodivers.* 2023. <https://doi.org/10.1002/cbdv.202200566>.

22. Mashchenko P.S., Sakhratov V.A., Kalikina I.Y., et al. Study of the Component Composition of the *Mentha asiatica* Essential Oil by Gas Chromatography-Mass Spectrometry. 2022. <https://doi.org/10.29234/2308-9113-2022-10-2-34-40>

23. UniProt. Retrieved from <https://www.uniprot.org/uniprotkb/F2X679/entry#sequences>

24. ENA. European Nucleotide Archive. Retrieved from <https://www.ebi.ac.uk/ena/browser/view/AEA49038>

25. Avé D.A., Gregory P., Tingey W.M. Aphid repellent sesquiterpenes in glandular trichomes of *Solanum berthaultii* and *S. tuberosum*. *Ent. Exp. et Appl.* 1987 44(2), 131-138. <https://doi.org/10.1111/j.1570-7458.1987.tb01057.x>

26. Yu X., Zhang Y., Mo Y., et al. Expression of an (E)-beta-farnesene synthase gene from Asian peppermint in tobacco affected aphid infestation. *The Crop J.* 2013 1(1), 50-60. <https://doi.org/10.1016/j.cj.2013.07.005>

27. Riani L.R., Macedo A.L., Chedier L.M., Pimenta D.S. Chemical analysis of essential oil and hydrolates of leaves, inflorescences and stems of *Piper chimonanthifolium* Kunth. *Rev. Virtual Quim.* 2017 9, 1560-1569.

28. Bouyahya A., Mechchate H., Benali T., et al. Health Benefits and Pharmacological Properties of Carvone.

29. Health Benefits and Pharmacological Properties of Carvone. Retrieved from https://www.researchgate.net/publication/356603741_Health_Benefits_and_Pharmacological_Properties_of_Carvone [accessed Feb 23 2024]. *Biomolecules* 2021 11, 1803. <https://doi.org/10.3390/biom11121803>

30. A kind of preparation method of eugenol methyl ether. Patent CN201310338973.1A. 2013-08-06. China.

31. Methyl eugenol (allylveratrol). Retrieved from https://en.wikipedia.org/wiki/Methyl_eugenol

32. Nepetalactone. Retrieved from <https://www.wikidoc.org/index.php/Nepetalactone>

33. Espín-Iturbe T., López Yañez B.A., García A.C., et al. Active and passive responses to catnip (*Nepeta cataria*) are affected by age, sex and early gonadectomy in male and female cats. *Behav. Process.* 2017 142, 110-115. <https://doi.org/10.1016/j.beproc.2017.06.008>

34. Batume C., Mulongo I.M., Ludlow R., et al. Evaluating repellence properties of catnip essential oil against the mosquito species *Aedes aegypti* using a Y-tube olfactometer. *Sci Rep.* 2024 14, 2269. <https://doi.org/10.1038/s41598-024-52715-y>

35. An Q., Ren J.-N., Li X., et al. Recent Updates on bioactive properties of Linalool. *Food Funct.* 2021 12, 10370-10389. <https://doi.org/10.1039/D1FO02120F>

36. Mughal M.H. Linalool: A mechanistic treatise. *J Nutr Food Technol.* 2019 2(1), 1-5. <https://doi.org/10.30881/jnfrt.00014>

37. Dos Santos E.R.Q., Maia J.G.S., Fontes-Junior E.A., et al. Linalool as a Therapeutic and Medicinal Tool in Depression Treatment: A Review. *Curr. Neuropsychopharmacol.* 2022 20(6), 1073-1092. <https://doi.org/10.2174/1570159X19666210920094504>

38. Cal K., Krzyzaniak M. Stratum corneum absorption and retention of linalool and terpinen-4-ol applied as gel or oily solution in humans. *J. Dermatol. Sci.* 2006 42, 265-267. <https://doi.org/10.1016/j.jdermsci.2006.02.007>

39. Yanchenko V.O., Voronina-Tuzovs'kykh YU.V., Poletay V.M.. Khimiya pryrodnykh spoluk (Izoprenoyidy ta steroyidy). Navchal'nyy posibnyk. Chernihiv: NUCHK imeni T.H. Shevchenka, 2023. 191s.
40. Linalool. Retrieved from <https://www.essentialoil.in/linalool.html>
41. Kamatou G. P. P., Viljoen A.M. Linalool – A Review of a Biologically Active Compound of Commercial Importance. *Nat. Prod. Commun.* 2008 3(7), 1183–1192.
42. Technical Resources International. Summary of Data for Chemical Selection. 1997. Retrieved from http://ntp.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/Linalool
43. Liu Y., Wang Z., Cui Z., et al. Progress and perspectives for microbial production of farnesene. *Bioresour Technol.* 2022 347, 126682.
44. Ma T., Deng Z., Liu T. The past and present of vitamin E. *Synth Biol J.* 2020 1, 174-86.
45. d'Acampora Zellner B., Casilli A., Dugo P., et al. Odour fingerprint acquisition by means of comprehensive two-dimensional gas chromatography-olfactometry and comprehensive two-dimensional gas chromatography/mass spectrometry. *J. Chromatogr. A.* 2007 1141, 279-286. <https://doi.org/10.1016/j.chroma.2006.12.035>
46. Peana A.T., D'Aquila P.S., Panin F., et al. Anti-inflammatory activity of linalool and linalyl acetate constituents of essential oils. *Phytomedicine.* 2002 9(8), 721-6. <https://doi.org/10.1078/094471102321621322>.
47. Api A., Belsito D., Bhatia S., et al. RIFM fragrance ingredient safety assessment, Linalyl acetate, CAS Registry Number 115-95-7. *Food Chem. Toxicol.* 2015 82, 39-48. <https://doi.org/10.1016/j.fct.2015.01.010>
48. Patel R., Gonçalves L., Leveridge M., et al. Anti-hyperalgesic Effects of a Novel TRPM8 Agonist in Neuropathic Rats: A Comparison with Topical Menthol. *Pain.* 2014 155, 2097-2107. <https://doi.org/10.1016/j.pain.2014.07.022>
49. Patel T., Ishiuiji Y., Yosipovitch G. Menthol: A refreshing look at this ancient compound. *JAAD.* 2007 57(5), 873-878.
50. Gökalp F. The Investigation Of Menthol's Bioactivity As Theoretical By Using DFT (Density Functional Theory). *J. of Sci.* 2015 11(3), 363-364. <https://doi.org/10.18466/cbujos.43606>