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Review Article

Potential Use of Essential Oils and Their Individual Components in Cosmeceuticals: A Review

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Abstract

The cosmetic industry is searching for new active ingredients from renewable natural sources to make more environmentally friendly and safe products. Botanical extract is a nearly limitless source of these new actives due to the current consumer demands as well as international regulations. Due to both their fragrant nature for the creation of fragrances and perfumes and the numerous advantageous properties of their individual components (EOCs), such as anti-inflammatory, antimicrobial, and antioxidant properties, essential oils (EOs) emerge as a very common natural ingredient in cosmetics and toiletries. Additionally, nowadays, the cosmetic industry includes EOs or different mixtures of their individual components (EOCs), either as active ingredients or as preservatives, in various product ranges (e.g., moisturizers, lotions, and cleansers in skin care cosmetics; conditioners, masks or anti-dandruff products in hair care products; lipsticks, or fragrances in perfumery). However, because each essential oil's distinct chemical profile is linked to a different set of advantages, it is challenging to generalize about how they might be used in cosmetics and toiletries. Formulators frequently spend time looking for appropriate combinations of EOs or EOCs to achieve particular advantages in the finished products. The literature on the most recent developments in the use of EOs and EOCs in the production of cosmetic products is updated in this work's review of the literature. Additionally, certain particular issues pertaining to the security of EOs and EOCs in cosmetics will be covered. It is expected that the information contained in this comprehensive review can be exploited by formulators in the design and optimization of cosmetic formulations containing EOs.

More Information

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Keywords: Essential oils; Natural fragrances; Natural antimicrobial; Cosmeceuticals; Cosmetic industry

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Introduction

Essential oils (EOs) are biologically active volatile molecules that are produced in a variety of plant organs, including flowers, buds, leaves, branches, stems, seeds, fruits, forests, roots, etc. [1]. Additionally, several active substances are found in EOs, including alkaloids, tannins, steroids, glycosides, resins, phenols, volatile oils, and flavonoids [2,3]. To address consumer concerns about the negative effects of synthetic antioxidants, which have hazardous side effects on consumers and subsequently cause numerous cancers, EOs are currently gaining popularity as natural alternatives to synthetic antioxidants. Therefore, new and affordable sources of natural antioxidants are becoming more accessible in order to preserve and improve customers' health and generate food security [4].

Due to the high concentration of volatile, aromatic, and bioactive components, EOs and extracts play a significant role in many sectors [5]. Additionally, these powerful substances play a crucial role in the pharmaceutical, food, agricultural, cosmetic, and health industries and have inherent antioxidant and antibacterial capabilities [6]. Additionally, changing to a more "natural cosmetic" has become necessary due to current international regulations, which forbid the use of many conventional chemicals in the production of goods for human consumption and recommend gradually replacing them with alternative substances, preferably derived from renewable natural sources, such as plants and microorganisms (biotechnological sources) [7-11]. A wide variety of cosmetically acceptable active ingredients are produced by plants and microorganisms, and these ingredients can be used to make a variety of cosmetics and toiletries, such as creams that protect against UV radiation and pollution, produce fragrances, or lessen the effects of aging on the skin [1,9,12,13].

An essential piece of research exploring the advantages connected with the use of botanical extracts in the formulation of various cosmetic products has been inspired by current consumer interests and market trends. The goal of this is to use their biological characteristics to create new goods that can improve human health, beauty, and wellness. The most valued

goods for meeting some of the demands made in the design of new products are essential oils (EOs) and their individual components (EOCs), in particular [14-17]. In order to take advantage of some of their capabilities, such as analgesic, antibacterial, and antimicrobial properties, but mostly their pleasant aroma, EOs have been widely incorporated in a wide range of cosmetic items, perfumes, and home products [18]. This review strives to offer a current viewpoint on the use of EOs and each of their component parts in the cosmetic business today. Additionally, some fundamental issues regarding the potential need for safety measures while using EOs and EOCs in the creation of cosmetics and toiletries will also be covered.

General characteristics of essential oils

Essential oils (Eos) are highly hydrophobic natural substances that are widely used in the food and pharmaceutical industries, pest management, perfumery, cosmetics, and toiletries. They are derived from aromatic plants, which can include flowers, roots, bark, leaves, seeds, peel, fruits, wood, and whole plants [16,19-22]. They comprise a large family of compounds known as essential oil components (EOCs), each of which has its own distinct chemical fingerprint [22-30]. Therefore, a single essential oil should be considered as a complex mixture of bioactive compounds, with their final compositional profile, and hence their bioactivity, dependent on different factors: (i) method of extraction, drying, and storage; (ii) time of harvest and climate conditions, and (iii) plant species and which part of the plant was used for their isolation [11]. This compositional richness is a crucial component in the wide spectrum of essential oil applications, and it promotes better wellness, hygiene, and aesthetics [31].

Commonly, EOs are liquids that have a density below that of water. They can also be combined with alcohols, ethers, and lipids but are not water-soluble. The majority of EOs come from angiosperm plants, such as those in the Apiaceae, Asteraceae, Lamiaceae, Lauraceae, Myrtaceae, and Rutaceae families [1,32], which play a very important role in defense, signaling, or as part of their secondary metabolism [19,33]. Figure 1 includes some examples of EOs, with their origin, properties, and active components.

EOs should be considered as a renewable bio-resource of active ingredients that can be exploited for the production of eco-sustainable products, with their antioxidant, bactericidal, virucidal, fungicidal, anti-parasitical, insecticidal, and medicinal properties being a very important benefit for this type of applications [34-39]. They can be used in the manufacture of a wide variety of cosmetic goods, such as creams, gels, and ointments, without the requirement for the addition of chemical preservatives, in particular, because some of their constituent components have bactericidal and fungicidal properties [40]. It is important to note that EOs have a number of disadvantages, including high volatility, poor water solubility, and thermal and chemical lability (the majority of these molecules are vulnerable to oxidation when exposed to the environment), which makes their handling challenging for a logical design of cosmetic products [17,19,41], It necessitates careful management of their conditioning, storage, and packaging processes. A careful quantification of their maximum concentrations in a given formulation is required to ensure the production of safe cosmetic products because the role of EOs, and their individual components, in the formulations is not always positive and represents a potential source of allergenic reactions [30].

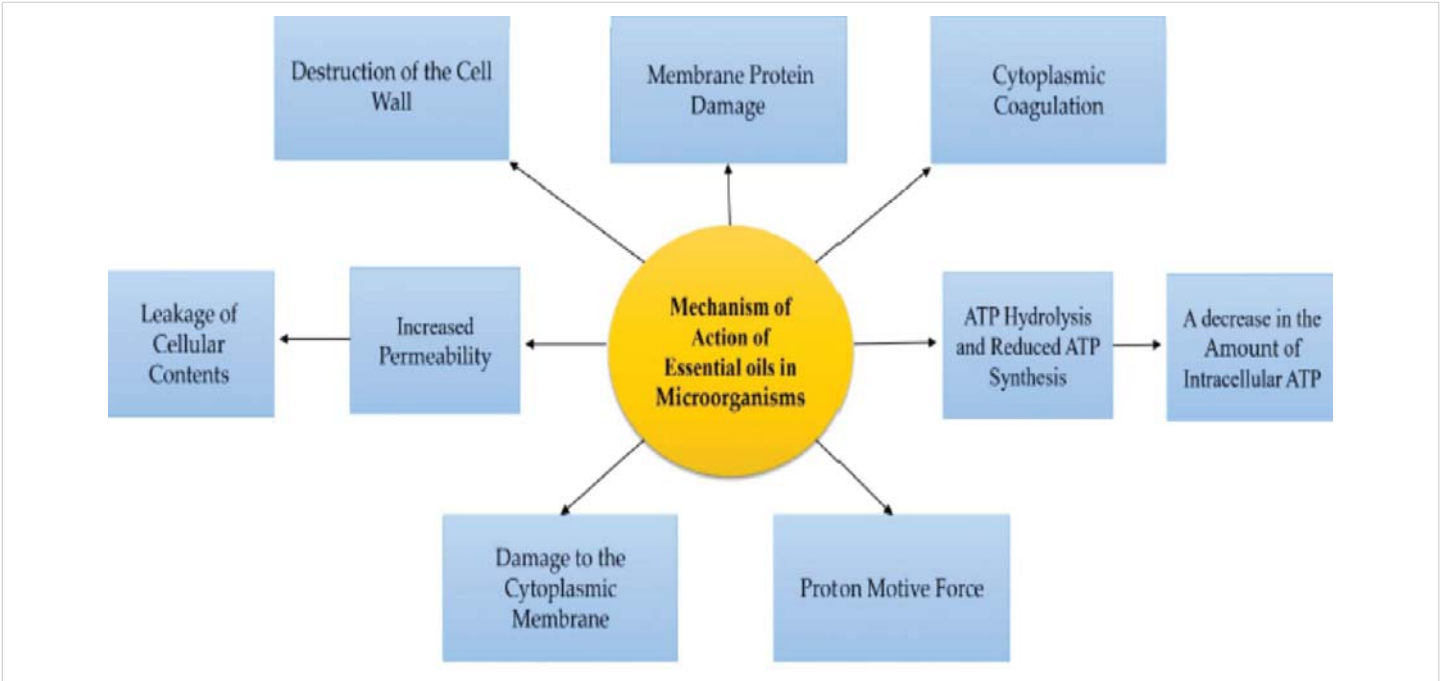

Figure 1: Different forms of EOs' effects on microorganisms and their mechanisms.

The main compounds constituting essential oils

From a chemical point of view, EOs are very complex mixtures of low molecular weight volatile compounds (in some cases more than 100), the so-called essential oil components (EOCs), which appear at quite different concentrations [24]. However, the biological features of EOs, which are often controlled by two or three components present at the highest concentrations (20% - 70% w/w), do not, however, reflect the compositional richness of EOs [34]. On the other hand, the chemical makeup and consequently the quality of a particular essential oil depend on a variety of factors, including genetics, the season of harvest, the location of the crop, the section of the plant used, and the technique of manufacturing [42,43].

Lipophilic terpenoids, phenylpropanoids (aromatic chemicals), and short-chain aliphatic hydrocarbon derivatives (terpenes) make up the majority of essential oils. The latter are aromatic or hydrocarbons generated from phenols, ethers, esters, aldehydes, ketones, alcohols, oxides, and alcohols [11,42,44]. Figure 2 shows some representative molecular structures of different essential oil components (EOCs) that can appear in EOs. The composition of EOs is associated with the existence of specific biosynthetic pathways in plants [45]. The biosynthesis of the many types of necessary components follows extremely precise pathways, which are typically classified based on the specific chemical composition of the component [11]. Thus, aromatic phenylpropanoids are obtained from the shikimic acid pathway, which results in the formation of phenylalanine, terpenoids derived from the isopentenyl diphosphate (IPP), and its isomer dimethylallyl diphosphate (DMAPP) [44,46]. On the other hand, terpenoids are composed of different isoprene units (C_5H_8) which are commonly assembled in a head-to-tail fashion following a direct assembly process, or by cyclization, rearrangements, or other types of conversions from aliphatic isoprenoid precursors [42]. Repeated addition of IPP units results in prenyl diphosphate precursors, which are then changed by terpene-specific synthetases to produce the terpene skeleton. To create the final terpene molecules with the desired chemical structures and characteristics, these go through secondary enzymatic modification, typically by a redox process [11].

It should be noted that in addition to the unique compositional diversity of EOs linked to their biosynthetic pathways, it is also possible to isolate extracts with various compositions from a given plant type; thus, the final composition of the EOs may vary depending on the methods used for their extraction. This can be explained by the unique characteristics of the different constituents found in essential oils, particularly their volatility. Since terpenoids, such as sterols or carotenoids, remain in the non-volatile fraction found in plant resins or gums, remaining as a residue in the distillation process, genuine essential oils obtained by distillation contain a high amount of low volatile components, such as diterpenes [42]. It should be noted that the weight ratio between volatile and non-volatile compounds is strongly dependent on the specific essential oil, and ranges from 99:1 for grapefruit oil to 60:40 for bergamot oil [47,48].

Applications of EOs in cosmetic products

People have been interested in using essential oils and herbal extracts as cosmetics for a long time, and active

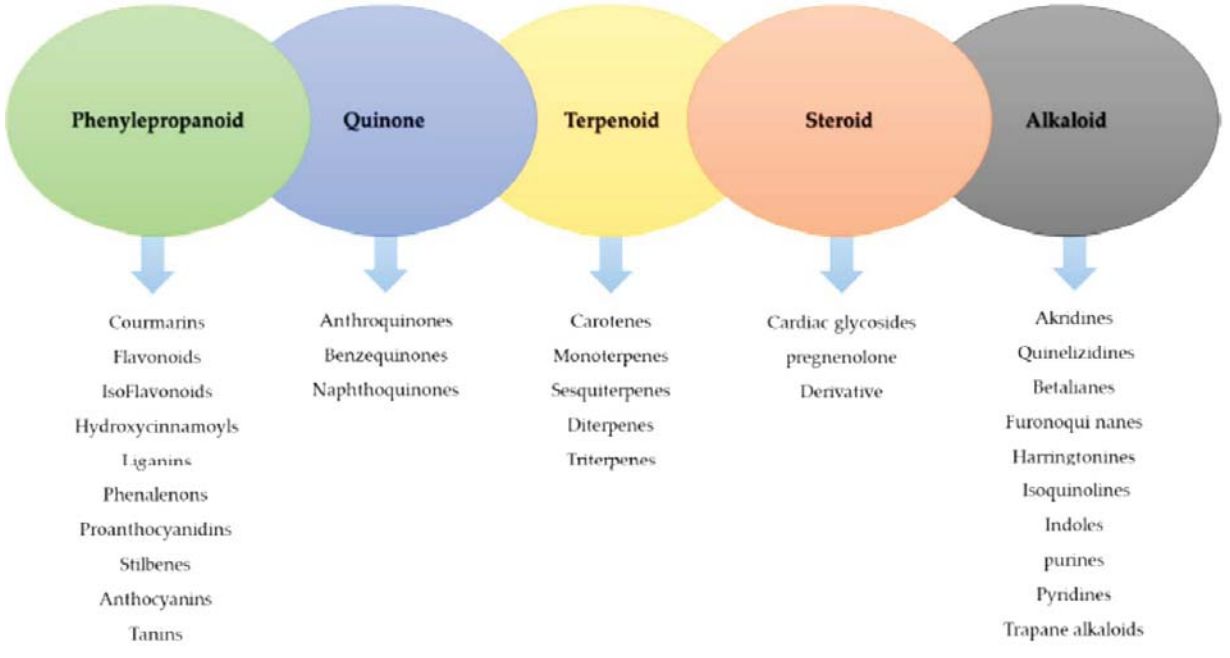

Figure 2: Classification of the active ingredients of essential Oils [21].

ingredients derived from plants have been employed in perfumes and cosmetics. Historical evidence from the nations where these plants were first cultivated, including India, China, Egypt, and Iran, attests to the long-standing use of medicinal plants in cosmetics. In order to address their health needs, it is estimated that more than 80% of the world's population uses conventional medicine (plant extracts or their active ingredients) [49]. For example, in ancient Egypt, the oil of medicinal plants was extracted by steaming, while the Romans and Greeks used the distillation method for extraction. The use of medicinal herbs also increased with the rise of Islamic culture thanks to creative methods, and technologies for extracting oil, EO, and their substance advanced in a useful direction. Additionally, the essential oils (EO) derived from plants like Cedrus libani, Ocimum kilimandscharicum, Artemisia annua, Acacia vestita, Piper angustifolium, Sassafras albidum, and Rosmarinus officinalis contain camphor, which has been known to have aromatic properties for centuries and was used as a medicine in ancient China and Japan. It has been employed in numerous Asian and European nations for medical, gastronomic, and aesthetic purposes [50,51].

Currently, consumers' tendency to purchase herbal cosmetics, which are both environmentally friendly and renewable, has increased [52]. In recent years, "natural cosmetics" recorded a large quota of cosmetics (about $40 billion by 2021, which is about 10% of the global cosmetics market) [53]. Plant EOs are utilized in a variety of cosmetic products such moisturizers, lotions, and cleansers for the skin because of their anti-inflammatory, antibacterial, and antioxidant characteristics. Hair care products, lipsticks, and perfumes all employ cosmetics, conditioners, masks, or anti-dandruff products [53].

By adding rosemary and chamomile EOs to shampoo, EOs can quickly penetrate the scalp, feed the hair follicles, moisturize the hair, strengthen the hair, and eliminate the adverse molecules that block the pores of the skin [54]. EOs significantly influence hair growth stimulation and hair loss prevention [55]. According to a report, topical mint oil made from Mentha piperita is normally applied at a modest dose (3% weight on weight) to promote hair growth [56]. One of the most common applications of EOs in skin care is to prevent acne from appearing, using the ability of EOs to inhibit Propionibacterium acnes, which Citronella's EO has the ability to do [57]. Due to their ability to block the majority of UV photons between the wavelengths of 290 and 400 nm, EOs can be used in sunscreen products to shield the skin against sunburn, wrinkles, and other skin-damaging effects [58]. Calendula officinalis essential oils were used in a cream formulation that was tested in a lab setting. The outcomes showed that the cream formulation had good sun protection qualities [59].

Cosmetic products have preservatives added to them to keep bacteria from spoiling them and lengthen their shelf lives. The customer must also be shielded from any pathogens. Although chemical preservatives stop germ growth, customers are skeptical about their safety. Producing preservative-free or self-preserving cosmetics is therefore of great interest [60]. Therefore, the use of plant essences and extracts in the manufacture of cosmetics as multipurpose antimicrobial substances, both as an alternative to natural preservatives and with anti-pathogenic qualities, can aid in improving the quality of these products. In herbal cosmetics, some Nepta species, such as Nepeta cataria var (Citriodora), Nepeta cataria, and Nepeta grandiflora, are utilized. Nepetalactone and geraniol in N. cataria, citronellol and geraniol in N. citrodora, and o-cymene, c-terpinene, carvacrol, and p-cymene in N. grandiflora were the principal chemicals in these three species [61]. Table 1 shows a Potential application of some EOs in the design of different cosmetic formulations.

Conclusion

The cosmetic industry is becoming more and more interested in the family of compounds known as essential oils (EOs) and their specific components (EOCs). This is a result of their numerous biological qualities, which can be used to promote well-being, attractiveness, and health. These features include those that are antibacterial, antifungal, anti-inflammatory, and antioxidant. Due to this, essential oils are now widely used in products for hair and skin care as well as natural preservatives in many formulations. This has expanded the spectrum of uses for essential oils beyond the fragrance industry, creating an almost unlimited list of applications that are constantly expanding. Therefore, essential oils have become essential components contributing to the optimal balance of physical wellness. However, the safety concerns related to the use of EOs and EOCs in the final products cannot be hidden due to their significant contribution to the present growth of the cosmetic industry towards greener and eco-sustainable products, making it vital to be cautious with their dose. Therefore, it is clear that EOs and EOCs are a very important source of bioactive molecules for the cosmetic industry, even though it is mandatory a careful analysis of their application conditions. On the other hand, the use of essential oils in cosmetics and toiletries is advantageous not only in terms of the cosmetic advantages of the products and their function as preservatives but also because it enhances the brand image of commercial goods. This necessitates advancing study in order to better understand the biological functions of these compounds and any potential toxicological implications, which will pave the way for the creation of essential oil-based cosmetic products. Therefore, considering the interest of the cosmetic industry in replacing traditional actives with greener bioactive ingredients, it is necessary to perform more systematic tests evaluating the real performance of essential oils in final formulations.

Table 1: Potential use of some EOs in creating various cosmetic compositions [39,41,43,46,48,51,55,57,59,61].

Application	Essential Oil	Plant	Main Components	Properties	Function
Skincare	Rosemary	*Rosmarinus officinalis*	borneol; camphene; camphor; _β-caryophyllene; 1,8-cineole; p-cymene; limonene; linalool; myrcene; _α-pinene; _β-pinene; _α-terpineol	antibacterial antioxidant	anti-acne
	Camellia	*Camellia japonica*	_β-amyrin; cycloartenol; lanosterol; lupeol; _β-sitosterol; squalene	antibacterial antioxidant	anti-aging moisturizer
	Evening primrose	*Oenothera biennis*	_β-amyrin; 1-hexacosanol; linoleic acid; ϒ-linolenic acid; 1-tetracosanol; squalene	antibacterial antioxidant	anti-wrinkles moisturizer anti-acne
	Sandalwood	*Santalum spicatum*	_α-bisabolol; (E)-farnesol; nuciferol; _α-santalol; _β-santalol	antiseptic antioxidant	anti-aging
	Chamomile	*Matricaria chamomilla*	_α-bisabolol; bisabolol oxide; bisabolon oxide; chamazulene; 1,8-Cineole; _β-farnesene; _α-Terpineol	anti-inflammatory wound healing	anti-acne anti-aging
Hair care	Sweet orange	*Citrus sinensis*	limonene; myrcene; _α-pinene; _β-pinene; sabinene	antibacterial antioxidant	antidandruff
	Lavender	*Lavandula officinalis*	borneol; caryophyllene; lavandulol; lavandulol acetate; linalool; linalyl acetate; _α-terpineol; terpinene-4-ol	antibacterial antioxidant	hair growth conditioning
	Peppermint	*Mentha piperita*	carveone; 1,8-cineole; limonene; menthol; menthone; methyl acetate; neomenthol	antibacterial antioxidant	hair growth conditioning
	Thyme	*Thymus vulgaris*	_α-cadinene; ϒ-cadinene; _-cadinene; _-cadinol; _α-cadinol; _β-caryophyllene; p-cymene; elemol; _β-eudesmol; germacrene; limonene; ϒ-muurolene; myrcene; trans-_β-ocimene; _β-pinene; ϒ-terpinene; _α-terpineol	antibacterial antioxidant	antidandruff hair growth
	Bergamot	*Citrus bergamia*	bergamottin; bergapten; citropten; limonene; linalool; linalyl acetate; _α-pinene; _β-pinene; ϒ-terpinene	antibacterial anti-inflammatory	antidandruff hair growth

References

1. Jain PL, Patel SR, Desai MA. Patchouli oil: An overview of the extraction method, composition and biological activities. J Essent Oil Res. 2022; 34:1-11.
2. Amirifar A, Hemati A, Asgari Lajayer B, Pandey J, Astatkie T. Impact of various environmental factors on the biosynthesis of alkaloids in medicinal plants. In Environmental Challenges and Medicinal Plants; Aftab, T., Ed.; Springer: Cham, Switzerland. 2022; 229–248.
3. Asgari Lajayer B, Ghorbanpour M, Nikabadi S. Heavy metals in contaminated environment: Destiny of secondary metabolite biosynthesis, oxidative status and phytoextraction in medicinal plants. Ecotoxicol Environ Saf. 2017 Nov;145:377-390. doi: 10.1016/j.ecoenv.2017.07.035. Epub 2017 Jul 28. PMID: 28759767.
4. Khodaei N, Nguyen MM, Mdimagh A, Bayen S, Karboune S. Compositional diversity and antioxidant properties of essential oils: Predictive models. LWT. 2021; 138:110684.
5. Samadi S, Asgari Lajayer B, Moghiseh E, Rodríguez-Couto S. Effect of carbon nanomaterials on cell toxicity, biomass production, nutritional and active compound accumulation in plants. Environ Technol Innov. 2021; 21: 101323.
6. Aćimović M, Šovljanski O, Šeregelj V, Pezo L, Zheljazkov VD, Ljujić J, Tomić A, Ćetković G, Čanadanović-Brunet J, Miljković A, Vujisić L. Chemical Composition, Antioxidant, and Antimicrobial Activity of *Dracocephalum moldavica* L. Essential Oil and Hydrolate. Plants (Basel). 2022 Mar 31;11(7):941. doi: 10.3390/plants11070941. PMID: 35406925; PMCID: PMC9002726.
7. Mahesh SK, Fathima J, Veena VG. Cosmetic Potential of Natural Products: Industrial Applications. In Natural Bio-Active Compounds: Volume 2: Chemistry, Pharmacology and Health Care Practices; Swamy MK, Akhtar MS, Eds.; Springer: Singapore, 2019; 215–250. 2015, 222, 461–487.
8. Hernández-Rivas M, Guzmán E, Fernández-Peña L, Akanno A, Greaves A, Léonforte F, Ortega F. Rubio G, Luengo GS. Deposition of Synthetic and Bio-Based Polycations onto Negatively Charged Solid Surfaces: Effect of the Polymer Cationicity, Ionic Strength, and the Addition of an Anionic Surfactant. Colloids Interfaces 2020; 4: 33.
9. Bowman DM, van Calster G, Friedrichs S. Nanomaterials and regulation of cosmetics. Nat Nanotechnol. 2010 Feb;5(2):92. doi: 10.1038/nnano.2010.12. PMID: 20130584.
10. Kentin E, Kaarto H. An EU ban on microplastics in cosmetic products and the right to regulate. Rev Eur Comp Int Environ Law. 2018; 27: 254-266.
11. Henkler F, Tralau T, Tentschert J, Kneuer C, Haase A, Platzek T, Luch A, Götz ME. Risk assessment of nanomaterials in cosmetics: A European union perspective. Arch Toxicol. 2012; 86:1641–1646.
12. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils-A review. Food Chem Toxicol. 2008; 46: 446-475.
13. de Barros Fernandes RV, Marques GR, Borges SV, Botrel DA. Effect of solids content and oil load on the microencapsulation process of rosemary essential oil. Ind Crops Prod. 2014; 58: 173–181.
14. Lucia A, Toloza AC, Guzmán E, Ortega F, Rubio RG. Novel polymeric micelles for insect pest control: encapsulation of essential oil monoterpenes inside a triblock copolymer shell for head lice control. PeerJ. 2017 Apr 20;5:e3171. doi: 10.7717/peerj.3171. PMID: 28439460; PMCID: PMC5401625.
15. Wang HD, Chen CC, Huynh P, Chang JS. Exploring the potential of using algae in cosmetics. Bioresour Technol. 2015 May;184:355-362. doi: 10.1016/j.biortech.2014.12.001. Epub 2014 Dec 8. PMID: 25537136.
16. Sharmeen JB, Mahomoodally FM, Zengin G, Maggi F. Essential Oils as Natural Sources of Fragrance Compounds for Cosmetics and Cosmeceuticals. Molecules. 2021 Jan 27;26(3):666. doi: 10.3390/molecules26030666. PMID: 33514008; PMCID: PMC7865210.
17. Sarkic A, Stappen I. Essential Oils and Their Single Compounds in Cosmetics-A Critical Review. Cosmetics. 2018; 5: 11.

18. Lubbe A, Verpoorte R. Cultivation of medicinal and aromatic plants for specialty industrial materials. Ind Crops Prod. 2011; 34: 785-801.

19. Raut JS, Karuppayil SM. A status review on the medicinal properties of essential oils. Ind Crops Prod. 2014; 62: 250-264.

20. De Groot AC, Schmidt E. Essential Oils: Contact Allergy and Chemical Composition; CRC Press: Boca Raton, FL, USA, 2016.

21. Burt S. Essential oils: their antibacterial properties and potential applications in foods--a review. Int J Food Microbiol. 2004 Aug 1;94(3):223-53. doi: 10.1016/j.ijfoodmicro.2004.03.022. PMID: 15246235.

22. Ni ZJ, Wang X, Shen Y, Thakur K, Han J, Zhang JG, Hu F, Wei ZJ. Recent updates on the chemistry, bioactivities, mode of action, and industrial applications of plant essential oils. Trends Food Sci Technol. 2021; 110:78-89.

23. Dhifi W, Bellili S, Jazi S, Bahloul N, Mnif W. Essential Oils' Chemical Characterization and Investigation of Some Biological Activities: A Critical Review. Medicines (Basel). 2016 Sep 22;3(4):25. doi: 10.3390/medicines3040025. PMID: 28930135; PMCID: PMC5456241.

24. da Silva BD, Bernardes PC, Pinheiro PF, Fantuzzi E, Roberto CD. Chemical composition, extraction sources and action mechanisms of essential oils: Natural preservative and limitations of use in meat products. Meat Sci. 2021 Jun;176:108463. doi: 10.1016/j.meatsci.2021.108463. Epub 2021 Feb 11. PMID: 33640647.

25. Aljaafari MN, AlAli AO, Baqais L, Alqubaisy M, AlAli M, Molouki A, Ong-Abdullah J, Abushelaibi A, Lai KS, Lim SE. An Overview of the Potential Therapeutic Applications of Essential Oils. Molecules. 2021 Jan 26;26(3):628. doi: 10.3390/molecules26030628. PMID: 33530290; PMCID: PMC7866131.

26. Figueiredo AC, Barroso JG, Pedro LG, Scheffer JJC. Factors affecting secondary metabolite production in plants: Volatile components and essential oils. Flavour Fragr J. 2008; 23: 213-226.

27. Pavela R. Essential oils for the development of eco-friendly mosquito larvicides: A review. Ind Crops Prod. 2015; 76: 174-187.

28. Ngahang Kamte SL, Ranjbarian F, Cianfaglione K, Sut S, Dall'Acqua S, Bruno M, Afshar FH, Iannarelli R, Benelli G, Cappellacci L, Hofer A, Maggi F, Petrelli R. Identification of highly effective antitrypanosomal compounds in essential oils from the Apiaceae family. Ecotoxicol Environ Saf. 2018 Jul 30;156:154-165. doi: 10.1016/j.ecoenv.2018.03.032. Epub 2018 Mar 20. PMID: 29549739.

29. Quassinti L, Bramucci M, Lupidi G, Barboni L, Ricciutelli M, Sagratini G, Papa F, Caprioli G, Petrelli D, Vitali LA, Vittori S, Maggi F. In vitro biological activity of essential oils and isolated furanosesquiterpenes from the neglected vegetable Smyrnium olusatrum L. (Apiaceae). Food Chem. 2013 Jun 1;138(2-3):808-13. doi: 10.1016/j.foodchem.2012.11.075. Epub 2012 Nov 27. PMID: 23411181.

30. Jamalova DN, Gad HA, Akramov DK, Tojibaev KS, Musayeib NMA, Ashour ML, Mamadalieva NZ. Discrimination of the Essential Oils Obtained from Four Apiaceae Species Using Multivariate Analysis Based on the Chemical Compositions and Their Biological Activity. Plants (Basel). 2021 Jul 26;10(8):1529. doi: 10.3390/plants10081529. PMID: 34451574; PMCID: PMC8401412.

31. Rustaiyan A, Faridchehr A. Constituents and biological activities of selected genera of the Iranian Asteraceae family. J Herbal Med. 2021; 25: 100405.

32. Razafiarimanga ZN, Judicael L, Randriamampianina, Randrianarivo HR, Sadam SMb, Rakoto DAD, Jeannoda VL. Chemical composition and antimicrobial properties of the essential oil from the leaves of Helichrysum ibityense R.Vig. & Humbert (Asteraceae). GSC Biol Pharm Sci. 2021; 15: 143-153.

33. Shanaida M, Hudz N, Białoń M, Kryvtsowa M, Svydenko L, Filipska A, Paweł Wieczorek P. Chromatographic profiles and antimicrobial activity of the essential oils obtained from some species and cultivars of the *Mentheae* tribe (*Lamiaceae)*. Saudi J Biol Sci. 2021 Nov;28(11):6145-6152. doi: 10.1016/j.sjbs.2021.06.068. Epub 2021 Jun 26. PMID: 34759738; PMCID: PMC8568706.

34. Ghavam M, Manconi M, Manca ML, Bacchetta G. Extraction of essential oil from Dracocephalum kotschyi Boiss. (Lamiaceae), identification of two active compounds and evaluation of the antimicrobial properties. J Ethnopharmacol. 2021 Mar 1;267:113513. doi: 10.1016/j.jep.2020.113513. Epub 2020 Oct 24. PMID: 33172599.

35. Damasceno CSB, Fabri Higaki NT, Dias JFG, Miguel MD, Miguel OG. Chemical Composition and Biological Activities of Essential Oils in the Family Lauraceae: A Systematic Review of the Literature. Planta Med. 2019 Sep;85(13):1054-1072. doi: 10.1055/a-0943-1908. Epub 2019 Jul 1. PMID: 31261421.

36. Salleh WM, Ahmad F, Yen KH. Chemical compositions and biological activities of the essential oils of Beilschmiedia madang Blume (Lauraceae). Arch Pharm Res. 2015 Apr;38(4):485-93. doi: 10.1007/s12272-014-0460-z. Epub 2014 Aug 8. PMID: 25098422.

37. Caputo L, Smeriglio A, Trombetta D, Cornara L, Trevena G, Valussi M, Fratianni F, De Feo V, Nazzaro F. Chemical Composition and Biological Activities of the Essential Oils of *Leptospermum petersonii* and *Eucalyptus gunnii*. Front Microbiol. 2020 Apr 15;11:409. doi: 10.3389/fmicb.2020.00409. PMID: 32351456; PMCID: PMC7174609.

38. Lobine D, Pairyanen B, Zengin G, Yılmaz MA, Ouelbani R, Bensari S, Ak G, Abdallah HH, Imran M, Mahomoodally MF. Chemical Composition and Pharmacological Evaluation and of Toddalia asiatica (Rutaceae) Extracts and Essential Oil by in Vitro and in Silico Approaches. Chem Biodivers. 2021 Apr;18(4):e2000999. doi: 10.1002/cbdv.202000999. Epub 2021 Mar 19. PMID: 33738900.

39. Silva FBD, Santos NOD, Pascon RC, Vallim MA, Figueiredo CR, Martins RCC, Sartorelli P. Chemical Composition and In Vitro Cytotoxic and Antimicrobial Activities of the Essential Oil from Leaves of Zanthoxylum monogynum St. Hill (Rutaceae). Medicines (Basel). 2017 May 19;4(2):31. doi: 10.3390/medicines4020031. PMID: 28930247; PMCID: PMC5590067.

40. Benelli G, Pavela R, Petrelli R, Cappellacci L, Canale A, Senthil-Nathan S, Maggi F. Not just popular spices! Essential oils from Cuminum cyminum and Pimpinella anisum are toxic to insect pests and vectors without affecting non-target invertebrates. Ind Crops Prod. 2018; 124: 236–243.

41. Pouresmaeil M, Sabzi M, Movafeghi A, Maggi F. Exploring the bio-control efficacy of Artemisia fragrans essential oil on the perennial weed Convolvulus arvensis: Inhibitory effects on the photosynthetic machinery and induction of oxidative stress. Ind Crops Prod. 2020; 155: 112785.

42. Mann J, Davidson RS, Hobbs JB, Banthorpe DV, Harborne JB. Natural Products: Their Chemistry and Biological Significance; Longman: London, UK, 1994. 50. Steward, D. The Chemistry of Essential Oils Made Simple; Care Publications: New York, NY, USA, 2005.

43. Turek C, Stintzing FC. Stability of Essential Oils: A Review. Compr Rev Food Sci. Food Saf. 2013; 12:40-53.

44. Senatore F. Influence of harvesting time on yield and composition of the essential oil of thyme (Thymus pulegioides L.) growing Wild in Campania (Southern Italy). J Agric Food Chem. 1996; 44: 1327-1332.

45. Pichersky E, Noel JP, Dudareva N. Biosynthesis of plant volatiles: nature's diversity and ingenuity. Science. 2006 Feb 10;311(5762):808-11. doi: 10.1126/science.1118510. PMID: 16469917; PMCID: PMC2861909.

46. Franz CM, Novak J. Sources of essential oils. In Handbook of Essential Oils. Science, Technology and Applications. Baser KH, Buchbauer G. Eds.; CRC Press: Boca Raton, FL, USA. 2010; 39-81.

47. Colquhoun TA, Verdonk JC, Schimmel BC, Tieman DM, Underwood BA, Clark DG. Petunia floral volatile benzenoid/phenylpropanoid genes are regulated in a similar manner. Phytochemistry. 2010 Feb;71(2-3):158-67. doi: 10.1016/j.phytochem.2009.09.036. Epub 2009 Nov 2. PMID: 19889429.

48. Luque de Castro MD, Jiménez-Carmona MM, Fernández-Pérez V. Towards more rational techniques for the isolation of valuable essential oils from plants. Trends Anal Chem. 1999; 18:708-716.

49. Foroughi A. A review on medicinal plants; an emphasis on antimicrobial effects. Vet Res Biol Prod. 2022; 35: 2-17.

50. Chen W, Vermaak I, Viljoen A. Camphor--a fumigant during the Black Death and a coveted fragrant wood in ancient Egypt and Babylon--a review. Molecules. 2013 May 10;18(5):5434-54. doi: 10.3390/molecules18055434. PMID: 23666009; PMCID: PMC6270224.

51. Zheljazkov VD, Cantrell CL, Jeliazkova EA, Astatkie T, Schlegel V. Essential Oil Yield, Composition, and Bioactivity of Sagebrush Species in the Bighorn Mountains. Plants (Basel). 2022 May 1;11(9):1228. doi: 10.3390/plants11091228. PMID: 35567228; PMCID: PMC9103225.

52. Mahesh SK, Fathima J, Veena VG. Cosmetic potential of natural products: Industrial applications. In Natural Bio-Active Compounds; Springer: Singapore, 2019; 215-250.

53. Guzmán E, Lucia A. Essential oils and their individual components in cosmetic products. Cosmetics. 2021; 8:114.

54. Abelan US, de Oliveira AC, Cacoci ÉSP, Martins TEA, Giacon VM, Velasco MVR, Lima CRR. Potential use of essential oils in cosmetic and dermatological hair products: A review. J Cosmet Dermatol. 2022; 21:1407-1418.

55. Benson HA, Roberts MS, Leite-Silva VR, Walters K. Cosmetic Formulation: Principles and Practice; CRC Press: Boca Raton, FL, USA, 2019.

56. Oh JY, Park MA, Kim YC. Peppermint Oil Promotes Hair Growth without Toxic Signs. Toxicol Res. 2014 Dec;30(4):297-304. doi: 10.5487/TR.2014.30.4.297. PMID: 25584150; PMCID: PMC4289931.

57. Lertsatitthanakorn P, Taweechaisupapong S, Aromdee C, Khunkitti W. In vitro bioactivities of essential oils used for acne control. Int J Aromather. 2006; 16:43-49.

58. Lohani A, Mishra AK, Verma A. Cosmeceutical potential of geranium and calendula essential oil: Determination of antioxidant activity and in vitro sun protection factor. J Cosmet Dermatol. 2019 Apr;18(2):550-557. doi: 10.1111/jocd.12789. Epub 2018 Sep 24. PMID: 30251317.

59. Mishra A, Mishra A, Chattopadhyay P. Assessment of In vitro Sun Protection Factor of Calendula Officinalis L. (Asteraceae) Essential Oil Formulation. J Young Pharm. 2012 Jan;4(1):17-21. doi: 10.4103/0975-1483.93575. PMID: 22523455; PMCID: PMC3326776.

60. Varvaresou A, Papageorgiou S, Tsirivas E, Protopapa E, Kintziou H, Kefala V, Demetzos C. Self-preserving cosmetics. Int J Cosmet Sci. 2009 Jun;31(3):163-75. doi: 10.1111/j.1468-2494.2009.00492.x. Epub 2009 Mar 19. PMID: 19302511.

61. Mohamed HF, Mahmoud AA, Alatawi A, Hegazy MH, Astatkie T, Ahl SA, Hussein A. Growth and essential oil responses of Nepeta species to potassium humate and harvest time. Acta Physiol Plant. 2018; 40:204.