IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A review: Extraction and therapeutic potential of essential oil

Pradeep Kumar[1], Smita Singh[1]

Department of pharmacy, Saroj Institute of Technology & Management, Lucknow

Abstract

Essential oil is an aromatic and volatile compound found in various parts of plants, and it is used in a variety of pharmaceutical applications. Essential oil has traditionally been used for medicinal purposes. Essential oils are secondary metabolites produced by a variety of medicinal plants that have pharmaceutical, agricultural, and cosmetic application. This article provides an overview of essential oils, their uses, extraction methods, side effects, and other factors that affect essential oils. The stability and bioactivity of essential oils determine their effectiveness. The stability of essential oils is influenced by a range of factors, including the environment, extraction, and storage. Because of their applications, these compounds have gotten a lot of attention. However, few EOs are water soluble, and heat, oxidation, and light conveniently degrade them. Essential oils cover a wide range of topics. The numerous health benefits associated with the use of essential oils or their derivatives have been well-documented.

KEYWORDS: Metabolite, Pharmaceutical, Cosmeceutical, Extraction, Bioactivity.

Introduction

Since ancient times, natural compounds have been the basis of health care in the world and still draw attention in the traditional and contemporary attempts [1]. Essential oils are considered to be secondary metabolites and important for plant defence mechanisms [2]. Essential oils are generally complex mixtures of volatile organic compounds biosynthesized as secondary metabolites determining the specific aroma, flavour and fragrance of plants. Essential oils could be extracted from different plant organs by different extraction methods [3]. Approximately 3000 essential oils are known till now. Essential oils are one of the plant extracts that have been used for treatment of various health problems since ancient times [4]. According to ISO standards, essential oils are defined as products obtained from raw plant materials which must be isolated by physical means only. The physical methods used are distillation (steam, steam/water and water), expression (also known as cold pressing), or dry distillation of natural materials [5]. The essential oil of aromatic herbs is traditionally obtained by hydro distillation, steam distillation, or solvent extraction. These processes cost not expensive but can induce thermal degradation, hydrolysis and water solubilization of some fragrance constituents [6]. Traditional medicines include herbal medicines composed of herbs, herbal materials, herbal preparations, and finished herbal products, that contain as active ingredients parts of plants, or other plant materials, or combinations [7]. Extensive phytochemical analysis has led to the characterization and identification of major components of EOs, which are of wide interest, especially to the cosmetics and pharmaceutical industries [8]. EOs are as well very useful in the treatment of different diseases and their medicinal application has become very popular and this is also valid with many of their constituents as single fragrance compounds [9]. The extraction product can vary in quality, quantity and in composition according to climate, soil composition, plant organ, age and vegetative cycle stage. So, in order to obtain essential oils of constant composition, they have to be extracted under the same conditions from the same organ of the plant which has been growing on the same soil, under the same climate and has been picked in the same season [10].

ANCIENT HISTORICAL BACKGROUND

Essential oils have been used by many cultures around the world for centuries for different purposes according to each culture. It is unknown exactly whether the Essential oils were used as healing agents or for domestic use in the beginning. However, recently great consideration has been given to the effective use of Essential oils in clinical procedures [11]. Ancient Egyptians have used aromatic oils as early as 4500 BC in cosmetics and ointments. They used to make a mixture of different sources of herbal preparations such as aniseed, cedar, onion, myrrh, and grapes in perfume or medicine. On the other hand, the use of aromatic oils was first recorded in traditional Chinese and Indian medicine between 3000 and 2000 BC [12]. In particular, the recorded history about China and India listed more than 700 substances including cinnamon, ginger, myrrh, and sandalwood as being effective for healing. In addition, Greek history documented the use of different Essential oils for the first time between 500 and 400 BC, including thyme, saffron, marjoram, cumin, and peppermint [13]. In the 18th and 19th centuries, chemists documented the active components of medicinal plants and identified many substances such as caffeine, quinine, morphine, and atropine, which were considered to play an important role in their biological effects [14]. Some Essential oils such as lavender, peppermint, and myrrh are still being used pharmaceutically and could be used effectively in the upcoming future as suitable alternatives for many synthetically produced medications [15].

EXTRACTION OF ESSENTIAL OIL

Essential oils can be extracted from several plants with different parts by various extraction methods. The manufacturing of essential oils, and the method used for essential oil extraction are normally dependent on botanical material used. Extraction method is one of prime factors that determine the quality of essential oil. Inappropriate extraction procedure can lead to the damage or alter action of chemical signature of essential oil. This results in the loss in bioactivity and natural characteristics. [16]. The chemical profile of essential oils varies in the number of molecules, stereochemical properties of molecules, and also depends on the type of extraction [17].

HYDRO DISTILLATION

Hydro distillation is one of the oldest and easiest method of oils extraction which was revealed by Avicenna and the first to develop extraction through the alembic. Rose was the first plant extract used and purified by this method. The procedures start with immersing the plant materials directly into water inside the vessel, and whole mixture was boiled. The devices include a heating source, vessel, a condenser to convert vapor from vessel onto liquid, and a decanter to collect the condensate and to separate essential oils with water.

This extraction technique is considered as a unique method to extract plant materials like wood or flower and is frequently used for extractions involving hydrophobic natural plant material with a high boiling point. The general hydro distillation process has been modified by using new technologies as reported by a few researchers [18].

HYDRO DIFFUSION

Hydro diffusion extraction method is an extraction process in which steam is supplied to a container which holds plant materials. This technique is only applied on dried plant samples that can be damaged at boiling temperature. In the steam distillation process, steam is applied from the bottom of the steam generator, whereas in the hydro diffusion method, steam is supplied from the top of the generator. This process was carried out at low pressure or vacuum and steam temperature can be reduced below 100°C [19].

STEAM DISTILLATION

In essential plant oil extraction, steam distillation method is the broadest technique applied. The percentage of essential oils being extracted by this technique is 93% and the remaining 7% can be further extracted by other methods [20]. Basically, the process started by heating of plant material using steam which is supplied from steam generator. Heat is the main factor determining how effectively the plant material structures break down and burst and release the aromatic components or essential oils [21].

SOLVENT EXTRACTION

Ordinary solvents like acetone, petroleum ether, hexane, methanol, or ethanol have been implemented by this technique to extract fragile or delicate flower materials which cannot be extracted using heat or steam supplied [16]. Generally, the plant samples are mixed with solvents to be extracted by mildly heating the mixture, and the process is followed by filtration and evaporation of the solvents. The filtrate contains a resin (resinoid), or the mixture of wax, fragrance, and essential oil. Alcohol is combined with the filtrate mixture in order to dissolve the essential oil into it and thereafter distilled at low temperature. During the distillation process, the alcohol absorbs fragrance and is evaporated while the aromatic absolute oil remains in the pot residue. Compared to other methods, this method is more complicated for essential oils extraction, and as a result, time-consuming and more expensive [22].

MICROWAVE-ASSISTED EXTRACTION (MAE)

Microwave energy is a non-ionizing radiation that covers a 3-order of magnitude scale from 300 MHz to 300 GHz (wavelength in air or vacuum between 1 m and 1 mm). Microwaves are electromagnetic waves made up of two oscillating perpendicular fields: electrical field and magnetic field. The principle of heating using microwave energy is based on the direct effects of microwaves on molecules of the material. The transformation of electromagnetic energy in calorific energy occurs by two mechanisms: ionic conduction and dipole rotation in both the solvent and the sample. In many applications these two mechanisms take place simultaneously, which effectively changes microwave energy to thermal energy. In the case of plant sample extraction, the effect of microwave energy is strongly dependent on the nature of both the solvent and the matrix. Most of the time, the solvent selected has a high dielectric constant, so that it strongly absorbs the microwave energy. The treatment of plant material with microwave irradiation during extraction can result in enhanced recovery of secondary metabolites and aroma compounds [23].

SOLVENT-FREE MICROWAVE EXTRACTION (SFME)

Due to the growing concern for the impact of petroleum-based solvents on the environment and the human body, a greener technique, namely solvent-free microwave extraction (SFME), was developed in recent times with considerable success in line with the same principles as MAE. The obvious benefits of using SFME are reduction of pollution and handling costs, as the result of the simplified manipulation procedure, easy clean-up and labour saving. These would be especially important considerations in both laboratory and industry [24]. Based on a relatively simple principle, solvent-free microwave extraction (SFME) involves placing plant material in a microwave reactor, without the addition of any solvent or water. The internal heating of the in-situ water within the plant material distends the material and makes the glands and oleiferous receptacles burst. This process thus frees essential oil which is evaporated by the in-situ water of the plant material. SFME is not a modified microwave assisted extraction (MAE) which uses polar or non-polar solvents (such as hexane) and neither is it a modified hydro-distillation which uses a large quantity of water [25].

SUPERCRITICAL FLUID EXTRACTION (SFE)

In recent years, SFE has received a great deal of attention as the full potential of this technology in analytical applications has begun to emerge. Today, SFE has become an acceptable extraction technique used in many areas. SFE of active natural products from herbal, or more generally, from plant materials has become one of the most important application areas. The high solvation power of supercritical fluids (SF) was first reported over a century ago [9]. Demonstration of SFE technology for industrial applications was reported by Zosel at the Max Planck Institute for Kohlemforschung in 1969 [26]. A wide variety of solvents is available for use as SFs, including carbon dioxide, nitrous oxide, ethane, propane, n-pentane, ammonia, fluoroform, sulphur hexafluoride and water. Carbon dioxide is currently the solvent of choice, as it can easily reach supercritical conditions and has clear advantages. SFE has consolidated in some areas, including environmental, pharmaceutical and polymer analysis [27].

MICROWAVE HYDRODIFFUSION AND GRAVITY (MHG)

Microwave Hydro diffusion and Gravity (MHG) is a new and green technique for the extraction of essential oils. This green extraction technique is an original "upside down" microwave alembic combining microwave heating and earth gravity at atmospheric pressure. MHG was conceived for laboratory and industrial scale applications for the extraction of essential oils from different kind of aromatic plants [28]. Based on a relatively simple principle, this method involves placing plant material in a microwave reactor, without any added solvent or water. The internal heating of the in-situ water within the plant material distends the plant cells and leads to the rupture of glands and oleiferous receptacles. The heating action of microwaves thus frees essential oil and in situ water which are transferred from the inside to the outside of the plant material [29]. MHG is also an environmentally friendly procedure extraction without using added solvents and contemplating a lower consumption and resources, as opposed to traditional extraction techniques [30].

Table 1 Advantages and disadvantages of the main extraction method for essential oil [31]

Method of extraction	Advantages	Disadvantages
Hydro-distillation (HD)	• Inexpensive method of EO extraction • Easy to construct • Suitable for field operation	• High temperature applied • Thermal degradation can be induced • Time taking method
Steam-distillation (SD)	• Less time taking as compared to HD • Suitable for field operation • Limits the potential for oxidation to alter the natural components of EO • Increased energy efficiency (compared to HD)	• Extraction yield is low (0.001 percent to nearly 4 percent) • Temperatures above normal • Extraordinary extraction time • Chemical changes to the oil's constituents • Volatile molecule depletion
Microwave Assisted Hydro Distillation (MAHD)	• More efficient heating • Energy transfer is quick. • Heating process that can be controlled • Elimination of some process steps, resulting in an increase in production. • Reduced extraction time and energy consumption, as well as CO2 emission	• High power could lead to lower essential oil yields. • The oil components may biodegrade as a result of the high power.
Solvent Free Microwave Extraction (SFME)	• Extraction costs are lower in terms of energy and time. • Selectivity and high yield • Thermo labile constituents are given protection. • Reduces CO2 emissions in the atmosphere, reducing environmental	• To obtain the highest yield of EO, the plant materials used in this method must be dried. • This method is better suited to a laboratory scale than an industrial pilot scale organic

	impact. • Atmospheric pressure dry distillation without the addition of water or any organic solvent	solvent process.
Soxhlet	• It does not necessitate a large capital investment. • Produces a high EO extraction yield. • The sample is brought into contact with fresh portions of the solvent on a regular basis, which aids in the removal of the analyte from the matrix. • The excess energy in the form of heat aids in improving the system's extraction kinetics.	• A Soxhlet extraction can take anywhere from 1 to 72 hours. • Before analysing the extracted solutes, they must be concentrated. • Because of the presence of interfering compounds, extraction is not selective. • Organic solvents that are expensive, toxic, and high-purity are required. • Extremely high temperatures were used. • Thermal degradation and volatilization losses.
Organic solvent	• Increases the amount of essential oils produced • The approach is simple and effective.	• Extraction time is extensive. • Solvent consumption is unusually high. • Organic toxic residues found in the extracted product • Reproducibility is frequently lacking. • The solubility of the compound in the specific solvent used limits the number of work that can be done.
Supercritical Fluid Extraction (SFE)	• Applying a moderately low critical pressure and temperature • Extraction yields of high quality in a short period of time • As a "green alternative," it is regarded as such. • Non-flammable and non-toxic • High purity is available. • Removes the need for cleanup. • Easily removed from the extract; able to recover some organic compounds that HD was unable to extract	• requires a significant investment (expensive technique) • This process generally requires the use of difficult-to-handle equipment. • With pure CO2, extraction rates are relatively slow.
Microwave Generated Hydro	• extraction rate is shorter • Use of energy resources is being conserved.	• Lower microwave power does not allow for complete recovery of essential oil.

distillation (MGH) **and Microwave Hydro diffusion Gravity** (MHG)	• No use of a solvent. • Environment-friendly • Compared to other approaches, it reproduces natural aromas better.	• Higher microwave power, on either hand, may burn the biomass and cause EO pyrolysis.

IDENTIFICATION METHODS OF ESSENTIAL OIL:

Gas chromatography (GC):

GC analyses were performed with TRACE GC (Thermo Finnigan, Dreieich, Germany) with flame ionization detection (FID) and Chrom Perfect software (Axel Semrau, Sprockhoevel, Germany). Compounds were separated on 30 m×0.25 mm (i.d.) fused silica apolar columns coated with a 0.25-µm film bonded either (5%-phenyl)-methylpolysiloxane (DB-5 MS) or 100% dimethylpolysiloxane (DB-1 MS, Agilent Technologies, Boeblingen, Germany). Both columns were maintained at 80 °C for 2 min and then programmed at 10 °C/min to 270 °C, which was maintained for 10 min. Helium was used as carrier gas with constant flow of 1 mL/min. Liquid injection of 1 µL was conducted with a split ratio of 1:100. For SPME-GC the fiber was desorbed as described below. Injector and detector temperatures were held at 200 °C and 280 °C, respectively. After analysis, quantification was performed as % peak area using integration data [32].

Gas chromatography/mass spectrometry (GC/MS):

GC/MS was performed with ion trap mass spectrometer GCQ and GCQ Software (Thermo Finnegan, Driesch, Germany). Columns and temperature programs were used as described for GC. Helium was used as carrier gas with constant linear velocity of 30 cm/s. Liquid injection of 0.5 µl was used with a split ratio of 1:20. For SPME-GC the fiber was desorbed as described below. The injection temperature was 200 °C. Ion source and transfer line temperatures were held at 180 °C and 275 °C. The spectrometer was operated in positive electron impact (EI) mode with a scan rate of 0.8 s/scan and in a scan range from 35 to 300 amu. Compounds were identified by parallel comparison of their retention times and mass spectra with data from the database "Terpenoids and Related Compounds in Essential Oils" (Dr. Hochmuth Scientific Consulting, Hamburg) with the help of the Mass Finder software 2.3 (Dr. Hochmuth Scientific Consulting, Hamburg) as well as by comparison with actual mass spectra from reference substances and with literature MS data [32].

Biological activities of essential oil in pharmaceutical field:

1. Anti-inflammatory and anti-oxidant activity

Inflammation is a major biological mechanism that enables the body to adapt to harmful stimuli from the environment. When a stimulus generates a partial response over time, the inflammation can be acute and last only a few days. It can also be chronic if the external injury lasts a long time, the individual is especially sensitive, or they have autoimmune diseases. Prolonged use of such medications to help chronic inflammation can have serious side effects, such as ulcers and gastritis with NSAIDs and the risk of over-infection with glucocorticoids [33]. Antimicrobial, antiseptic, antiparasitic, anti-inflammatory, and antioxidant properties of nutmeg essential oil (Myristica fragrans). In Poly I:C-affected fibroblast cell culture, nutmeg essential oil preparations with aluminometasilicate have stronger anti-inflammatory activity. When compared to preparations without aluminometasilicate, the oil with the excipient has a higher level of cytoprotection from Poly I:C-induced necrosis, and both the oil and hydrolats with excipient more effectively prevent IL-6 release [34]. When the balance of free radicals and antioxidants transitions in favour of the oxidising species, oxidation occurs. Free radicals can cause a variety of biological events by affecting various cell components, including such genetic material or proteins, and resulting in ailments like cancer, neurological disorders, and chronic inflammation [33]. Citrus aurantium peel essential oil's anti-inflammatory properties and in vitro antioxidant activity (pEOCa) . Limonene and Linalool are the main constituents of pEOCa . The use of pEOCa prevented CCl4-induced liver damage, thereby avoiding free radical damage [34].

2. Anti-bacterial activity

Plants were used in cremation by the Ancient Egyptians to prevent bacterial growth and prevent decay, which was attributed to their essential oils to a large extent. Strong in vitro evidence suggests that essential oils can kill a wide range of pathogenic bacteria, including Listeria monocytogenes, Listeria innocua, Salmonella typhimurium, Escherichia coli O157:H7, Shigella dysenteria, Bacillus cereus, Staphylococcus aureus, and Salmonella typhimurium (3). Zingiber officinale Rosc. (Ginger) rhizome essential oil (EO) was tested against MDR Escherichia coli (3.125 l/ml), Klebsiella pneumonia (3.125 l/ml), Enterococcus faecalis (0.78 l/ml), and Staphylococcus aureus (1.56 l/ml) bacteria. S. aureus (94%) was found to have the greatest percentage of biofilm inhibition by EO, followed by K. pneumoniae (91%), E. coli (89%), and E. faecalis (89%) [36]. Volatile terpenes are the most abundant source of Cannabis sativa L., and they are responsible for its aromatic properties. The study shows that hemp EO can inhibit or reduce bacterial proliferation, making it a viable option for reducing microorganism contamination particularly in the food processing industry The findings show that hemp EO is effective against Gram-positive bacteria but not Gram-negative bacteria [37]. Finger citron essential oil (FCEO, Citrus medica L. var. sarcodactylis) was studied for its antibacterial activity and mechanism against food-borne bacteria. The three main components were limonene (45.36 %), -terpinene (21.23 %), and dodecanoic acid (7.52%). FCEO had a significant impact on sustaining bacteria's growth rate, resulting in cell wall lysis, intracellular ingredient leakage, and cell death [38].

3. Anti-microbial activity and wound healing

Intervention of microbial infections has always been one of pharmacology's highest and most optimistic goals. This is an ever-evolving field due to microorganisms' order to create new drug - resistant processes on a continuous basis. The presence of certain components, notably mono- and sesquiterpenes, which are known to be potent antibacterial agents, specifies the antibacterial activity of essential oils. The effects of Chenopodium botrys essential oil on cutaneous wound healing markers in male Sprague-Dawley rats. When compared to the other groups, variables such as healing tissue alignment, re-epithelialization, and epithelial formation in the CB treated group showed a significant increase. In addition, when compared to the control and basal cream groups, CB treatment reduced wound surface area and the number of lymphocytes and neutrophils while increasing the number of blood vessels, collagen to total ratio, and collagen to cell ratio [39]. The wound healing activity of an optimised ecualyptus-based essential oil nanoemulsion was comparable to that of gentamycin. When compared to pure EEO and the negative control, the collagen content of the optimised EEO nanoemulsion increased significantly. The collagen content of the optimised nanoemulsion-treated animals, on the other hand, was comparable to that of the standard gentamycin-treated animals [40].

4. Chemotherapy

One of the most common treatments for cancer patients is chemotherapy. Chemotherapy drugs are also expected to induce nausea and vomiting as side effects. In the acute phase of chemotherapy (the first 24 hours), aromatherapy with peppermint essential oil reduced nausea and vomiting in breast cancer patients [41]. Because of the rise in chemotherapeutic drug resistance, treating colorectal cancer is one of the most difficult tasks. Natural compounds isolated from medicinal plants and other sources are frequently used as novel drugs to treat a variety of human illnesses. The study found that E. camaldulensis essential oil has significant antioxidant and anticancer activity in a concentration and time-dependent manner, which could be due to the reduction of free radicals and induction of the apoptosis process in colorectal cancer cells [42].

5. Repellent and insecticidal activity

Insecticides, repellents, and synthetic pesticides have been determined to be toxic to humans, necessitating the use of alternative control methods. Linalool is the compound that has insecticidal properties against fruit and house pests. The effects that this compound has on the central nervous system explain this action [43]. Basil essential oil (O. basilicum L.) has insecticidal properties and can be used instead of synthetic chemicals. The goal of this replacement is to ensure human and environmental safety [44]. These metabolites, such as EOs, have potent insecticidal activity against a wide range of insects and other pests, and could thus be used as a replacement for synthetic insecticides.

Conclusion:

This review focuses on the extraction techniques for a variety of essential oils, as well as their potential as anticancer, antiviral, antimicrobial, and skin penetration enhancing agents, particularly in the pharmaceutical field. Due to the market appeal of natural products, the use of essential oils in food, cosmetics, and pharmaceuticals has increased significantly in recent years. Unfortunately, essential oils are lipophilic in nature, proclivity for degradation and oxidation, and high volatility are seen as major drawbacks, making them less therapeutic in pharmaceutical fields than essential oil-based products. As a result, new technological approaches to creating better delivery methods for essential oils may be considered in the future to ensure high bioavailability and therapeutic effects.

Reference

1. Albayrak S, Silahtarlıoğlu N. Determination of biological activities of essential oil and extract obtained from Achillea coarctata Poir. Advances in Traditional Medicine. 2020 Mar;20(1):77-88.
2. Hyldgaard M, Mygind T, Meyer RL. Essential oils in food preservation: mode of action, synergies, and interactions with food matrix components. Frontiers in microbiology. 2012 Jan 25; 3:12.
3. Lammari N, Louaer O, Meniai AH, Elaissari A. Encapsulation of essential oils via nanoprecipitation process: Overview, progress, challenges and prospects. Pharmaceutics. 2020 May;12(5):431
4. Dagli N, Dagli R, Mahmoud RS, Baroudi K. Essential oils, their therapeutic properties, and implication in dentistry: A review. Journal of International Society of Preventive & Community Dentistry. 2015 Sep;5(5):335.
5. Ferhat MA, Meklati BY, Chemat F. Comparison of different isolation methods of essential oil from Citrus fruits: cold pressing, hydro distillation and microwave 'dry' distillation. Flavour and Fragrance Journal. 2007 Nov;22(6):494-504.
6. Guan W, Li S, Yan R, Tang S, Quan C. Comparison of essential oils of clove buds extracted with supercritical carbon dioxide and other three traditional extraction methods. Food Chemistry. 2007 Jan 1;101(4):1558-64.
7. Robinson MM, Zhang X. Traditional medicines: global situation, issues and challenges. The world medicines situation. 2011 Mar 30;3.
8. Moghaddam M, Mehdizadeh L. Chemistry of essential oils and factors influencing their constituents. In Soft chemistry and food fermentation 2017 Jan 1 (pp. 379-419). Academic Press.
9. Adorjan B, Buchbauer G. Biological properties of essential oils: an updated review. Flavour and Fragrance Journal. 2010 Nov;25(6):407-26.
10. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils–a review. Food and chemical toxicology. 2008 Feb 1;46(2):446-75.
11. Elshafie HS, Camele I. An overview of the biological effects of some mediterranean essential oils on human health. BioMed research international. 2017 Nov 5;2017.
12. Baser KH, Buchbauer G. Handbook of essential oils: science, technology, and applications. CRC press; 2009 Dec 28.
13. Pauli A, Schilcher H. 12 In Vitro Antimicrobial Activities of Essential Oils Monographed in the European Pharmacopoeia 6th Edition. ESSENTIAL. 2009 Dec 28:353.
14. R. Tisserand, "Essential Oil Safety: A Guide for Health Care Professionals. Churchill Livingstone," Churchill Livingstone, 1995.
15. Ali B, Al-Wabel NA, Shams S, Ahamad A, Khan SA, Anwar F. Essential oils used in aromatherapy: A systemic review. Asian Pacific Journal of Tropical Biomedicine. 2015 Aug 1;5(8):601-11.
16. Tongnuanchan P, Benjakul S. Essential oils: extraction, bioactivities, and their uses for food preservation. Journal of food science. 2014 Jul;79(7): R1231-49.

17. Akthar MS, Degaga B, Azam T. Antimicrobial activity of essential oils extracted from medicinal plants against the pathogenic microorganisms: A review. Journal Issues ISSN. 2014; 2350:1588.
18. El Asbahani A, Miladi K, Badri W, Sala M, Addi EA, Casabianca H, El Mousadik A, Hartmann D, Jilale A, Renaud FN, Elaissari A. Essential oils: From extraction to encapsulation. International journal of pharmaceutics. 2015 Apr 10;483(1-2):220-43.
19. Vian MA, Fernandez X, Visinoni F, Chemat F. Microwave hydro diffusion and gravity, a new technique for extraction of essential oils. Journal of chromatography a. 2008 May 9;1190(1-2):14-7.
20. Masango P. Cleaner production of essential oils by steam distillation. Journal of Cleaner Production. 2005 Jun 1;13(8):833-9.
21. Babu KG, Kaul VK. Variation in essential oil composition of rose-scented geranium (Pelargonium sp.) distilled by different distillation techniques. Flavour and fragrance journal. 2005 Mar;20(2):222-31.
22. Rostagno MA, Prado JM, editors. Natural product extraction: principles and applications. Royal Society of Chemistry; 2013.
23. Li Y, Fabiano-Tixier AS, Vian MA, Chemat F. Solvent-free microwave extraction of bioactive compounds provides a tool for green analytical chemistry. TrAC Trends in Analytical Chemistry. 2013 Jun 1; 47:1-1.
24. Lucchesi ME, Chemat F, Smadja J. Solvent-free microwave extraction: An innovative tool for rapid extraction of essential oil from aromatic herbs and spices. Journal of Microwave Power and Electromagnetic Energy. 2004 Jan 1;39(3-4):135-9.
25. Lang Q, Wai CM. Supercritical fluid extraction in herbal and natural product studies—a practical review. Talanta. 2001 Jan 5;53(4):771-82.
26. Zougagh M, Valcárcel M, Rıos A. Supercritical fluid extraction: a critical review of its analytical usefulness. TrAC Trends in Analytical Chemistry. 2004 May 1;23(5):399-405.
27. Zill-E-Huma H. Microwave Hydro-diffusion and gravity: a novel technique for antioxidants extraction (Doctoral dissertation, Université d'Avignon).
28. Vian MA, Fernandez X, Visinoni F, Chemat F. Microwave hydrodiffusion and gravity, a new technique for extraction of essential oils. Journal of chromatography a. 2008 May 9;1190(1-2):14-7.
29. López-Hortas L, Gannon L, Moreira R, Chenlo F, Domínguez H, Torres MD. Microwave hydro diffusion and gravity (MHG) processing of Laminaria ochroleuca brown seaweed. Journal of Cleaner Production. 2018 Oct 1; 197:1108-16.
30. Li XM, Tian SL, Pang ZC, Shi JY, Feng ZS, Zhang YM. Extraction of Cuminum cyminum essential oil by combination technology of organic solvent with low boiling point and steam distillation. Food chemistry. 2009 Aug 1;115(3):1114-9.
31. da Silva WM, Kringel DH, de Souza EJ, da Rosa Zavareze E, Dias AR. Basil essential oil: Methods of extraction, chemical composition, biological activities, and food applications. Food and Bioprocess Technology. 2021 Aug 20:1-27.
32. Mohammadi P, Ghorbani M, Mohammadi P, Keshavarzi M, Rastegar A, Aghamohammadhassan M, Saghafi A. Dispersive micro solid-phase extraction with gas chromatography for determination of Diazinon and Ethion residues in biological, vegetables and cereal grain samples, employing D-optimal mixture design. Microchemical Journal. 2021 Jan 1;160:105680.
33. Cimino C, Maurel OM, Musumeci T, Bonaccorso A, Drago F, Souto EM, Pignatello R, Carbone C. Essential oils: pharmaceutical applications and encapsulation strategies into lipid-based delivery systems. Pharmaceutics. 2021 Mar;13(3):327.
34. Matulyte I, Jekabsone A, Jankauskaite L, Zavistanaviciute P, Sakiene V, Bartkiene E, Ruzauskas M, Kopustinskiene DM, Santini A, Bernatoniene J. The essential oil and hydrolats from Myristica fragrans seeds with magnesium aluminometasilicate as excipient: antioxidant, antibacterial, and anti-inflammatory activity. Foods. 2020 Jan;9(1):37.
35. Ben Hsouna A, Gargouri M, Dhifi W, Ben Saad R, Sayahi N, Mnif W, Saibi W. Potential anti-inflammatory and antioxidant effects of Citrus aurantium essential oil against carbon

tetrachloride-mediated hepatotoxicity: A biochemical, molecular and histopathological changes in adult rats. Environmental toxicology. 2019 Apr;34(4):388-400

36. Das A, Dey S, Sahoo RK, Sahoo S, Subudhi E. Antibiofilm and antibacterial activity of essential oil bearing Zingiber officinale Rosc.(Ginger) rhizome against multi-drug Resistant isolates. Journal of Essential Oil Bearing Plants. 2019 Jul 4;22(4):1163-71.
37. Iseppi R, Brighenti V, Licata M, Lambertini A, Sabia C, Messi P, Pellati F, Benvenuti S. Chemical characterization and evaluation of the antibacterial activity of essential oils from fibre-type Cannabis sativa L.(Hemp). Molecules. 2019 Jan;24(12):2302.
38. Mehalaine S, Belfadel O, Menasria T, Messaili A. Chemical composition and antibacterial activity of essential oils of three medicinal plants from Algerian semi-arid climatic zone. Phytothérapie. 2018 Dec 1;16(S1):S155-63.
39. Sayyedrostami T, Pournaghi P, Vosta-Kalaee SE, Zangeneh MM. Evaluation of the wound healing activity of Chenopodium botrys leaves essential oil in rats (a short-term study). Journal of Essential Oil Bearing Plants. 2018 Jan 2;21(1):164-74.
40. Alam P, Shakeel F, Anwer MK, Foudah AI, Alqarni MH. Wound healing study of eucalyptus essential oil containing nanoemulsion in rat model. Journal of oleo science. 2018:ess18005.
41. Eghbali M, Varaei S, Hosseini M, Yekaninejad MS, Shahi F. The effect of aromatherapy with peppermint essential oil on nausea and vomiting in the acute phase of chemotherapy in patients with breast cancer. Journal of Babol University of Medical Sciences. 2018 Sep 10;20(9):66-71.
42. Taheri E, Ghorbani S, Safi M, Sani NS, Amoodizaj FF, Heidari M, Chavoshi R, Hajazimian S, Isazadeh A, Heidari M. Inhibition of colorectal cancer cell line CaCo-2 by essential oil of eucalyptus camaldulensis through induction of apoptosis. Acta Medica Iranica. 2020 Aug 19:260-5.
43. Beier, R. C., Ii, J. A. B., Kubena, L. F., Hume, M. E., Mcreynolds, J. L., Anderson, R. C., & Nisbet, D. J. (2014). Evaluation of linalool, a natural antimicrobial and insecticidal essential oil from basil: Efects on poultry. Poultry Science, 93, 267–272.
44. Wang, Y., Zhang, L., Feng, Y., Zhang, D., Guo, S., & Pang, X. (2019). Comparative evaluation of the chemical composition and bio-activities of essential oils from four spice plants (Lauraceae)against stored-product insects. Industrial Crops and Products,140, 111640.