Chapter 15

Essential Oils: Sustainable Extraction Techniques and Nutraceuticals Perspectives

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Abstract

Essential oils in their unadulterated form, can be primarily classified into two fundamental chemical constituents, namely: hydrocarbons, oxygenated and terpenoidal bioactive compounds. The biochemical characteristics of essential oils exhibit significant variations contingent upon the specific extraction methods employed. While traditional techniques such as cold pressing, hydro-distillation, and maceration have long been prevalent, they are not without their drawbacks, such as lower yield, the potential for degradation of thermolabile compounds, and concerns regarding the environmental impact of solvent usage. In the pursuit of sustainable and effective extraction, modern methodologies have risen to prominence, including microwave-assisted, supercritical, and ultrasonic extraction techniques. These innovative approaches have circumvented the inherent limitations of conventional methods, offering novel possibilities for harnessing the full potential of essential oils. This chapter offers a brief review of both classical and contemporary extraction techniques, shedding light on their influence over the biochemical properties of essential oils. Furthermore, it delves into the promising perspectives of utilizing these oils in for nutraceutical applications, underscoring their potential for enhancing human well-being.

Key words Essential oil, Extraction, Biochemical activities, Conventional, Classical

1 Introduction

Essential oils can dissolve well in polar solvents including benzene, toluene, acetone, ethanol, and methanol, despite being volatile hydrophobic liquids with a comparatively lower density than water [1]. Due to the existence of a complex mixture of bioactive substances, the bioactivity, flavor, smell, and components of essential oils are well known [2]. They often originate from plants like leaves, exfoliate, twigs, flowers, petals, and pods. There are around 3000 essential oils recognized today, with over 300 of them being commercially important, primarily in the pharmaceutical, culinary, domestic, and cosmetic industries [3]. The increasing interest in the study of essential oils is attributed to their diverse biological

Tanmay Sarkar and Siddhartha Pati (eds.), *Bioactive Extraction and Application in Food and Nutraceutical Industries*, Methods and Protocols in Food Science, https://doi.org/10.1007/978-1-0716-3601-5_15,

functions, which encompass anti-inflammatory, antibacterial, antifungal, anticarcinogenic, antioxidant, antiviral, and antimutagenic properties [4]. The most extensively explored biological activity in essential oil research is the antioxidant activity considering that several biological molecules are affected by oxidation and thereby prompting many diseases such as cardiovascular and neurological disorders [5].

In recent times, many studies have elucidated the antioxidant properties of various essential oils in the hope of discovering safe, natural antioxidants. One such study was established by Shaaban et al., [6], who investigated the antioxidant activities of the essential oil from 25 spices including thyme, chamomile, clove leaf, eucalyptus cinnamon leaf, and basil. Tian et al. [7] reported that the antioxidant activities of essential oils from Egyptian corn silk and *Curcuma zedoaria*. Some group of bioactive compounds such as terpenoids, terpinene, terpinolene, 1,8-cineole, and terpenes has also been studied and found to boost essential oil's antioxidant activities [8]. Also, a wide variety of these plants oils has been found to exhibit antibacterial properties; as different spices and herbs, for example, have been traditionally employed as preservatives in food to kill bacteria [9]. Take, for instance, *Nandina Domestica Thunb*, which has been reported to be an effective preservative for different food products [10]. Bioactive constituents with antibacterial activities against the *H. pylori* from most essential oils include carvacrol, sabinene, nerol, and isoeugenol [11, 12]. Badekova et al. [13] reported the antibacterial activities of thymol and carvacrol against *E. coli*, which suppressed pathogenic bacterial strains: key components of essential oils from oregano and thyme.

In addition, synthetic antiviral drugs have been largely used for the treatment of viral diseases in humans such as the HSV (herpes simplex virus) [14]. The use of synthetic drugs is not without their attentive side effects, which necessitates the application of plant-based essential oil for the treatment of many viral diseases. Reichling [15] investigated the effectiveness of lemongrass essential oils which was reported to provide a significant anti-HSV-1 effect more than all the drugs that have been previously used. Furthermore, essential oils have a long history of use against inflammation because of their strong anti-inflammatory bioactive constituents. Inflammation has generally been linked to various diseases such as hypertension, cancer, and stroke [16]. Ogidi et al. [17] investigated the anti-inflammatory qualities of a pale, clear, cold-pressed *Aloe vera* essential oil with great potential as a carrier medium in aromatherapy. Sánchez et al. [18] experimented on diabetic rats and cases of cutaneous ischemia with *Aloe vera* oil reported to promote wound healing. In another study, oil extracted from *Aloe vera* plant has been used to treat carrageenan-induced edema in rat paw, which had anti-inflammatory characteristics and suppressed

cyclooxygenase activity [19]. The result obtained shows that *Aloe vera* oil demonstrated the strongest lipoxygenase inhibitory activity (up to 96%) with a concentration of 0.5 g/mL. Other oils such as thyme oil (86%) and bergamot oil (85%) were not lesser in their effectiveness [19]. Chandel et al. [20] also reported that chamomile oil had modest lipoxygenase inhibitory action at 0.5 g/mL, while it had significant lipoxygenase stimulating activity at 5 g/mL (123%).

Also, some essential oils have been proven to have a wide reach of fungicidal activities on post-harvest infections. The antifungal characteristics of essential oils are often maximized in the vapor phase for the storage of food [21]. However, because the food item may still decay in the vapor phase, more investigation is needed [21]. Hossain et al. [22] identified the resistance of carvacrol and thymol against food-borne fungi such as *Aspergillus flavus, Aspergillus parasiticus, and Aspergillus niger*. Essential oils from plant-based materials reduce free radicals, activates antioxidant enzymatic cells, and prevent the permeation of mutagens [23]. An aromatic plant-derived compound such as terpinene, and terpineol, was reported with such activity. Only a few studies have been conducted on the antimutagenicity of DNA repair by phenolic and terpenic compounds found in essential oils [24]. The quality characteristics and biological activities of essential oil are largely dependent on the extraction technique utilized.

2 Effects of Conventional Extraction on Biochemical Activities of Essential Oil

Due to the obvious wide range of extraction processes, the biochemical activities of essential oil components are highly diverse. The most common extraction procedures are cold pressing, hydrodistillation, and maceration, each with advantages and disadvantages. Take instance, cold pressing (expression) is solely employed in the extraction of citrus oils as it is primarily utilized to recover essential oils from citrus fruits. Expression is a four-step procedure that includes scarification, pressing, centrifugation, and filtration. In this process, the citrus skins are scrubbed (scarified) to rupture the microcellular structure holding the essential oils, which is thereafter pressed to extract the oily substance from the sample [25] (Fig. 1). The essential oil on the sample surface is then separated into layers using centrifugal pump and thereafter filtered to get pure essential oil.

One significant advantage that cold pressing has over other methods is their high degree of purity and higher biological activities of the oily extracts. In addition, the cold-pressed oil keeps the oil's original flavor and color while also preserving the oil's biologically active components. However, the drawback of cold pressing (expression) is that the sample is not generally extracted at optimal conditions, resulting in a low extraction yield. Furthermore, most

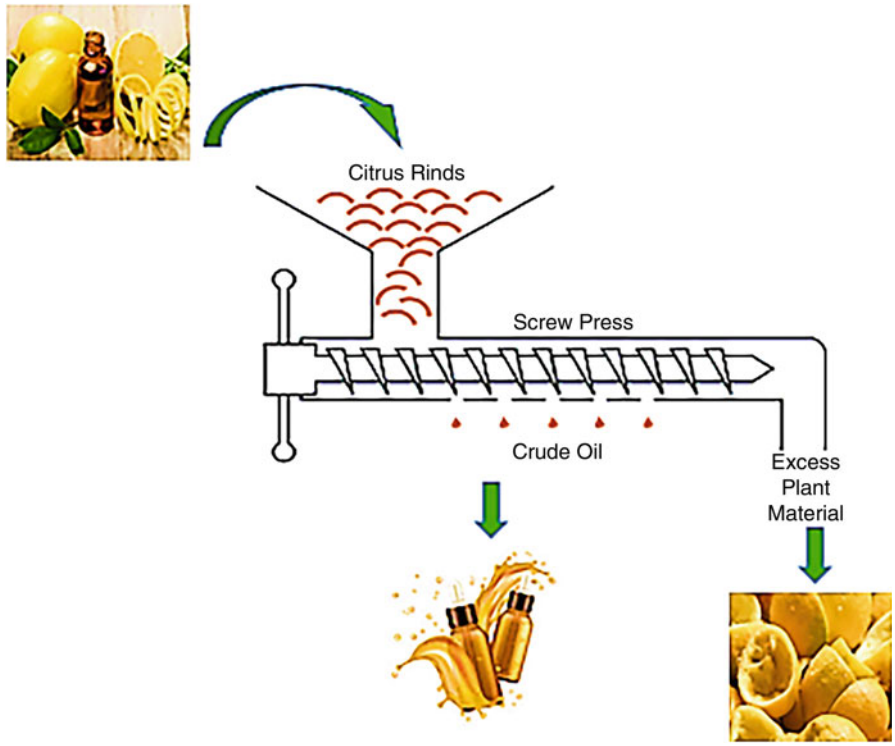

Fig. 1 Schematic diagram of a typical cold press extraction of citrus peel [26]

plant samples are unsuitable for cold pressing since they cannot sustain high mechanical pressure [25]. Furthermore, there is fluctuation or inconsistent moisture content in cold pressing, which might affect the biochemical activities of the essential oil as reported by Çakaloğlu et al. [25].

Furthermore, the earliest and easiest technique of extracting essential oils is the hydro-distillation technique, which begins with the immersion of the plant sample straight into the extracting solvent (water) within the reactor and then boiling the entire mixture. This extraction technique is said to be a one-of-a-kind approach for extracting oil from plant parts such as tough nuts, wood, seeds, and hard surface powders. It is commonly utilized for the extraction of oil that contains hydrophobic matter with a high boiling point. Because the oils are covered in water, this technique allows essential oils to be extracted at a controlled temperature without being overheated [27]. The capacity to separate plant components under 100 °C is the major benefit of this extraction process [28]. The hydro-distillation set-up consists of a heater source, a reactor, a condensation chamber that converts vapor from the reactor into liquid, and a decanter to capture the condensate and separate the water and essential oils mixture (Fig. 2).

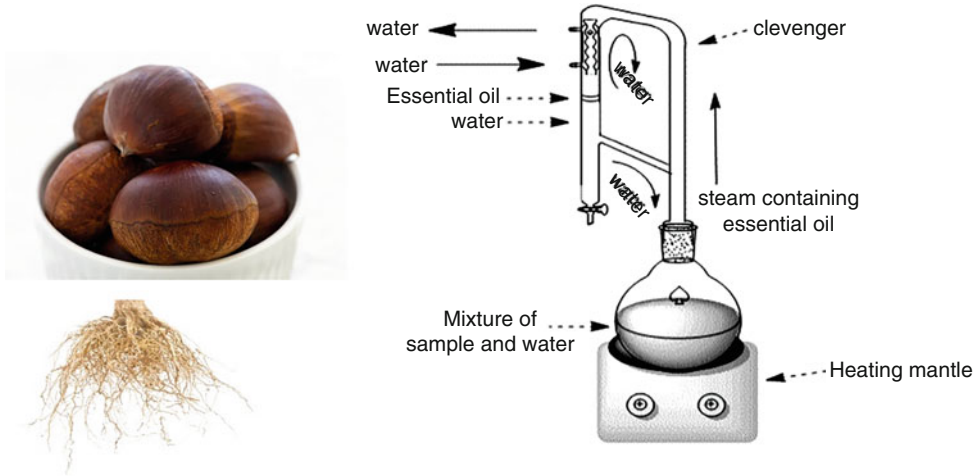

Fig. 2 Schematic diagram of a hydro-distillation apparatus [29]

To recover essential oils by hydro-distillation method, the plant sample is usually loaded and a considerable amount of extracting solvent (water) is poured and heated to a boiling temperature; conversely, steam is normally introduced. The essential oil is released from the cellulosic oil glands by the impact of high pressure. The water-oil vapor combination is condensed by evaporative cooling water. Distillate runs from the condensing compartment into a splitter, where the essential oil separates efficiently from the condensate. The advantage of this approach is the utilization of the extracting solvent (water) and the ease with which it can be set up [28]. This is put up before the dehydration of the plant material and works best when the material is dry. Compared to other extraction methods, it is a superior alternative due to the ease of use and accessibility of its ancillary equipment [30]. Unfortunately, there are some inherent disadvantages to using this approach. There are a number of drawbacks associated with extracting biological components, including excessive solvent use, poor output yield, liquid contamination, costly extraction, and an extended process time.

Maceration is another traditional method of essential oil extraction in which various carrier oils are used as solvents to extract the bioactive essential oil. The essential oil obtained through the maceration process is also called infused or macerated oils [31]. This technique is superior to distillation because it recovers higher molecular compounds from the plant samples [31–33]. The procedure involved loading into a closed vessel of a finely divided plant material and solvents (menstruum). The mixture of the plant sample and the solvent are kept for 7 days and intermittently stirred using a magnetic stirrer. The mixture is then pressurized to collect the fluid from the waste of the plant (marc). Then, filtering of the resulting liquid mixture is carried out to remove the infused oil as presented in Fig. 3.

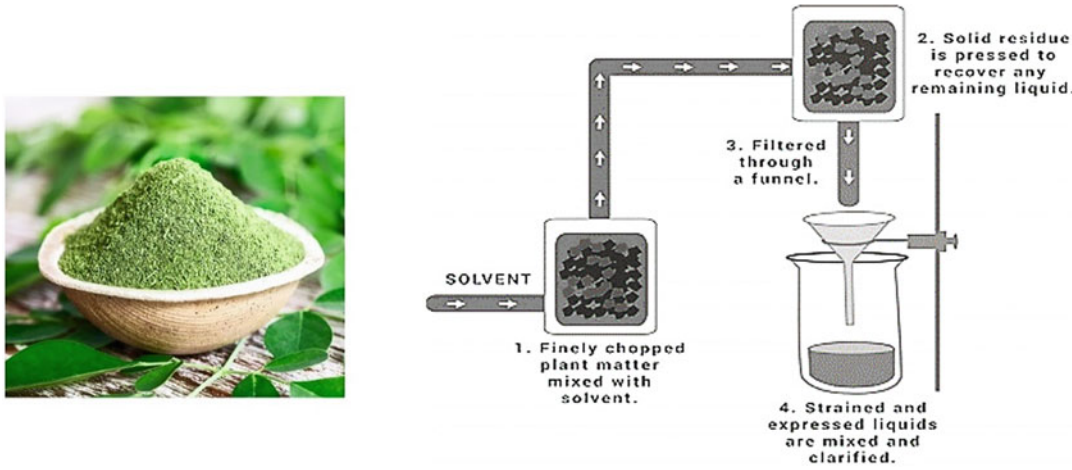

Fig. 3 Schematic diagram of maceration extraction of infused oils [34]

Past and recent studies had modified the use of the maceration method for the recovery of essential oil from plant sources. Notable among them are Kowalskia and Wawrzykowskib [35] who employed an ultrasound-assisted maceration technique to extract essential oil from thyme (*Thymus vulgaris L.*) dried leaves. Kowalski et al. [36] reported the use of maceration techniques as a preliminary extraction process before ultrasonic processing of essential oil from peppermint leaves, marjoram herb, and chamomile flowers. Mariane et al. [37] investigated the recovery of olive oil from Brazilian pink pepper using different stages of the maceration process. Soares et al. [38] incorporated the ultrasonic and maceration process for the extraction of enhancing flavoring of rosemary and basil extra virgin olive oil. Unfortunately, the use of maceration for extraction of essential oil has many limitations which include a longer duration for extraction which could take days for completions [39]. Higher solvent consumption and a low degree of other drawbacks affect the effectiveness of maceration extraction of essential oil [39].These limitations reduce the quality characteristics and hence the biochemical activities of their essential oils. Traditional extraction methods often take a long time, which means that some of the plant material's bioactive components will inevitably degrade. Examples of these conventional approaches are listed in Table 1.

3 Effects of Classical Extraction on Biochemical Activities of Essential Oil

Conventional procedures have been enhanced by new techniques such as microwave-assisted, supercritical, and ultrasonic essential oil extractions. Microwave-assisted extraction for example has more capabilities than the conventional solvent extraction mentioned in

Table 1
Conventional methods of extracting essential oils from various plant sources

Sample	Parts of plant	Conventional extraction methods	References
Pequi (*Caryocar brasiliense*)	Fruit	Cold pressing	[40]
Rice bran	Husk	Cold pressing	[41]
Cannabis sativa L. hemp	Leaves	Cold pressing	[42]
Fennel	Leaves	Cold pressing	[43]
Prunus serotine	Seeds	Cold pressing	[44]
Clove	Buds	Cold pressing	[45]
Hemp	Seeds	Cold pressing	[46]
Rosmarinus officinalis and *Origanum compactum*	Whole plant	Hydrodistillation	[47]
Lamiaceae (Mint)	Leaves	Hydrodistillation	[48]
Kumquat	Peels	Hydrodistillation, ultrasonic, microwave extraction	[49]
Schinus molle	Leaves and fruits	Hydrodistillation, fractional hydrodistillation, and steam distillation	[27]
Bitter orange	Peel wastes	Hydro-distillation	[50]
O. basilicum L.	Leaves	Hydrodistillation	[51]
O. vulgare L. subspecies *hirtum*	Aerial parts	Hydro-distillation	[52]
Litsea cubeba (Lour.) Pers.	Fruits	Hydro-distillation	[53]
Aquilaria malaccensis	Leaves	Hydro-distillation	[29]
Thymus serpyllum L. herb	Leaves	Maceration	[54]
Brazilian pink pepper	Fruit	Maceration	[37]
Rosemary and basil	Leaves	Maceration	[38]
Orange peels	Peels	Maceration	[55]

the previous section. In microwave-assisted extraction, conduction and convection occur at a pace that is so fast that it is frequently neglected or thought to be inconsequential since it occurs in a matter of seconds [56]. Microwave heating is usually through electromagnetic radiation with heat and mass transfer rate uniformly spread throughout the heating reactor; unlike the conventional approach where the heat transfer is not homogenous from the elevated temperatures to the lowest part [57]. The ability to extract pure essential oils free of undesirable impurities utilizing

microwaves has been shown in several research studies [58]. This opens up the possibility of shortening the extraction process, reducing energy consumption, using less solvent, increasing bioactive selectivity, and improving extraction yields [33, 59]. Ionic conduction and dipole rotation are the fundamental mechanisms at work in microwave extraction [60]. These two characteristics may coexist, with ionic conduction acting as a formidable obstruction to ion transport when present. This causes a temperature differential in the extraction media and also creates impedance. Meanwhile, the biological dipole moment is readjusted into the electric field by dipolar rotation [61]. Even as dipole revolves around its axis, an ionic flux is consequently present. In the microwave cavity, the electrical field produces an ionic current in the medium, which initiates the separation process. Because of their electromagnetic characteristics, microwaves' electric field is an orthogonal orientation to the magnetic fields [62]. So under the effect of the highly dynamic electrical field, the solvent provides resistance for its ion flux. Desai and Parikh [63] argued that the amount of turbulence in the passage of solvent ions into the plant tissue diminishes as the dipole rotation lowers, thereby reducing the thermal energy created in the media [64]. The pressure gradient is subsequently created, culminating in the transference of mass and energy into the reactor. This implies that solvents migrate from one zone to another to cause resistance in the media and hence to isolate bioactive chemicals from the constituents from the plant material [65]. However, uneven pressure gradients in the reacting vessels are typical of traditional extraction methods [66]. The appropriate selection of optimized extraction parameters is critical to the essential oil yield via electromagnetic-based microwave technology. One such factor is the microwave irradiation time. When the compounds of interest are stable to heat, a prolonged extraction time is necessary for the material with a greater dielectric constant such as ethanol, methanol, and water [67]. The shorter duration of extraction is one of the merits of microwave technology over the conventional methods of extraction. This helps in the preservation of thermo-labile constituents and hence a better biochemical quality of the essential oil extracted.

Above the critical temperature and pressure for a liquid or gas, another conventional extraction process known as supercritical fluid is constantly in use. Liquid and gas phases blend into one another and disappear altogether in the supercritical region. The diffusivity and density of supercritical fluids (SFs) are intermediate between those of liquids and gases. Different SFs have different solvating powers because its density varies with pressure and temperature, unlike liquids [68]. To isolate individual substances from a complex combination, this phenomenon is relied upon. Several different kinds of hydrocarbons, including those with four or more carbon atoms, nitrous oxide, sulphur hexafluoride, and fluorinated

hydrocarbons, have been studied as potential SFE solvents. Carbon dioxide (CO_2) is one of the most used SFE solvents since it is non-toxic, abundant, and cheap. In this way, supercritical processes may be carried out at pressures as low as 1 bar and temperatures as low as 20 °C. By use of these phenomena, it is possible to separate individual substances from a complex combination. Alkanes with four or more atoms, nitrous oxide, fluorinated gases, and fluorinated hydrocarbons have all been tested for in SFE solvents. On the other hand, carbon dioxide (CO_2) is the most often used SFE solvent since it is non-toxic, readily available, and inexpensive [69]. It paves the way for supercritical operations to take place at ambient or almost ambient pressures and temperatures. Density, diffusivity, depressurization, viscosity, and critical temperature are all crucial characteristics of supercritical fluids. The solubility of a supercritical fluid is proportional to its density, which in turn depends on its pressure and temperature. Once the density of the fluid is known, its solvating ability may be calculated with ease. Because the diffusion rates are so high, the extraction times are much shorter than they would be with liquid solvents. This is crucial because extraction rates are ultimately limited by the rate at which analyte molecules diffuse from the solid phase into the liquid phase [68]. Moreover, depressurization can be used to remove SFEs like carbon dioxide (CO_2) and nitrous oxide (N_2O) from analytes because they are gaseous at ambient temperature and pressure. Supercritical fluids have far lower viscosities than liquids (often by an order of magnitude), resulting in better flow properties [68]. This allows supercritical fluids to have direct access into the plant matrix quite more rapidly than traditional solvents. The majority of chemicals employed in analytical supercritical fluid extraction are non-toxic, inert, and generally affordable. Fluids with low critical temperatures such as CO_2 and N_2O can be used to supercritically extract thermally sensitive compounds.

Essential oil from aromatic plants with strong biochemical activity may now be extracted using the supercritical fluid extraction (SFE) technique rather than the time-consuming and tedious traditional methods. Effective and rapid extraction may be achieved using this technique without the need of high heat, tedious cleanup, or potentially harmful organic solvents. Most studies on the SFE of EOs look at how varying factors like temperature, pressure, fluid flow rate, sample size, modifiers, and fractionation affect extraction yield. The extraction yield, the amount of time and resources saved, and the accuracy of the data from future studies may all be greatly improved by adjusting these settings. Typical studies on the SFE of EOs look at how changing factors like temperature, pressure, fluid flow rate, sample size, modifiers, and fractionation affect the amount of extract that can be extracted. Estimating how temperature affects individual EOs may be challenging. The greater the temperature, the less dense the fluid,

which enhances the solubility of the EO, and hence explains the observed occurrence. So, the extraction yield is determined by the equilibrium between the density of SC-CO_2 and the volatility of the EOs at the specified circumstances, and this equilibrium shifts at various temperatures. Furthermore, as many EO constituents are thermo-labile, higher temperatures may accelerate their degradation. SFE has the advantage of producing a high yield at low pressure; this makes it a viable option for extracting EOs; however, in order to fully comprehend a solute's behavioral patterns in SFE, it is important to take into account four characteristics: the solute's cutoff point pressure; the solute's optimum solubility pressure; the solute's fractionation pressure; and the solute's physicochemical properties[68]. When greater pressures are applied, however, mass transfer and EO release are both enhanced from the plant matrix. Therefore, increasing the solvent power results in a decline in extraction selectivity and an increase in pressure. Separating the EO from the other co-extracted components requires a fractionation system with at least two separators when high pressures are applied.

The particle size, surface area, shape, and porosity of the plant matrix all have a significant role in the SFE yield, and all have an effect on the quality of the extracts. Limiting the particle size of a solid matrix increases surface area, decreases resistance to mass transfer, and improves extraction efficiency, all of which contribute to a shorter processing time. If the plant matrix is reduced too much, the solute may be re-adsorbed on its surface, so delaying the extraction process, and the pressure in the extractor may decrease [68]. Extraction efficiency is also affected by the rate at which the SF moves through the plant cells. By decreasing the flow rate, we may lower the linear velocity. Mass transfer resistance restricts the injection of analytes into a fluid at low flow rates, and unsaturated SC-CO_2 is introduced to the extraction vessel. As the flow rate of the fluid rises, the mass transfer resistance decreases until the fluid being removed is saturated, at which point equilibrium is established and maximum yield is achieved. Due to a decrease in residence time as flow rate rises, the system deviates from equilibrium and unsaturated fluid exits the extraction vessel, even while the mass transfer rate remains constant. This is because the leaves that can be extracted are skipped through if too much moisture enters their cells [70].

Furthermore, ultrasonic-assisted extraction (UAE) is increasing in popularity in the food and pharmaceutical sectors as a non-thermal extraction method for its many benefits [71]. This innovation was made to fix issues with both older and newer extraction methods. In comparison to conventional methods, UAE yields a more desirable essential oil quality profile, shorter extraction times, lower energy usage, fewer contaminants, and fewer or no solvent requirements [49]. UAE is a simple, effective,

and cheap technology when contrasted to other innovative extraction methods for essential oil recovery, such as supercritical fluid extraction (SFE) and microwave-assisted extraction (MAE) [71]. The flow of ultrasonic waves causes cell disturbances and a large contact surface area between the extracting solvent and sample material, enhancing mass and heat transfer, which is believed to be how UAE achieves its great efficacy in essential oil extraction [72]. The ultrasonic parameters (such as frequency and amplitude), product parameters (including viscosity and surface tension), and environmental factors (including temperature and pressure) all play significant roles in the formation of cavitation during UAE [73]. The classification of UAE technologies in food industries include low intensity-high frequency ($f > 100$ kHz) and high intensity-low frequency (20 kHz $< f <$ 100 kHz) ultrasound [74]. In the laboratory, UAE can be performed by immersing the plant material in water or other solvents (e.g., methanol or ethanol) and allowed to receive ultrasonic treatment at the same time [75].

Generally, process variables of significant importance contributing to the extractability of essential oil from plant materials include ultrasonic intensity/energy, solvent type, temperature, ultrasonic time, sample—solvent ratio, and ultrasonic power. Cavitation intensity is determined by the amount of ultrasonic energy supplied per unit volume of the plant samples. Moreover, there are lesser cavitation effects when an elevated ultrasonic wave is delivered to a bigger sample volume. Addressing both intensity and power density can be explained by considering the amount of energy applied to a given volume of sample (in joules per milliliter or watts per gram). Most studies investigate described this in terms of intensity (W/cm^2), but many additionally reported it in terms of power density (W/mL) as well. These variables are sometimes underestimated when replicating results from ultrasound, even though they're crucial for replicating sonication results from ultrasound. Moreover, ultrasonic cavitation and its thresholds are affected by the solvent's viscosity, surface tension, and vapor pressure. These three variables raise the cavitation threshold and sample resistance to device displacement when they are increased. It follows that to form cavities, the intensity of the oscillations must be increased. Due to decreased solvent vapor pressure, cavitation bubbles rupture more abruptly. This depends on the kind and strength of the interactions between a solute and its solvent as well as between a solvent and its solute. Oils being non-polar, non-polar solvents are the most effective at extracting oil. The effectiveness of oil extraction gradually decreases the polarity of a solvent. Solvents such as n-hexane and petroleum ether are both non-polar with the maximum oil extraction rate. Van der Waals forces are indeed very weak in such solvents, with inherent lower volatility and boiling temperatures. Van der Waals forces are also the only forces that exist within the non-polar solute molecules. In addition, due to

cavitation energy, as extraction time increases, cellular membranes are ruptured, thereby increasing the contact area between the ruptured cell walls and the extracting solvent, allowing for a greater amount of oil to permeate into the solvent. A 40-min increase in the UAE time can increase oil extraction yield from 23.46 to 26.71% at a fixed solvent-to-solid ratio [76]. Extraction efficiency declines with increasing extraction time because of equilibrium between the solid sample and solvents. Temperature is one of the most important factors in the ultrasonic extraction of essential oil. Cavitation bubbles increase with temperature rise and this results in a rise in contact surface area between extracting solvent and the cellulosic cell walls, as well as a corresponding drop in viscosity. Mass transfer improves extraction efficiency because the solvent with lower viscosity is better able to penetrate easily into the sample matrix. Marhamati et al. [76] reported that an increase in temperature from 40 to 50 °C, even when the solvent-to-solid ratio was kept the same, increased the oil extraction from 18 to 20%.

In summary, classical extraction methods, including steam distillation, solvent extraction, microwave-assisted extraction, and ultrasonic extraction, play a pivotal role in obtaining essential oils. However, it's essential to recognize that these methods can exert significant influences on the biochemical activities of essential oils, leading to several noteworthy consequences. Firstly, these extraction techniques have the potential to bring about alterations in the chemical composition of essential oils. The application of heat or solvents during the extraction process can induce modifications in the oil's chemical profile, consequently affecting its aroma and therapeutic attributes. This change in composition can be both beneficial or detrimental, depending on the specific compounds involved. Furthermore, the classical extraction methods can impact the yield and purity of essential oils. Some valuable constituents may be lost or degraded during the extraction process, while unwanted contaminants or solvent residues may be introduced, potentially compromising the oil's overall quality. Additionally, the changes in the chemical profile can have a direct bearing on the therapeutic efficacy of essential oils. Certain bioactive compounds responsible for the oils' beneficial properties may be either diminished or enhanced, which, in turn, affects their potential health benefits. Moreover, the stability of essential oils may be jeopardized during classical extraction. Exposure to heat or chemical solvents can lead to oxidative degradation, thereby reducing the oil's shelf life and diminishing its overall shelf-stability. The aroma and flavor of essential oils, integral to their various applications, are not exempt from the impacts of classical extraction. Some compounds contributing to the characteristic scent and taste of the oil may undergo alterations or loss during the extraction process, potentially affecting the sensory qualities of the oil. Lastly, the use of chemical solvents in classical extraction methods can raise safety

concerns. Residues of these solvents must be diligently removed to ensure the oil's suitability for therapeutic, culinary, or other applications. Failure to do so can render the oil unsafe for use. To address these concerns and mitigate the potential drawbacks, alternative extraction techniques, such as CO_2 extraction or cold pressing, are increasingly employed. These methods are known to preserve the biochemical activities and overall quality of essential oils to a greater extent, ensuring that the end-product maintains its intended attributes and benefits.

4 Conclusion

The extraction of essential oils (EOs) is gaining more attention than ever before, because of their numerous benefits. Moreover, due to the sensitivity of several of their biochemical constituents; extraction in extreme conditions is not feasible. Classical extraction methods which allow for lower temperatures and shorter processing periods have been described as enhanced technologies for extracting high-quality essential oils with minimal component losses. These methods have significant advantages over other conventional extraction methods in terms of preserving the main biochemical constituents of the oil. Many of essential oils' qualities, like antibacterial, antioxidant, and anti-inflammatory action, are determined by their constituents and the method of extracting them. This review therefore critically examined the mechanism and advantages of conventional and non-conventional extraction methods. This would surely help academics and business professionals choose the best extraction techniques to get the most out of their materials while maintaining the highest grade biochemical properties.

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