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Review Article

A comprehensive review of Patchouli plant: Comparison of microwave-assisted hydro-distillation and hydro-distillation methods

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Keywords
Patchouli oil, microwave-assisted hydro-distillation (MAHD), hydro-distillation (HD), extraction.

Abstract

Patchouli is a major herb that is widely used in the pharmaceutical and fragrance sectors. It is used in traditional medical practices to treat a variety of ailments, including influenza, headaches, a high fever, gastrointestinal discomfort, vomiting, diarrhea, and insect and snake bites. Within aromatherapy, patchouli oil is used to increase sexual desire and to lower stress, despair, and nervous tension. Patchouli oil is still often extracted using conventional techniques that require a lot of time and solvents. Previous investigations served as the basis for this study, which compared the process of extraction of patchouli oil using the techniques of microwave-assisted hydro-distillation and hydro-distillation. Comparisons were made on the basis of extraction time, power, solvents, and the final yield of oil. From these comparisons, we conclude that microwave-assisted hydro-distillation is a suitable method as a new green technology because it requires a shorter extraction time, a small amount of solvents, a small amount of energy, a high oil yield, a low cost, and is environmentally friendly.

1. Introduction

Patchouli often known as *Pogostemon Cablin Benth,* is an aromatic and a fragrant herb [1]. Belongs to the Lamiaceae family [2, 3] and shown in Fig. 1. Essential oils are a complex mixture of flavourful and volatile chemical compounds. Numerous international publications have emphasized the benefits of using essential oils [4]. Essential oils are mostly used in the perfumery business because of their great economic worth and medicinal benefits [5]. In 1845, Botanist Pelletier Sautelet discovered the patchouli plant for the first time in the Philippines under the name Pogostemon patchouli [6]. The Chinese Pharmacopoeia lists patchouli plants as a conventional Chinese drug because of their therapeutic qualities [7]. *Patchouli* plant originally originated in tropical Asia, but it is now widely cultivated in countries including Malaysia, India [8], Mauritius, West Africa, Thailand, Indonesia, China, Vietnam, and Philippines [9]. The optimal growing conditions for patchouli are up to 400 meters above sea level, temperatures around 22 and 28 °C, plenty of sunshine, and a minimum of 70% humidity, is the perfect temperature range [10]. Patchouli leaves, stems, blossoms, branches [11], fruits [12], and twigs [13] are used to create a precious essential oil known as patchouli oil [14, 15]. However, the essential oil content of roots, stems, and branches is lower than that of leaves [16].

Figure1. *Patchouli* plant (*Pogostemon cablin Benth*) [3].

Patchouli oil is among the 18 best essential oils with commercial relevance worldwide, out of a total of 300 essential oils [17]. As shown in Fig. 2 (A). 90% of the patchouli oil consumed worldwide is produced in Indonesia [18]. Most of the patchouli oil made in Indonesia is shipped to Japan, countries in Western Europe, and the US [19].

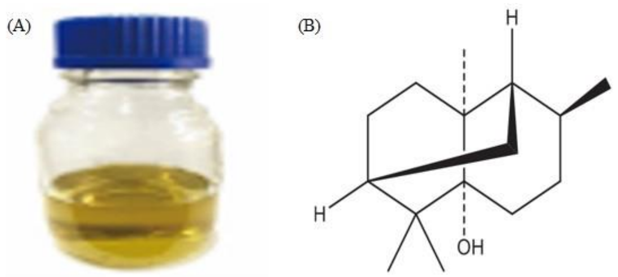


Figure 2. (A) Patchouli oil [22], (B) Chemical structure of patchoulol [23].

The countries with the highest production of patchouli oil are Singapore, Malaysia, and Indonesia. Oil production has continuously expanded as a result of rising global demand, and both its quantity and quality have improved thanks to extraction techniques emphasise environmentally sustainable production [12]. The plant produces natural products in the form of an endophyte- or self-produced metabolite [20]. The chemical compound known as patchouli alcohol (C15H26O), also known as patchoulol as shown in Fig. 2 (B), is one that primarily contributes to the potent and lingering fragrance of the oil [21], this gives it a distinctive aroma [9]. There are numerous methods for removing volatile oils from plant materials, including traditional techniques such as Soxhlet extraction [24–26], Steam distillation [27], maceration, hydro distillation (HD) and soaking, but it has disadvantages: take a lot of energy, a lot of solvents, and a long extraction time. The alternative techniques such as microwave-assisted hydro distillation (MAHD), an electric field, supercritical fluid extraction (SC-CO_2), and liquid CO_2 extraction [28]. (MAHD) is the most widely used method due to its simplicity, low cost, effectiveness in removing chemical compounds from plant materials, and minimal solvent requirement [29]. The aim of this study is to compare the extraction of bioactive chemicals from the patchouli plant using microwave-assisted hydrodistillation (MAHD) and hydrodistillation (HD) methods.

2. Materials and methods

2.1 Extraction methods

Several conventional methods, such as hydrodistillation, steam distillation, Soxhlet extraction and maceration are usually used to extract Patchouli essential oil. These conventional methods have some disadvantages, such as long extraction time, high energy use, degradation of components, and unwanted chemical changes in the oil. Hence, an improved extraction method that can increase yield, shorten the extraction time, and use less energy must be identified to meet the world demand for Patchouli essential oil [30].

2.1.1 Microwave-assisted hydrodistillation (MAHD) and hydro-distillation (HD) methods

Microwave-assisted hydrodistillation is an advanced technology that extracts essential oil from Patchouli leaves. It is found to be green technology because it uses less energy and solvent than conventional methods. Fast heating is the main advantage of microwaves. The microwave energy interacts with polar materials as waves to generate heat. When microwaves irradiate the biomaterials, they can force the liquid out of the cell. Unless other conventional methods, MAHD can heat the material simultaneously and at a higher rate, reducing the extraction time. Extraction of essential oil using

MAHD provides more valuable essential oil with high amounts of oxygenated compounds and also offers better production of the natural aroma of the essential oil. Microwave-assisted hydrodistillation technology was developed to extract essential oils from thyme and *Origanum glandulosum* Desf [31]. Shown in Fig. 3 and 4.

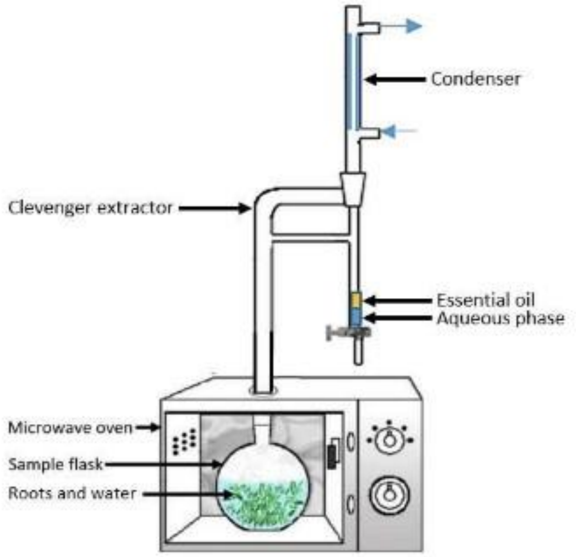


Figure 3. Microwave-assisted hydrodistillation system [32].

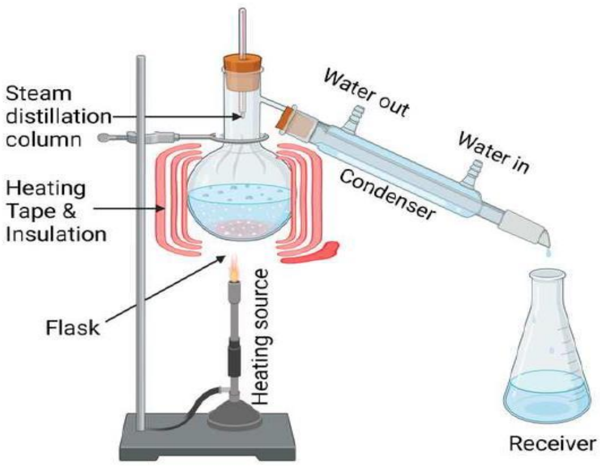


Figure 4. Hydrodistillation system [33].

2.2.2 Microwave-assisted hydrodistillation (MAHD)

The extraction efficiency in the MAHD process depends on a number of factors, including the microwave power, the liquid-to-material ratio, and the extraction period. These factors interact with each other and directly affect the extraction efficiency [34]. Because it has higher yields of essential oils, shorter extraction time [35], environmentally friendly as it emits less CO_2 [36], uses less energy and has lower extraction costs than other methods [37], the microwave-assisted hydrodistillation method has been identified as an alternative approach for extracting essential oils from plants [38]. Plant essential oils typically reside inside of cells, thus extra work is required to obtain them. When MAHD is used, the microwave not only has the ability to heat the material, but it also has a pumping effect that can cause moisture or oil to diffuse from the cell. The experimental results demonstrate that a stronger microwave is required to drive the oil to spread out of the plant tissues, resulting in a higher final yield [39]. Through MAHD, the oil made from patchouli leaves was described. For one hour, the microwave was run at 400 W. Through GC-MS analysis, the acquired data showed definitely that the oil included around 39.49% oxygenated and 60.25% non-oxygenated chemicals. 18 phenolic compounds were found in the oil, according to the LC-Q-TOF-MS data [31]. Microwave-assisted hydro distillation was used to extract the essential oil from Pogostemon cablin leaves grown in Indonesia, and gas chromatography-mass spectrometry (GC-MS) was used to analyse it. It was determined that around 97.97% of the oil existed. Were the leaf's main volatile compounds. Non-oxygenated chemicals were in the lead 59.82% of the total, followed by oxygenated compounds (38.15%) [40].

2.2.3 Hydro-distillation

Essential oils can be extracted from aromatic plants using a variety of techniques. A common method for obtaining essential oils from medicinal herbs and plants is hydro-distillation (HD) [41, 12]. However, there are a number of disadvantages to using standard (HD) procedures [42], including, the potential for volatile loss, and long extraction periods [43].

3. Results and discussion

3.1 Comparison between (MAHD) and (HD)

3.1.1 Comparison of bioactive compounds, energy and extraction time

The two principal substances that regulate and control the quality of patchouli oil are patchouli alcohol and β-patchoulene. Other minor sesquiterpenes include norpatchoulenol, cycloseychellene, caryophyllene,α-, β-, γ- and δ-patchoulene, pogostol, α- and β-bulnesene, seychellene,α- and β-guaiene [44] are shown in Table 1. Table 2 shows a comparison of the bioactive compounds extracted from patchouli leaves,

Table 1. Major bioactive Compounds of patchouli oil.

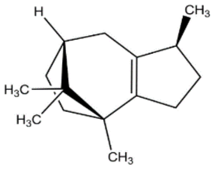
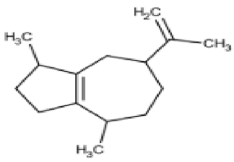
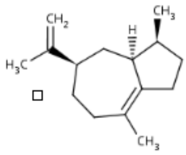
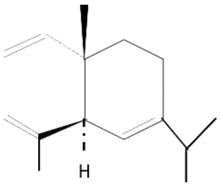
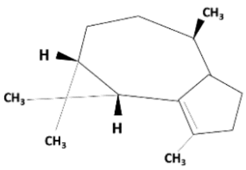
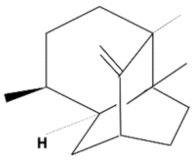
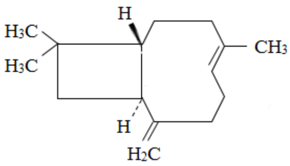
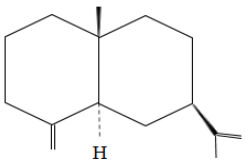
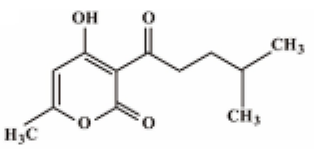
NO.	Compounds	Chemical structure	Molecular Formula	Molecular Weight (g/moll)	Reference
	Sesquiterpenes				
1	β-patchoulene		$C_{15}H_{24}$	204.35	[45]
2	α-Guaiene		$C_{15}H_{24}$	204.35	[46]
3	δ-Guaiene		$C_{15}H_{24}$	204.35	[46]
4	δ-Elemene		$C_{15}H_{24}$	204.35	[47]
5	α-Gurjunene		$C_{15}H_{24}$	204.35	[47]
6	Seychellene		$C_{15}H_{24}$	204.35	[47]
7	β-caryophyllene		$C_{15}H_{24}$	204.35	[48]
8	β-Selinene		$C_{15}H_{24}$	204.35	[47]
Oxygenated terpenes					
9	Pogostone		$\mathbf{C_{12}H_{16}O_4}$	**224.25**	**[22]**

Table 1. *(Continued)*

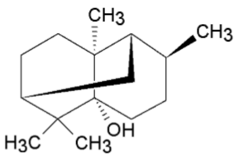
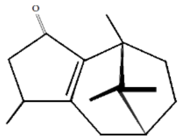
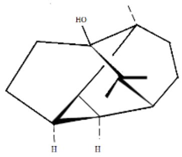
NO.	Compounds	Chemical structure	Molecular Formula	Molecular Weight (g/moll)	Reference
Oxygenated terpenes					
10	patchouli alcohol		$C_{15}H_{26}O$	222.37	[23]
11	β-patchoulenone		-	218	[48]
12	Nortetracyclo-patchoulol		-	206	[48]

Table 2. Comparison of bioactive compounds, energy and extraction time between (HD) and (MAHD).

Part of plant	Methodology	Analysis	Compounds	References
leaves	Patchouli oil was extracted by MAHD at 600 w for 60 min.	GC -MS	19 bioactive compounds	[10]
leaves	Patchouli oil was extracted by MAHD at 400w for 60 min.	LC-Q-TOF MS	18 phenolic compounds	[31]
leaves	Patchouli oil was extracted by MAHD at 400 w for 60 min.	GC -MS	29 bioactive compounds	[31]
leaves	Patchouli oil was extracted by MAHD at 400 W for 120 min.	GC-MS	16 bioactive compounds	[40]
leaves	Patchouli oil was extracted by HD for 180 min.	GC-MS	11 bioactive compounds	[40]
leaves	Patchouli oil was extracted by HD for 417 min.	GC-MS	14 bioactive compounds	[49]
leaves	Patchouli oil was extracted by MAHD at 280-700W for 126 min.	GC-MS	26 bioactive compounds	[49]
leaves	Patchouli oil was extracted by HD for 180 min.	GC-MS	21 bioactive compounds	[50]

energy and extraction time using microwave-assisted hydro-distillation (MAHD) and hydro-distillation (HD) methods.

3.2. Comparison of temperature

The samples were heated to 25 °C at the beginning of each extraction procedure. Regarding HD and MAHD, the extraction temperature was the same as the water boiling point at atmospheric pressure (100 °C). The extraction yield was found to be unaffected by the change in microwave power 500 W - 1,000 W. It took 57.0 minutes in HD and 6.0 minutes in MAHD to detect the first EO droplets. Three methods of heat transport are used by MAHD within the samples: irradiation, conduction, and convection. In contrast, only conduction and convection are used in HD to transmit heat. When samples were subjected to temperatures exceeding 110 °C, there was a drop in extraction yield [47]. The amount of patchouli oil produced declines after 45 minutes; during 60 minutes of extraction, the amount of oil produced by MAHD and HD, respectively, reduces from 2.33% to 1% and 0.9% to 0.43%. Longer extraction times can cause heat-sensitive bioactive chemicals to break down, which lowers the yield. Long-term exposure to high temperatures can cause the solvent to evaporate, which eventually reduces the amount of patchouli oil produced [40]

3.3. Comparison of mass and heat transfer

While in HD, the gradients are moving in the opposite way, the heat and mass gradients in MAHD are moving in a comparable manner. Because the samples may be heated more quickly and simultaneously when the heat and mass gradients are in the same direction, MAHD is able to extract more patchouli oil than traditional hydrodistillation [40]. The MAHD technique significantly increases sample extraction yield due to its larger extraction potential. This is due to the synergistic combination of mass and heat transfer phenomena. The mass transfer occurs from the inside to the outside in the HD and MAHD procedures Fig. 5 (B-D). Heat transmission rates between MAHD and HD differ, HD technique heat transfer from the exterior to the interior Fig. 5 (A). MAHD technique heat transfer from inside to outside Fig. 5 (C), partially due to internal heating of in situ water under microwave irradiation. This enhances oil diffusion from the inside of patchouli leaves via steam [47].

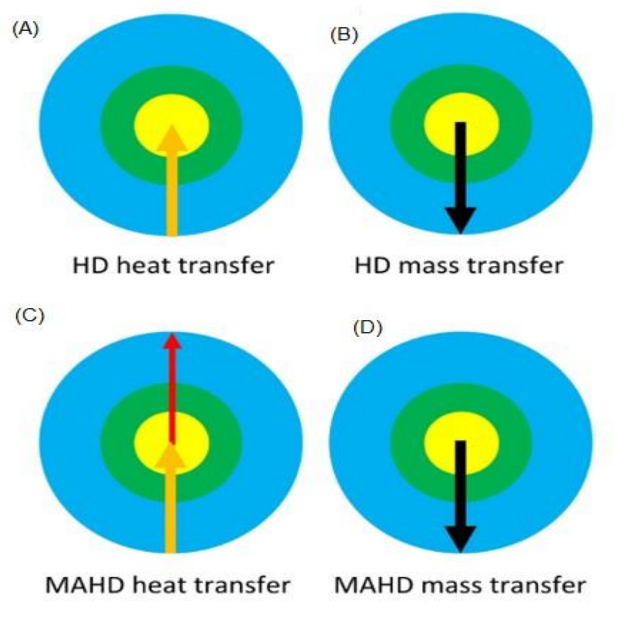


Figure 5. A diagram of the transfer of heat and mass during the (HD) and (MAHD) of the essential oil of patchouli leaves [47].

3.4 Industrial uses

Patchouli is an aromatic herb that is frequently utilized in expensive, colognes, fragrances, and treatments. A multitude of uses for patchouli essential oil are found in the aromatics sector because of its fixative qualities and oriental scent [9], and also efficient in deodorants, aftershaves, fine fragrances [40], shampoo, toilet soaps [51], make detergents, body lotions, scents, soaps [8], perfumers, cosmetics [52], and food flavouring [21]. Because it encourages relaxation, patchouli oil has also been utilized in incense sticks in the spirituality industry [8]. Furthermore, the Food and Drug Administration (FDA) has authorized patchouli oil as a natural food flavouring ingredient for ingestion by people. Patchouli oil is commonly used as a flavouring component in both alcoholic and non-alcoholic things. To flavour food, beverages, candies, and baked goods, this oil is used in extremely small quantities (2 mg/kg) [1]. Patchouli extract with a higher concentration of alcoholic chemicals has a higher market value because alcoholic functional categories can more readily bond to the perfume. As a result, the sector of perfumes uses it extensively. In the fragrance and flavouring industries, the extract, α and δ-guaienes components are utilized to add spicy scents and tastes. In room fresheners, α- and δ-guaienes molecules are also utilized. Medical uses for azulene chemicals include anti-inflammatory and peptic ulcer disease, antineoplastic treatment for leukemia, diabetes treatment, antiretroviral treatment for HIV-1, antimicrobial photodynamic therapy, and antifungals. Additionally, the Seychellene substance serves as an antioxidant [16].

3.5 Antimicrobial activity

Essential oils have the ability to stop microbial growth [53], help with wound care, and speed up healing [54]. Essential oil constituents are a wide range of organic substances with low and high molecular weights, which might affect the antibacterial or antimicrobial activity in different ways. Patchouli essential oil is more effective at inhibiting Gram-negative Shigella sp and Staphylococcus aureus growth [55]. Patchouli oil has potent antibacterial properties, as demonstrated by in vitro antimicrobial tests using molecular docking techniques. Pogostone and (-)-patchouli alcohol in particular have strong antibacterial properties [56]. Patchouli alcohol showed strong antibacterial action against Bacillus subtilis [57]. Patchouli essential oil has pharmaceutical active inhibitors with antifungal, antioxidant, antibacterial, and insecticidal properties, which were studied in rats with hepatic steatosis [58].

3.6 Medicinal uses

Natural plant products can be made from the fruits, flowers, bark, roots, leaves, seeds, and leaves of larger plants and lesser herbs. Approximately 1300 distinct plant species are thought to be frequently utilized for a variety of purposes, including the manufacturing of medications and treatments [59]. Throughout history, people have employed medicinal plants to treat a range of diseases. The world is seeing a global proliferation of this practice. The Lamiaceae family's species hold tremendous promise for the production of essential oils, which are used in traditional medicine for a range of biological diseases including burning, headaches, and diarrhea. Additionally, there have been reports of these species having antiviral, anti-insect spray, antibacterial, insecticide and anti-parasitic qualities [60]. Patchouli oil is included in different concentrations in medicines for liver diseases because it contains antioxidants [61]. Important biological characteristics of patchouli oil contribute to its ability to alleviate stress and inflammation without triggering allergic reactions. Patchouli's fresh leaves can be used to cure burns, soothe the nervous system, and regulate appetite [12]. Aromatherapy is used to calm nerves, relieve stress, despair control appetite [1], aphrodisiac characteristics to reduce stress, sleeplessness, anxiety as well as to increase intelligence and attention [8]. Patchouli alcohol has a higher potential for usage as an immunomodulatory medication in medical settings since it increases humoral immunity, suppresses cellular immune responses, and stimulates the mononuclear phagocytes system [44].

3.7 Pharmacological Uses

The Chinese Pharmacopoeia lists patchouli plants as a traditional Chinese medicine because of their therapeutic qualities [62, 63]. Traditional Chinese medicine uses a leaf concoction in combination with other drugs to treat headaches, colds, diarrhea, vomiting, chapped, acne, cracked, eczema inflamed and irritated [10]. patchouli oil is an essential component of "Huoxiang Zhengqi Pills (capsules, water)" and "Antiviral Oral Liquid," as well as the key raw component of over 30 additional Chinese patented medications [64]. Patchouli alcohol, often known as "patchoulol," is one of the primary ingredients of Pogostemon cabin oil, according to current studies. Used as an anti-inflammatory substance [65], anti-influenza, anti-tumorgenic [66], anti-ulcer, anti-mucositis, anti-colitis protective activities against brain and , lung injury [23] and Alzheimer's disease (AD) [67].

4. Conclusions

Patchouli essential oils have been used for medicinal applications since the middle ages due to their strong anti-viral, anti-fungal, anti-inflammatory, anti-oxidant, anti-cancer, anti-ulcer, anti-biotic, anti-bacterial and anti-insecticidal. Recently, Patchouli oil has found important applications in food industries, agricultural practices, cosmetic companies, sanitary articles and the latest pharmaceutical products. Patchouli oils are extracted from leaves, flowers, seeds, roots and fruits. The extraction of essential oils from the patchouli plant by applying modern and conventional extraction methods was evaluated based on previous studies. This study compared the hydrodistillation with microwave assistance's extraction time, extraction yield, and energy usage. It was concluded that the microwave-assisted hydro-extraction method to extract the essential oils from patchouli leaves uses less extraction time, less energy, and increases the final amount which found more bioactive compounds as well as environmentally friendly method.

Authors' contributions

Project administration, supervision, writing-review and editing, R.H.M.; Conceptualization, methodology, funding acquisition, writing-original draft and supervision A.H.N.; Resources, data curation, validation and methodology, R.M.Y.; Conceptualization, visualization, methodology, G.M.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The authors report no conflicts of interest.

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