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A Review of Processing Novelties of Extraction of Essential Oil from Cardamom

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Abstract

This review article summarizes the recent developments and processing novelties in the extraction of essential oil from cardamom. Cardamom is a highly valued spice due to its unique aroma and flavor, providing a range of culinary and medicinal benefits. Different methods are employed for extracting the essential oil from cardamom fruit, such as steam distillation, solvent extraction, and supercritical fluid extraction. This review article focuses on recently developed techniques in the extraction process, including Pressurized Liquid Extraction, Ultrasound-Assisted Extraction, Microwave-Assisted Extraction, and High-Pressure Assisted Extraction. Which improves the efficiency and yield of the extraction. Additionally, the article discusses the factors that influence the quality of the extracted oil, including temperature, pressure, and time, and how these can be optimized to enhance the oil's sensory, physical, and chemical properties. The use of cardamom essential oil in food processing, pharmaceuticals, and aromatherapy, and its increasing demand in the market are also discussed. Overall, the review provides insights into the advancements in cardamom essential oil extraction, which can benefit industries and researchers involved in producing and formulating natural products.

Keywords: Extraction, Essential oil, Microwave, Pharmaceuticals, Ultrasound.

1. Introduction

Cardamom originated from the evergreen rainforests of the Western Ghats in southern India and subsequently spread to other tropical regions such as Sri Lanka, Tanzania, Guatemala, and a few countries in Central America. The global cardamom output is expected to be around 55000 MT. In terms of the overall quantity, Guatemala is responsible for around 34,000 MT yearly, followed by India with approximately 21,000 MT (Vijayan, 2018). It is generally recognized for adding a pleasant aroma and flavor. Little cardamom, often known as the "Queen of Spices" (*Elettaria cardamomum* Maton), is one of the two types of cardamom that are used commercially. The other kind is large cardamom (*Amomum subulatum* species). Its dried fruit is among the most costly spices available. The dried fruit, either whole or crushed, is used as a flavoring element and in medicinal preparations. The volatile oil in cardamom is the most functionally important component (Raisaa et al, 2020). Little cardamom is more popular as a commercial item than large cardamom due to its superior aroma. Since ancient times, it has been widely used as a spice and as a medicinal herb (Mohammed et al, 2013). Additionally, it has been used in recipes by adding smashed seeds to beverages like coffee and tea. The pleasant aroma of cardamom oleoresin is due to its volatile essential oils, which have antispasmodic, analgesic, anti-inflammatory, and antifungal activities. Its dried fruit is one of the priciest spices that can be purchased on the market.

Essential oils are very intricate compositions that might be made up of hundreds of different components essential oils are composed of various types of compounds, including terpenes, sesquiterpenes, alcohols, aldehydes, ketones, acids, phenols, oxides, lactones, ethers, and esters. These compounds impart desirable sensory characteristics, such as flavor and aroma, to food products; hence, essential oils are widely used as food ingredients. In addition, some essential oils are believed to have antibacterial and antioxidant properties, which has spurred recent research on their potential health benefits. (Parthasarathy and Prasath 2012).

2. Cardamom oil

Cardamom oil is produced by distilling powdered cardamom seeds. The most prevalent technique for producing oil is steam distillation. The kind of distillation, the speed at which it is done, and the amount of time it takes all contribute to the final product's quality (Mani et al, 2017). Distilling high-quality cardamom would be too costly since the spice sells for more as a complete commodity. The process of distillation is most suited for lower grades that, when sold on their whole, cannot command a greater price. Nearly all volatile oil has been removed from the husk. The flavor of cardamom is mostly attributable to 1, 8-cineole, α-terpinyl acetate, linalyl acetate, and linalool (Parthasarathy and Prasath 2012).

3. Cardamom oleoresin

There are two parts to oleoresin: the oil, which is very volatile, and the resin, which is much more stable. The aroma is carried by the volatile oil, whereas the resin is made up of non-volatile materials like color, fat, pungent components, waxes, and so on. Only by combining an aromatic spice's oil and resin can its whole flavor profile be experienced. Steam or hydro-distillation is used to get volatile oil, whereas solvent extraction is used to acquire resin (Raissa, et al 2020). Cardamom seeds that have been crushed into a powder are subjected to a solvent extraction, which results in the production of a greenish oleoresin that contains around 70% volatile oil. There has been a gradual rise in the demand for cardamom oleoresin, most likely as a result of the softer and less abrasive flavor qualities that it has. There are also sensory distinctions between cardamom oleoresin and cardamom oil (Govindarajan et al., 1982).

4. Extraction of Essential Oil

Various methods have been utilized to extract essential oils from cardamom seeds, including steam distillation or hydro-distillation, solvent extraction, Supercritical CO2 extraction, solvent microwave extraction, pressurized liquid extraction, microwave-assisted extraction, and ultrasound-assisted extraction. These extraction techniques are commonly used for obtaining essential oils from plant sources. Essential oils are volatile compounds obtained from various plant components such as flowers, leaves, stem bark, and roots. The seeds of the cardamom fruit are collected just before they are mature in order to facilitate the distillation process that is used to get the essential oil of cardamom (Alexandros and Anastasios 2016). The yield obtain between 1-5% depending on the plant component utilized and the extraction procedure employed. By distilling the spices using steam, one may get the spices' volatile ingredients. The essential oils that are derived in this manner are endowed with the majority of the taste and smell attributes that are associated with spice. Volatile constituents 1, 8-cineole, and a-terpinyl acetate, which are considered to be the primary components of cardamom, actually have a role in the production of the spice's distinctive odor (Peter, et al 2019). According to the findings of several studies conducted by various researchers, the primary chemical components of cardamom essential oil are 1, 8 cineole, which accounts for 20–60% of the oil, and α-terpinyl acetate, which accounts for 20–55% of the oil. The principal chemical elements that are responsible for the sweet taste of the oil are α-terpinyl acetate, geranyl acetate, nerol, and α-terpineol (Emira et al, 2018). On the other hand, 1, 8- cineole is responsible for the oil's pungent odor. Even while their physicochemical aspects, such as their GLC and spectrophotometric characteristics, are used to define spice oils, in the end, spice oils are evaluated based on their sensory and aromatic qualities (Masha and Hamidreza 2014).

5. Steam distillation

The process of water distillation involves boiling the plant material in water either through the direct fire, steam jacket, closed steam jacket, closed steam coil, or open steam coil. This method allows for direct contact between the boiling water and the material. In contrast, steam distillation involves generating steam either within the still or in a separate satellite boiler where the plant material is not in direct contact with the boiling water (Mani et al. 2017). The equipment used for steam distillation is similar to that of water distillation, but the plant material is placed on a perforated grid above the boiling water to prevent heat damage. Steam distillation is commonly used on a large scale for the extraction of essential oils and is widely practiced in the flavor and fragrance industry (Sontakke et al, 2018). The essential oil of cardamom is primarily extracted using steam distillation with a yield of approximately 2.6%. The major compounds present in the essential oil of cardamom are 1, 8-cineole and α-terpinenyl acetate, which account for approximately 9.1% and 10.32% of the major compounds in the essential oil of cardamom (Emira et al. 2018).

6. Hydro distillation extraction

The most popular and widespread technique for the extraction of essential oil is known as hydro distillation. This procedure takes a considerable amount of time. However, essential oils' volatile and thermally sensitive components may be lost during hydro-distillation (Mani et al, 2017). In spite of the fact that essential oils have boiling points that are on the higher end of the spectrum, co-distillation may still result in a successful recovery of the oil. Despite having a boiling point between 150 and 300℃, most essential oil components may be evaporated with steam/boiling water at 100℃ because the vapor pressure of two immiscible liquids is equivalent to atmospheric pressure at that temperature (Nashwa, 2015). On the other hand, this technique is laborious and time-consuming since it calls for the physical separation of the oil and water phases of the condensate. To extract essential oils through hydro distillation, plant material is packed into a still, and then water is added to the mixture before being heated to a boiling point. Alternatively, live steam can be injected into the plant material. The heat from steam and water cause the essential oil to be released from oil glands inside the plant tissue. The vapor combination of water and oil is cooled indirectly with water, which results in the condensation of the vapor mixture. Oil and distillate water automatically separate in a separator once the distillate flows there from the condenser. The extraction of essential oil yield is 5% and the major constituents of volatile are 1, 8-cineole, and α-terpinenyl acetate of 10.38% and 17.23% respectively (Mohammed et al, 2014).

7. Pressurized liquid extraction

Pressurized Liquid Extraction (PLE) is a new method for essential oil extraction, where a solvent or solvent mixture is subjected to high pressure and temperature beyond the boiling point of the solvent. This technique improves the extraction efficiency over methods performed under ambient conditions. PLE is also known as Pressurized Solvent Extraction (PSE), Subcritical Solvent Extraction (SSE), or Accelerated Solvent Extraction (ASE). The application of high temperatures increases the solubility, diffusion rate, and mass transfer characteristics of the solvent while reducing surface tension and viscosity. Compared to other extraction methods, PLE offers several advantages, such as low solvent quantities, a shorter extraction time, and automation feasibility. PLE can be performed in static, dynamic, or a combination of the two modes (Mohammed et al, 2014).

Researchers have investigated ways to improve PLE via the use of solvent modifiers that increase the solubility of target analyses and improve the interaction between the extraction solvent. The extraction yield for PLE was 3.1%, which was the highest, and at the optimum condition, the content of desirable oxygenated components like 1, 8-cineole, and α-terpinenyl acetate was higher compared to hydro distillation and steam distillation methods. The results showed that PLE could significantly reduce the temperature of the essential oils, which is beneficial for heat-sensitive substances like essential oils. Additionally, the levels of 1, 8-cineole, and α-terpinenyl acetate, the major components of cardamom essential oil, were relatively higher with PLE. (Janu et al, 2012).

8. Solvent-free microwave extraction

The term "solvent-free microwave extraction" (SFME) refers to a process carried out at atmospheric pressure based on the combination of distillation and heating by microwaves. Azeotropic distillation is the method that allows the essential oil to be extracted from the plant material after it has been entrained by the water that is already there. After that, the vapor goes via a condenser that is located outside the microwave cavity, to condense (Peter et al, 2019). In the receiving flask, the distillate is continually collected. In order to get the moisture content of the plant material back to its original level, the surplus of water was cohobated, then refluxed, and returned to the extraction vessel. The essential oil is collected straight and dried without any solvent extraction procedure. Microwave extraction without the use of any solvents has been put to use in order to get essential oils from a variety of source materials. The SFME is neither a modified microwave-assisted extraction (MAE) using organic solvents, nor is it a modified hydro-distillation (HD) using a huge amount of water (Marie et al, 2006). The essential oil of cardamom has been broken down into its component parts and has been found to mostly consist of the following six compounds: 1, 8-cineole, α-terpinyl acetate, linalool, linalyl acetate, α-terpineol, and terpineol which shown in Table 2. These six compounds account for roughly 90% of the essential oil from cardamom's aromatic components, and they are all oxygenated compounds. Cardamom is a spice that is used in cooking. Depending on the conditions of the extraction, the yield ranged anywhere from 35% to 52% for 1, 8-cineole, and from 19% to 30% for α-terpinyl acetate (Emira et al, 2018).

9. Supercritical fluid extraction

SCFE is a method for extracting oil and other plant components using supercritical fluid at the vapor-liquid critical point. Only when the solvent has been exposed to temperature and pressure levels in excess of its critical point is it possible to enter the supercritical state. At the critical point, there is no distinguishable gas or liquid phase, and the solvent acts more like a gas with liquid-like solvating characteristics (Samer et al, 2007). However, the gas-like viscosity causes rapid mass transfer. Carbon dioxide (CO_2) is a popular solvent because it is inexpensive, readily available, safe to handle, non-flammable, non-toxic, has modest critical characteristics, and can be recycled from reaction streams. Carbon dioxide (CO_2) is a solvent that is considered to be non-hazardous to human health. Additionally, since this method recycles CO_2, it eliminates the greenhouse effect, which is harmful to the surrounding environment. Both the food and pharmaceutical sectors are beginning to see the benefits of SCFE. The extraction procedure takes less time, is extremely selective, and is ecologically benign since it does not utilize organic solvents. The primary advantage of this method is that it does not need any further separation stages to get the oil out of the substrate.

The volatile concentrates produced using SFE do not contain the high molecular mass chemicals that are generally co-extracted by conventional solvents, and their aroma is closer to that of the starting material than that of the volatile concentrates obtained through water or steam distillation. Because of its chemical and physical qualities, compressed carbon dioxide is almost solely utilized to extract volatiles or fragrance components for human nutrition, as well as for the pharmaceutical and perfume industries (Paul and Bhattacharjee, 2018). It has a low critical temperature and pressure (31.06 °C; 7.38 MPa), is non-toxic, non-combustible, and cheap. The behavior of supercritical CO_2 is similar to that of a lipophilic solvent; however, its selectivity may be adjusted, allowing for values that range from those of a gas to those of a liquid. This gives it an advantage over liquid solvents. Working with carbon dioxide at a low density is required in order to carry out the SFE method of obtaining a pure essential oil (Bruno et al, 2004). When added together, the components made up less than 1.9% of the distilled cardamom oil. In a similar manner, around 13 less volatile minor components (LVMC) were eluted following terpinyl acetate in GLC. These LVMCs were present at a level of 2.2% in the distilled oil, but they were present at a level of 4.0-6.0% in the extract produced at various pressures (Gopala Krishnan and Narayanan 1991).

10. Microwave-assisted extraction (MAE)

When compared to other traditional procedures, the extraction technique known as microwave-assisted extraction (often abbreviated as MAE) is believed to have a high throughput as well as a high extraction efficiency (Panawan et al, 2020). During MAE, a microwave generator sends waves of radiation through a polarizable substance made up of the solvent and the oil. Radiations at microwave frequencies interact with dipoles already present in the sample matrix, causing those dipoles to oscillate in reaction to the shifting electromagnetic fields. As the dipoles oscillate and rotate, they release energy as heat, which is conducted from the surface into the bulk of the material. Microwave radiations interact with the water contained inside the cells of the oil-bearing substance, penetrating the target tissues quickly and uniformly, in addition to the dipoles from the solvent utilized in the extraction process (Alexandros and Anastasios 2016). This heat causes water vapor to develop and has electroporation effects, which break down the oilseed's cell wall so that its contents may be more easily extracted. As a result, the extraction process takes only around 15 to 20 minutes, requires a smaller amount of solvent, works with polar and nonpolar solvents, boosts yield with high repeatability, and produces products with better color, odor, and flavor. In the food and chemical sectors, the use of microwave radiation has been shown to substantially impact the velocity of various operations (Panawan et al, 2020). Essential oils, antioxidants, pigments, and scents are just some of the natural products that have attracted a lot of interest in recent years, and dielectric heating has played a key role in their extraction. In terms of both product quality and yield, microwave irradiation comes out on top because it enables the direct coupling of molecules by selective absorption. As a consequence, the end products of microwave irradiation are superior to those obtained via the use of traditional heating and extraction methods. Microwave-assisted extraction has been shown to have a considerable impact on mass transfer while also providing excellent throughput and extraction efficiency (Janu et al, 2012). Different investigations report microwave power anywhere from 275 W to 1,000 W and temperatures between 30 and 60°C. Increases in microwave power (from 70 to 210 W) were shown to directly increase the 1, 8 cineole content, whereas increases in microwave power (above 210 W) were found to reduce the compound's abundance. This method is useful for extracting 1, 8-cineole-rich essential oils at a purity level of 20.6%.

11. High pressure-assisted extraction (HPAE)

When compared to traditional extraction methods, high pressure-assisted extraction (HPAE) stands out as novel and advantageous since it does not involve heating the substrate, protecting the integrity of the bioactive chemicals and other biological activities. The process may be classified as high-pressure (above 100 MPa), medium to high-pressure process (10 to 100 MPa), or low pressure depending on the magnitude of the external pressure that is being exerted against it (below 10 MPa) (Mohammed et al, 2013). Depending on the temperature at which it is carried out, the procedure may alternatively be known as pressured hot water extraction or pressurized liquid extraction. The pressure that is exerted causes the plant tissues to become disorganized, causes disruptions in both the cell wall and the cell membrane, and it makes it easier for soluble substances to go from the solvent to the substrate. The underlying idea that drives HPAE is described as the phase behavior theory. This theory states that the solubility of a chemical increases as the pressure at which it is held increases. The pressured environment allows the solvent to swiftly penetrate cells, make contact with cellular components, and then actively dissolve the desired parts (Janu et al, 2012). Compared to other extraction methods, HPAE has several benefits, including preventing heat degradation of food components, acting quickly and evenly throughout the substrate, preserving high bioactivity by preserving covalent connections, needing less time, and yielding more oil. Whereas, in this method essential oil contains 38.91% α-terpinyl acetate and 32.8% 1, 8-cineole, with a stated yield of 2.6% shown in Table 1.

12. Ultrasound-assisted extraction technique (UAE)

The ultrasound-aided extraction (UAE) approach is a low-cost, low-complication, and high-efficiency replacement for standard extraction methods. It has been shown that UAE is an appropriate extraction technique by its technical benefits, which include the intensification of mass transfer, the disruption of cells, the improvement of solvent penetration and the capillary effect, the high recovery yield, and the quick extraction time. The yield is 4.9% shown in Table 1 and the quality (α-terpinyl acetate/1, 8-cineole ratio) of the extracted essential oil was shown to be significantly affected by the sonication power and sonication duration. This method may be used to quickly and efficiently extract high-quality essential oil from a variety of aromatic plants (Raissa et al, 2020). It has been reported that ultrasound makes the extraction of sensitive and thermally unstable plant components easier by providing less harsh circumstances. The relative concentrations of the detected chemicals were found to be variable depending on the extraction technique used. The major components of cardamom essential oils varied from 26.59% to 39.34% from 1, 8-cineole, and from 22.94% to 40.56% for α-terpinyl acetate, depending on the extraction conditions. The UAE approach expedited the extraction of high-quality cardamom essential oil while also increasing the process's efficiency and reducing its environmental impact (Nashwa and Morsy, 2015).

Table 1 Extraction methods and essential oil yield of cardamom

Extraction methods	**Solvent**	**Conditions**	**Essential Oil yield %**		**Reference**
			Elettaria Cardamonum	***Amomum Subulatum***	
Supercritical fluid	CO_2	Temperature 30-50℃ Pressure 10-30MPa Flow rate 1.0-1.5 L/min	7.4	NR*	Samer Hamdan et al. 2007
	Propane	Temperature 25℃ Pressure 2-5 MPa Flow rate 1.0-1.5 L/min	5.7	NR	
	CO_2 + Ethanol	Temperature 25℃ Pressure 8-10MPa Flow rate 1.0-1.5 L/min	4.6	NR	
	CO_2	Temperature 40-60℃ Pressure 10-60MPa Flow rate 0.02L/min	7.8	NR	Narayanan et al. 1991
Solvent Extraction	Petroleum ether	Soxhlet apparatus Ratio 1;2w/v Temperature 40℃	7.3	NR	Samer Hamdan et al. 2007
Hydro distillation	water	Temperature 150-300℃	5.0	5.1	Mahsa Jabbar et al. 2014
Steam Distillation	Ethyl acetate	Temperature 100℃ 250mL distillation Time 3-6hrs	2.6	5.6	Sontakke et al. 2018 Raissa et al. 2020
	n-hexane		3.0	5.6	
Solvent-free microwave extraction	Water	Power 1000W, 10W in increment	2.6	NR	Marie et al. 2006
Microwave-assisted extraction	Dichloromethane	Power 450 W	2.3	NR	Panawan et al. 2020
Pressurized liquid Extraction	Ethanol-water	Temperature 90-150℃ Flow rate 1.0-4.0mL/min	3.1	NR	Mohammad et al. 2013
Ultrasound-assisted extraction	Dichloroethene	-	4.9	NR	Hassan et al. 2012

*NR- Not Reported

13. Bioactive compounds in cardamom

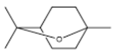
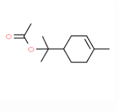
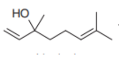
Green cardamom (*Elettaria cardamomum*) and black cardamom (*Amomum subulatum*) are both used as spices in cuisines worldwide. They contain several bioactive compounds that have potential health benefits. Some of the major bioactive compounds in green cardamom include 1, 8-cineole, limonene, and Terpinolene. On the other hand, black cardamom contains essential oils rich in compounds such as 1, 8-cineole, and Terpinolene. The volatile constituents of both cardamoms are shown in Table 2. Overall, both green and black cardamom are rich sources of bioactive compounds with potential health benefits due to their antioxidant, anti-inflammatory, and anti-cancer properties. The activity of major constituents in cardamoms is shown in Table 3. These compounds have been studied for their potential to improve digestive health, reduce oxidative stress, and prevent chronic diseases such as diabetes, cardiovascular disease, and cancer. Studies have also suggested that cardamom extracts may have antimicrobial, anti-inflammatory, and immunomodulatory properties. However, more research is needed to fully understand the mechanisms of action and potential health benefits of the bioactive compounds in green and black cardamom.

Table 2 Volatile constituents of *Elettaria Cardamonum* and *Amomum Subulatum*

S.no	Constituents	Essential oil %	
		E. cardamomum	*A. Subulatum*
1	α- Pinene	1.5	1.3
2	β- Pinene	0.2	0.7
3	sabinene	2.8	-
4	Myrcene	1.6	0.4
5	α- Phellandrene	0.2	1.6
6	Limonene	11.6	2.4
7	1, 8- Cineole	36.3	41.7
8	γ- Teripene	0.7	-
9	ρ- Cymene	0.1	2.6
10	Terpinolene	0.5	-
11	β-Linalool	3	3.0
12	Linalyl acetate	2.5	-
13	Terpinen-4-ol	0.9	1.7
14	α- Terpineol	2.6	0.6
15	α- Terpinyl Acetate	31.3	1.80
16	Citronellol	0.3	-
17	Nerol	0.5	0.9
18	Geraniol	0.5	12.5
19	Methyl eugenol	0.2	-
20	Trans-Nerolidol	2.7	-
21	α- Citral	-	-
22	ρ-Cresol	-	-
23	γ- Cadinene	0.3	0.12
24	α-Thujene	0.1	-

Source: Parthasarathy et al. 2012, Mahsa Jabbar et al. 2014, Emira noumi et al. 2014.

Table 3 Major constituents of essential oil in cardamom and its activity

Major Constituents	Structure	Flavor Description	Activity
1,8-cineole		Fresh, cool odor, taste, the very diffusive and poor tendency	It is known for its mucolytic and spasmolytic action on the respiratory tract, with proven clinical efficacy. It is also helpful in therapeutic benefits in inflammatory airway diseases, such as asthma and chronic obstructive pulmonary disease (COPD).
α-terpinyl acetate		Mildly herbaceous, sweet spicy, variation in odor, warm, mildly spicy taste.	It exhibits multi-target direct ligand potential in Alzheimer's disease. It is significant in anticholinesterase activity.
Sabinene		Sweet, floral, fruity, odor and taste,	It is responsible for antibacterial and antiseptic behaviors in oil. It is used in perfume, flavor, and pharmaceutical industries due to its anti-inflammatory properties.
ß-linalool		Floral taste, creamy floral taste	It is used as a scent in 60 to 80% perfumed products and, cleaning agents like soap, shampoo, and detergents. It also exhibits antimicrobial and antifungal properties.

14. Applications in the food industry and pharmacological properties

- Cardamom Oleoresin is a powerful flavoring & aromatic agent which popularly used as an ingredient for aroma in chewing gums, natural fresheners, perfumery, soaps, and cosmetics.
- Cardamom oil has strong antiseptic & antimicrobial properties for use as a preservative agent contains photochemical known for fighting cancer and Excellent ingredient for preventing blood platelet clumping.
- Cardamom is good for vocal cords. Singers often use cardamom as it is known to improve their voice.
- Cardamom oil is used in various medicinal preparations, cough tonics, digestion ailments, and aromatherapy (Razafimamonjison et al, 2020).

15. Conclusion

Recent trends in oil extraction have focused on reducing the use of toxic organic solvents and developing renewable and green solvents to produce safer and higher-quality products, making oil extraction more environmentally friendly. In this regard, traditional extraction approaches have emerged as viable alternatives to conventional methods for recovering target components from various solutions. For example, Ohmic-aided hydro-distillation (OAHD) is a volumetric heating technique that enables greater process control, shorter process time, and reduced distillation costs without affecting yield or distillate quality. However, scaling up and commercializing OAHD face challenges such as safety concerns, reluctance by industries to adopt emerging techniques, and investigating other potential applications and safety aspects. Considering the economic, ecological, and security implications of extraction methods, there is a growing need for pertinent research in exploring other possible OAHD applications, addressing safety issues, and scaling up the process. Until these points are effectively addressed, the industrial application of OAHD may remain a topic of debate. It is expected that this review will encourage further research on OAHD and promote its commercial application in the future. Essential oils extracted from plants utilizing cutting-edge extraction methods have bright future prospects. In contrast to more conventional approaches, contemporary methods have been examined to see whether or not they are more productive and versatile in meeting the ever-increasing demand from customers for goods that are both trustworthy and of the highest possible standard. Because they are non-thermal processes, the majority of the revolutionary procedures produce goods of greater quality. Additionally, they have been shown to be useful in reducing the time, energy, and solvent use required to create high-quality plant extracts. Despite these benefits, sustainable processing with a guarantee of a safe product requires a combination of several methods, notably the thermal processes Additionally, similar extraction methods can be employed in various industries, including food and beverages, cosmetics, and pharmaceutical, for the production of various products like formulations, therapeutic agents, flavorings, and fragrances. Overall, continued research and development can lead to the optimization of these techniques, making them more accessible and providing a more efficient, environmentally friendly, and sustainable solution for cardamom oleoresin extraction for various end-uses.

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