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Optimizing Jasmine Flower Extraction: A Review of Modern Approaches

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Jasmine, renowned for its enchanting fragrance and therapeutic properties, holds significant cultural, economic, and industrial value globally. Primarily cultivated for its flowers, jasmine is widely used in perfumery, cosmetics, aromatherapy, and pharmaceuticals. Value addition, such as producing essential oils, teas, and skincare products, enhances profitability, extends shelf life, and reduces post-harvest losses. Traditional extraction methods like steam distillation (SD) and solvent extraction (SE) face limitations, including low yield, long extraction times, and degradation of heat-sensitive compounds. To overcome these challenges, innovative technologies such as supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), subcritical water extraction (SWE), pulsed electric field (PEF), and cold plasma extraction have emerged. These methods offer higher efficiency, improved yield, and reduced environmental

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impact. For example, SFE using supercritical CO_2 achieves superior oil yields, while MAE and UAE reduce extraction time and energy consumption. SWE eliminates organic solvents, making it a sustainable alternative, and PEF and cold plasma enhance extraction by disrupting cell membranes. Despite their advantages, challenges such as high equipment costs, scalability, and optimization of parameters remain. Future research should focus on techno-economic analysis, environmental impact assessment, and scalable industrial prototypes. By integrating these advanced technologies, the jasmine industry can achieve sustainable growth, support rural livelihoods, and meet the rising demand for natural and organic products. This review highlights advancements in jasmine processing, emphasizing the potential of innovative extraction methods to revolutionize the industry while preserving its aromatic and therapeutic qualities.

Keywords: Aromatic; cosmetics; pharmaceuticals; plasma extraction; supercritical fluid extraction.

1. INTRODUCTION

Jasmine, renowned for its enchanting fragrance and delicate beauty, holds significant cultural, economic, and industrial importance worldwide. Primarily cultivated for its flowers, jasmine is widely used in the perfume, cosmetics, aromatherapy, and pharmaceutical industries. However, the true potential of jasmine extends beyond its raw form, as value addition can significantly enhance its economic and functional benefits. Value addition refers to the process of transforming raw jasmine flowers into higher-value products, thereby increasing profitability, shelf life and marketability. The global demand for natural and organic products has surged in recent years, creating opportunities for jasmine-based value-added products such as essential oils, concretes, absolutes, floral waters, teas, and skincare formulations. For instance, jasmine essential oil extracted through steam distillation or solvent extraction, is a highly sought-after ingredient in luxury perfumes and therapeutic products due to its calming and aphrodisiac properties (Choudhury et al., 2008). Similarly, jasmine tea, a popular beverage in many cultures, combines the health benefits of tea leaves with the aromatic essence of jasmine flowers, offering a unique sensory experience. Value addition also plays a crucial role in reducing post-harvest losses and ensuring sustainable utilization of jasmine. By processing flowers into stable products like dried jasmine buds or infused oils, producers can extend the shelf life of this perishable commodity and access broader markets. Furthermore, the integration of modern technologies, such as supercritical fluid extraction and encapsulation, has opened new avenues for innovation in jasmine-based products (Aziz et al., 2018).

In addition to economic benefits, value addition in jasmine supports rural livelihoods, particularly in countries like India, China, and Egypt, where jasmine cultivation is a traditional occupation. By adopting value-added practices, farmers and small-scale entrepreneurs can diversify their income streams and improve their resilience to market fluctuations.

Jasmine flowers, particularly *Jasminum grandiflorum* and *Jasminum sambac*, are widely cultivated for their aromatic and therapeutic properties. Jasmine essential oil (JEO) is a key product derived from these flowers, used extensively in perfumery, aromatherapy, and cosmetics. The traditional methods of JEO extraction, such as steam distillation (SD) and solvent extraction (SE), have limitations, including low yield, long extraction times, and the potential degradation of heat-sensitive compounds. These drawbacks have prompted the exploration of innovative extraction technologies that can enhance yield, preserve bioactive compounds and reduce environmental impact.

This review provides a comprehensive overview of the latest advancements in jasmine flower processing, focusing on emerging extraction technologies. It also highlights the potential health benefits of jasmine-derived products and their applications in various industries.

2. JASMINE FLOWER: AN OVERVIEW

2.1 Botanical and Chemical Composition

Jasmine, belonging to the genus *Jasminum* in the Oleaceae family, is a fragrant flowering plant native to tropical and subtropical regions. The genus comprises over 200 species, with *Jasminum grandiflorum* (Spanish jasmine) and *Jasminum sambac* (Arabian jasmine) being the most commercially significant due to their high essential oil content and aromatic properties. Jasmine plants are typically shrubs or vines, characterized by their white or yellow flowers, which bloom at night and release a strong, sweet fragrance. Jasmine flowers are small, with a tubular corolla and five to nine lobes. The flowers are usually white, although some species produce yellow or pink blooms. The leaves are opposite or alternate, pinnate or trifoliate, and the plant produces small, black berries as fruits. It is cultivated extensively in countries like India, Egypt, China, and Morocco. The flowers are harvested early in the morning when their fragrance is most potent, as the volatile compounds responsible for the aroma are at their peak concentration during this time.

2.1.1 Chemical composition

Jasmine flowers are rich in various bioactive compounds, including volatile organic compounds (VOCs), flavonoids, phenolic acids, and terpenoids. These compounds contribute to the flower’s fragrance, therapeutic properties, and antioxidant activity. The primary aromatic compounds in jasmine flowers are responsible for their distinct fragrance. Benzyl acetate, a major component of jasmine essential oil, gives it a sweet, floral aroma. Linalool, a monoterpene alcohol with a floral scent, is known for its calming and anti-anxiety properties. Jasmine, a sesquiterpene, adds depth to the floral fragrance, while benzyl alcohol, an aromatic alcohol, imparts a mild, sweet scent. Indole, a nitrogen-containing compound, plays a crucial role in the floral aroma, particularly in *Jasminum grandiflorum*.

The composition of these volatile compounds varies depending on the species, growing conditions, and extraction methods. For instance, *Jasminum grandiflorum* typically has higher levels of benzyl acetate and linalool, whereas *Jasminum sambac* is richer in benzyl alcohol and indole (Choudhury et al., 2008). Flavonoids, a class of polyphenolic compounds found in jasmine flowers, are known for their antioxidant and anti-inflammatory properties. The major flavonoids include quercetin, a potent antioxidant that protects cells from oxidative stress; kaempferol, which has anti-inflammatory and anticancer properties; and apigenin, known for its calming effects and traditional use as a sedative (Wang et al., 2014).

Phenolic acids are another group of bioactive compounds in jasmine flowers that enhance their antioxidant capacity. These include caffeic acid, recognized for its antioxidant and anti-inflammatory effects; chlorogenic acid, which exhibits antimicrobial and antiviral properties and ferulic acid, known for its protective effects against UV radiation and oxidative stress. Due to these properties, jasmine extracts are widely used in cosmetic and pharmaceutical applications (Li et al., 2019).

Terpenoids, a diverse group of compounds, contribute to the fragrance and therapeutic properties of jasmine. The major terpenoids found in jasmine include linalool, which has a floral scent and calming effects; geraniol, a monoterpene alcohol with a rose-like aroma that is commonly used in perfumery and aromatherapy; and farnesol, a sesquiterpene alcohol with antimicrobial properties. These terpenoids play a significant role in the complex fragrance profile of jasmine, making it a popular choice in aromatherapy and perfumery (Bakkali et al., 2008).

Yeamsuriyotai et al., (2025) explored the use of *Jasminum officinale* essential oil nanoemulsion (JEN) as an innovative postharvest treatment to delay browning in jasmine (*Jasminum sambac*) petals. JEN, formulated via spontaneous emulsification, effectively reduced browning-related enzyme activities (PAL, PPO, POD) and maintained flower quality by preserving cell integrity, freshness, and color during storage. Results suggest JEN is a promising solution for preventing enzymatic browning and extending the shelf life of jasmine flowers.

2.2 Traditional Uses and Health Benefits

Jasmine has been used in traditional medicine for centuries, particularly in Ayurveda and Chinese medicine, for its calming, antidepressant, and aphrodisiac effects. Modern research has validated many of these traditional uses, demonstrating JEO's potential in treating anxiety, depression, and skin disorders. Additionally, jasmine tea, a popular beverage, is known for its soothing and antioxidant properties.

3. CONVENTIONAL EXTRACTION METHODS

3.1 Steam Distillation (SD)

Steam distillation (SD) is one of the most traditional and widely used methods for extracting essential oils from jasmine flowers. In this process, steam is passed through the plant material, causing the volatile compounds to evaporate. The steam and volatile oils are then condensed and collected, with the essential oil separating from the water due to differences in density. SD is particularly suitable for jasmine due to its high content of heat-sensitive aromatic compounds, such as benzyl acetate, linalool, and indole, which are responsible for the flower's characteristic fragrance. However, the method has limitations, including long extraction times, high energy consumption, and the potential degradation of heat-sensitive compounds, which can affect the quality and yield of the extracted oil. Despite these drawbacks, SD remains a popular choice for jasmine essential oil extraction due to its simplicity and cost-effectiveness, especially in small-scale operations (Choudhury et al., 2008; Danh et al., 2013).

3.2 Solvent Extraction (SE)

Solvent extraction (SE) is a widely used method for obtaining jasmine essential oil, particularly for delicate flowers like jasmine that contain heat-sensitive aromatic compounds. In this process, the flowers are soaked in a solvent, such as hexane or ethanol, which dissolves the essential oils and other lipophilic compounds. The solvent is then evaporated under reduced pressure, leaving behind a concentrated extract known as concrete. Further processing with alcohol can yield an absolute, which is a highly concentrated and pure form of the essential oil. Solvent extraction is advantageous for its ability to capture a broader range of compounds, including non-volatile components, which contribute to the oil's complexity and fragrance. However, the method has drawbacks, such as the potential presence of toxic solvent residues, which can limit its use in food and pharmaceutical applications. Additionally, SE is more time-consuming and expensive compared to steam distillation, making it less suitable for large-scale production (El Asbahani et al., 2015; Ferhat et al., 2007).

3.3 Cold Pressing

Cold pressing of jasmine flowers is a rare and delicate extraction method primarily used for obtaining essential oils. Unlike steam distillation or solvent extraction, cold pressing involves mechanically pressing the flowers at low temperatures to extract aromatic compounds without using heat or chemicals. This method helps preserve the delicate floral notes and bioactive compounds of jasmine, maintaining its purity and therapeutic properties. However, due to the low oil yield from jasmine flowers, cold pressing is not widely used compared to enfleurage or solvent extraction (Baser & Buchbauer, 2015). The process is more common in citrus oils but has been explored for jasmine in niche perfumery and artisanal applications due to its potential for yielding a more natural and unaltered fragrance profile (Lawrence, 2007).

4. INNOVATIVE EXTRACTION TECHNOLOGIES

4.1 Supercritical Fluid Extraction (SFE)

Supercritical fluid extraction (SFE) is an advanced technique used for extracting bioactive compounds from various plant materials. It operates by manipulating temperature and pressure to maintain a substance in its supercritical state, enabling efficient extraction (Fig. 1). This method is particularly valuable in medicinal and nutritional applications. Carbon dioxide (CO_2) is the most commonly used supercritical fluid due to its favourable physical properties, requiring relatively low pressure (7.38 MPa) and temperature (304 K) for operation. Studies indicate that SFE yields are generally higher than those obtained through hydro-distillation and steam distillation. However, a major drawback of this technique is the high equipment cost which limits its widespread industrial use. Despite this, SFE has demonstrated superior efficiency in extracting essential oils and bioactive compounds from various sources, including apricot, myrtle, palm, *Juniperus* species, soybeans, rosemary, sunflower, jojoba, sesame, celery, parsley, almond, and pistachio (Rassem *et al*., 2019).

The supercritical CO_2 extraction of oil from Jasmine bloom had been studied. The two SFE parameters, namely pressure and temperature were optimized using RSM. The pressure had a close impact on the extracted oil yield while temperature moderately affected the oil. The optimum oil yield of 12.18 % mg oil extracted/100 g dry flower was acquired using 325 K and 200 bar of temperature and pressure, respectively (Table 1). A total number of six chemical compounds were tentatively identified in the Jasmine flower extracted oil at the optimal SFE conditions. Thus, Jasmine bloom is endowed with the appreciable quantity of oil using SFE (Rassem *et al*., 2019).

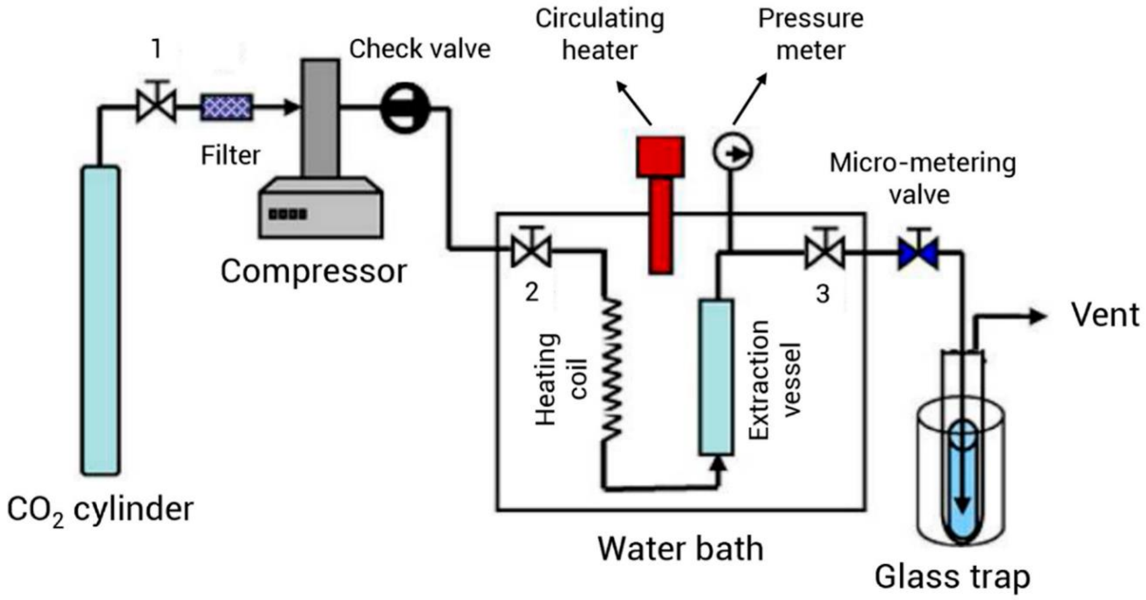

Fig. 1. A schematic diagram of the supercritical CO_2 extraction technique (Danh et al., 2013)

Table 1. The yield of Jasmine oil (mg oil extracted/100 g dry flower) (Rassem *et al*., 2019)

Run	Pressure (bar)	Temperature (K)	Observed Yield (%)
1	100	300	8.1
2	100	350	3.8
3	100	325	8.8
4	200	325	12.18
5	200	300	11.32
6	200	350	9.1
7	300	300	9.8
8	300	325	7.9
9	300	350	6.7

4.2 Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction uses electromagnetic waves to heat the plant material, leading to rapid and efficient extraction. MAE has been shown to reduce extraction time and energy consumption while increasing yield.

The phase-power control microwave hydro-diffusion and gravity (PC-MHG) system was designed and fabricated at the Plasma Technology for Agricultural Application Laboratory, School of Science, Walailak University, Nakhon-sri-thammarat, Thailand, as shown in Fig. 2. The heating chamber comprised a 30 × 30 × 40 cm^3 aluminum chamber with ventilating fans and a microwave leakage-suppression door. The microwave generator, a magnetron, is connected to a waveguide (5 × 10 × 12 cm^3) in which microwave energy is transferred to the heating chamber. The electrical current passes through a phase-power control unit, resulting in continuous and adjustable microwave power from 0 to about 520 W (Sommano et al., 2015).

Studies conducted by Sommano et al (2015) shows jasmine flower treated with a phase-power control microwave hydro-diffusion and gravity (PC-MHG) system utilizes the advantage of green microwave technology, can reduce the processing time and consume less energy, which is environmentally friendly. A substantial yield of jasmine volatile oil was achieved within 6 minutes using PCMHG, whereas SSDE required approximately 5 hours to obtain the volatile oil. Moreover, the chemical constituents of the oils extracted by both techniques were similar. These improved system benefits make MHG a good alternative for the extraction of floral essential oil. This work will be fruitful in the future development of large-scale industrial prototype

MAE systems. Similar study conducted by Liu et al. (2018) for lavender essential oil extraction shows optimized MAE, achieving a yield of 3.19% in just 40 minutes, compared to 120 minutes for conventional hydro-distillation.

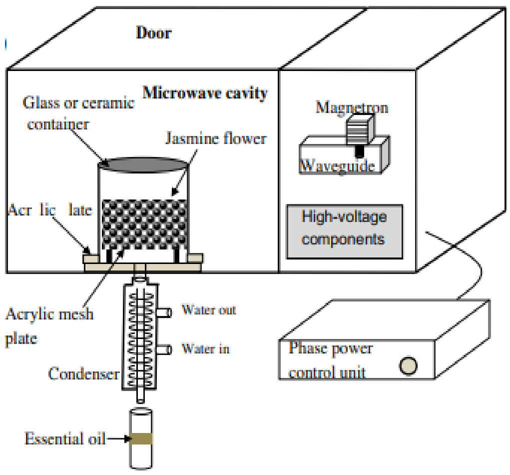

Fig. 2. Schematic diagram of phase-power control microwave hydro-diffusion and gravity (PC-MHG) system (Sommano et al 2015)

4.3 Ultrasound-Assisted Extraction (UAE)

Ultrasound-assisted extraction uses high-frequency sound waves to disrupt plant cell walls, facilitating the release of essential oils. UAE has been shown to improve extraction yield and reduce processing time. The study conducted by Abera et al., (2024) focussed on the optimization and evaluation of phenolic and flavonoid compounds in Jasmine leaf extract using microwave and ultrasonication-assisted extraction methods. Bioactive compounds, including phenolic and flavonoid compounds, were extracted by evaluating various process parameters. The optimized leaf extract was assessed based on solute-to-solvent ratio, microwave power, extraction time, and frequency. The optimized results from microwave-assisted extraction yielded a total phenolic content of 180.05 mg/g and a total flavonoid content of 60.5 mg/g in the extract. In contrast, the ultrasonication-assisted extraction achieved a higher yield, with a total phenolic content of 210.8 mg/g and a total flavonoid content of 90.4 mg/g in the extract. The extract contained significant amounts of gallic acid (13.49%), rutin (37.37%), and octadecenoic acid (23.98%). Additionally, esters, aromatic compound derivatives, and unsaturated fatty acids were highlighted in the extract owing to their potential antioxidant and antimicrobial applications. The antioxidant activity of Jasmine leaf extract was evaluated using both extraction methods with the ultrasonication-assisted extract showing significantly higher effectiveness.

Similar results conducted by Lilia et al. (2018) demonstrated that ultrasound pretreatment increased the yield of lavender essential oil by 36% compared to conventional methods. UAE can also enhance the antioxidant activity of the extracted oil, making it suitable for cosmetic and pharmaceutical applications.

4.4 Subcritical Water Extraction (SWE)

Subcritical water extraction (SWE) is an innovative and eco-friendly technique for extracting lipophilic compounds, including essential oils (EOs), from plant materials using water in its subcritical state. (Fig. 3). This state is achieved at temperatures ranging from 100 to 374.15 °C and pressures below 22.1 MPa (Basak et al., 2023). SWE is recognized as a sustainable extraction method, as it eliminates the need for organic solvents and prevents the generation of toxic waste. In its subcritical state, water undergoes significant changes in physical properties due to the weakening of intermolecular hydrogen bonds. This results in reduced viscosity, increased diffusivity, and a dielectric constant similar to common organic solvents like methanol, ethanol, acetonitrile, acetone, and dimethyl sulfoxide (Song et al., 2022) Additionally, the polarity of water decreases under subcritical conditions, enhancing the solubility of EOs and their components. Compared to traditional organic solvents, subcritical water offers several advantages, including higher extraction efficiency, improved extract quality, shorter extraction times, and greater safety due to its non-flammable, non-toxic, and readily available nature (Díaz-Reinoso et al., 2023). As a result, subcritical water serves as an environmentally friendly alternative to organic solvents for extracting essential oils, such as jasmine oil (Giray et al., 2008).

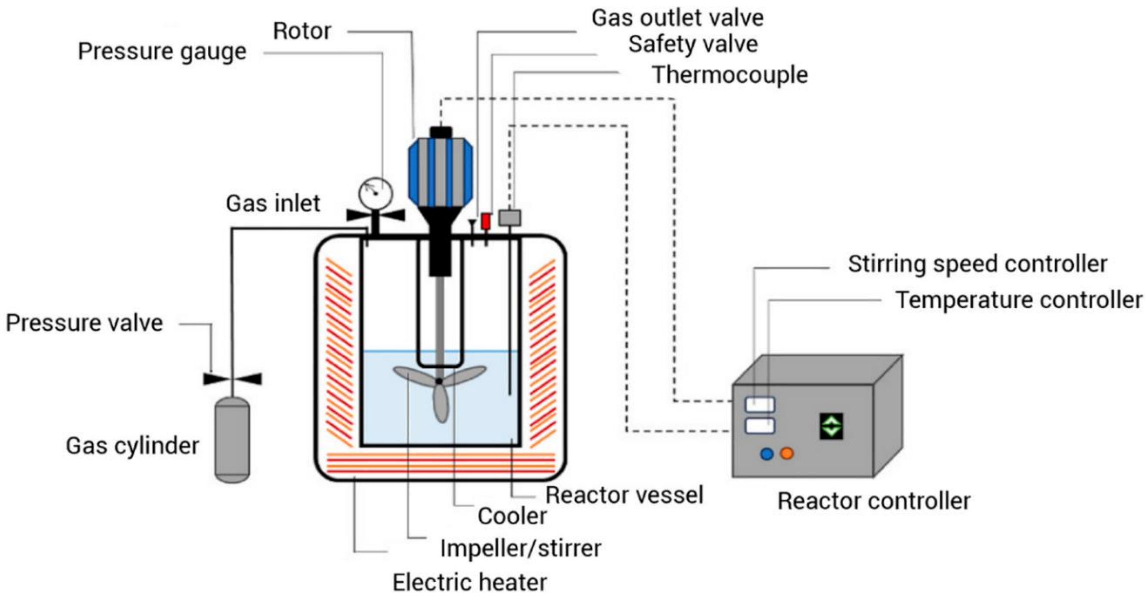

Fig. 3. A schematic diagram of the subcritical water extraction system. (Díaz-Reinoso et al., 2023)

4.5 Pulsed Electric Field (PEF) and Cold Plasma Extraction

Pulsed electric field and cold plasma are emerging technologies that can enhance the extraction of essential oils by disrupting cell membranes. Pulsed electric field (PEF) is an advanced technology that utilizes short, high-intensity electric pulses, typically lasting milliseconds to microseconds, to enhance extraction processes (Niu et al., 2020). The PEF system consists of a treatment chamber, a high-voltage DC power supply, an energy storage capacitor, and a spark gap switch. The high-voltage source charges the capacitors until the spark gap triggers a breakdown, delivering a rapid voltage surge (shock) to the treatment chamber where the sample is placed (Nio et al., 2020: Raso et al., 2022) PEF is particularly effective as a pretreatment method for improving the extraction of bioactive compounds from plant materials. It works by inducing electroporation, which disrupts biological membranes and breaks down plant cell structures. This process facilitates the release of essential oils (EOs) and significantly enhances the extraction efficiency (Raso et al., 2022). As a result, PEF is a promising technique for optimizing the extraction of valuable compounds from plant sources (Redondo et al., 2018). Hadri et al., (2023) investigated the impact of PEF pretreatment in lavender oil extraction, finding that it significantly enhanced yield and efficiency. Under optimal conditions (1 kV/cm, 100 pulses, 60 min), lavender oil yield increased to 4.0% with PEF pretreatment compared to 2.95% without, while reducing energy consumption by approximately 50%.

Plasma is the fourth state of matter that exists naturally in the universe (e.g., the polar aurora) but can be produced artificially by electrical discharges in a gas. Plasma is composed of reactive oxygen species, reactive nitrogen species, ultraviolet (UV) radiation, free radicals, and charged particles. It is an ionized gas that can be classified into thermal plasma (TP) and cold plasma (CP). In TP, all species exist in a thermodynamic equilibrium, while in the CP, the electrons and heavier species are in thermal non-equilibrium (Pankaj et al ., 2018). Based on the pressure conditions, plasma can be categorized into atmospheric pressure, high-pressure, and low-pressure plasma. Plasma can be generated from gases such as oxygen, ozone, nitrogen using different sources of energy including thermal, electrical, optical, electromagnetic, and gamma radiation (Heydari et al., 2023). Plasma jet and dielectric barrier discharge (DBD) are the most widely used plasma-generating devices (Fig. 4). The plasma jet system comprises two concentric electrodes, where the inner electrode is connected to a radio frequency power, ionizing the working gas that exits the nozzle, giving it a “jet-like” appearance. In contrast, DBD consists of two metal electrodes, at least one of which is covered with

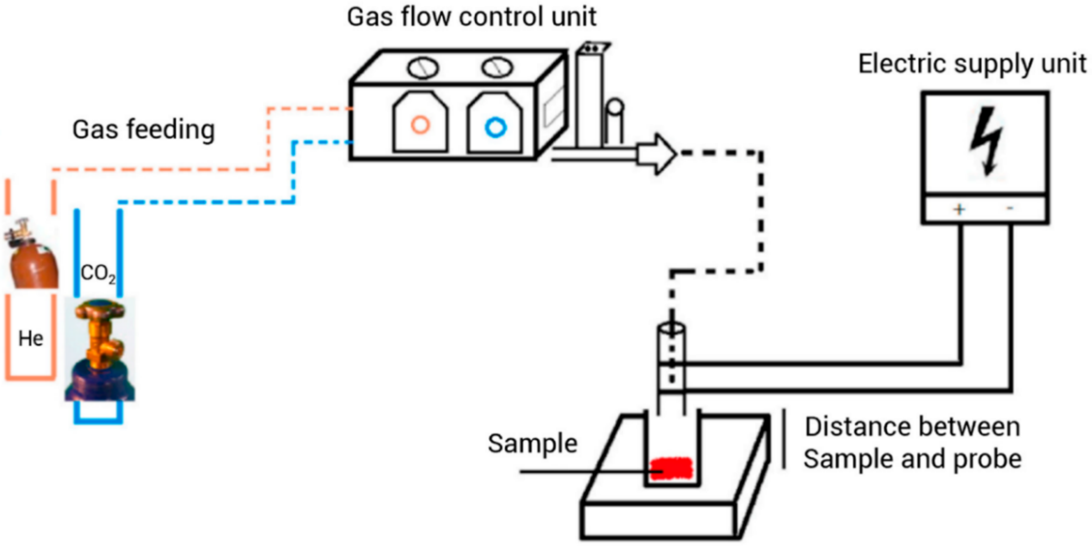

Fig. 4. A schematic diagram of the dielectric barrier discharge (DBD) plasma system (Ucar et al., 2021)

a dielectric barrier. The dielectric barrier acts as a stabilizing material that prevents any arc transfer, and helps create a large number of micro-discharges for homogeneous treatments. When a material is exposed to plasma treatments, the reactive species can modify its surface by the formation of hydrophilic groups or oxidation (Molina et al., 2024). These modifications are limited to the surface of the plasma-treated material and do not affect their internal properties. Also, small cracks and fissures may appear in the epidermal cell structure. The formation cracks and hydrophilic groups improve the EO extraction from aromatic plants (Jadhav et al., 2021; Surowsky et al., 2015).

5. CHALLENGES AND FUTURE PROSPECTS

While innovative extraction technologies offer significant advantages, several challenges remain. The high initial cost of equipment and the need for optimization of extraction parameters are major barriers to industrial adoption. Additionally, the scalability of these methods needs to be thoroughly investigated. Future research should focus on the techno-economic analysis of these technologies and their environmental impact compared to conventional methods.

6. CONCLUSION

Innovative extraction technologies, such as SFE, MAE, UAE, and SWE, offer promising alternatives to traditional methods for jasmine flower processing. These methods not only improve yield and product quality but also reduce energy consumption and environmental impact. As the demand for natural and sustainable products continues to grow, the adoption of these technologies in the jasmine industry is expected to increase. However, further research is needed to address the challenges of scalability and cost-effectiveness.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author hereby declare that no generative AI technologies such as ChatGPT, COPILOT, etc were used in the preparation of manuscript Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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