2026 Volume: 02 Issue: 06 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-16

EUCLAYPTUS OIL CANDLE INHALATION FOR DECONGESTANT EFFECT DURING COMMON COLD

Syeda Humaira[1], Swati Rathore*[1], N.S. Lodhi[1], Neelima Goswami[1], R.B. Goswami[1]

[1]Sagar Institute of Research Technology & Science-Pharmacy, Bhopal, Madhya Pradesh, India.

Article Received: 13 May 2026
Article Revised: 03 June 2026
Published on: 23 June 2026

***Corresponding Author: Swati Rathore**
Sagar Institute of Research Technology & Science-Pharmacy, Bhopal, Madhya Pradesh, India.
DOI: https://doi-doi.org/101555/ijrpa.1625

ABSTRACT

This work reports the utilization of solar thermal energy to generate Eucalyptus essential oil, reducing the dependence on conventional energy and minimizing the environmental impact. The study optimized oil extraction by traditional steam distillation using response surface methodology and applied the results to a Schaffer Concentra to driven solar steam distillation setup. The optimum factors included leaf size (0.02 m), extraction temperature (97.76 °C), solid/solvent ratio (0.61), and extraction time (206 min), with temperature being crucial. The major oil components were 1-8 cineole (57.53-78.45%) and α-Pentene (15.27-27.83%). The outdoor experiments achieved an efficiency of 27% and produced 2 kg/h steam at an average solar insulation of 700 W/m2. Despite consistent processing temperatures favoring conventional steam distillation, the solar extraction process offers an eco-friendly alternative. In line with the sustainable development goals, this initiative is well-suited for sunny regions and small businesses targeting niche markets.

KEYWORDS: Eucalyptus essential oil, Steam distillation, Schaffer concentrator, Response surface methodology.

I. INTRODUCTION

In contrast to solar thermal energy, which provides a more environmentally friendly alternative, production of essential oil in aromatherapy and medicine historically and conventionally relies on conventional energy sources. The usual methods for extracting volatile oils from aromatic plants use processes, including solvent extraction, solvent distillation, cold pressing, and maceration, each best suited for specific plants and results. The concentrated extracts are widely used in various industries and are considered of great importance as export products for most developing countries. In recent times, there has been an increasing demand for sustainable industrial processes involving renewable energy sources. The conventional methodologies, which primarily need fossil energy for their operation, pose a significantly negative environmental impact. The present study aims to address the challenge of reducing dependency on fossil energy by utilizing solar thermal energy in a decentralized manner to extract essential oil from the leaves of the plant. Now, according to the WHO, 21,000 plant species have therapeutic potential. These plants contribute to fragrances, lotions, and skincare products in the cosmetics industry by providing aromatic and medicinal properties. Essential oils are widely used in aromatherapy for their aromatic and healing properties. Eucalyptus oil has long been revered in traditional medicine and aromatherapy for its remarkable healing and therapeutic properties. Extracted from the leaves of the Eucalyptus globules tree, commonly known as the blue gum tree, this essential oil is rich in compounds such as eucalyptol (cineole), which exhibit strong antibacterial, antiviral, anti-inflammatory, and decongestant actions. In recent years, the use of eucalyptus oil has expanded beyond medicinal applications into wellness and lifestyle products such as candles, balms, diffusers, and inhalants. Among these, eucalyptus oil-infused candles have gained considerable popularity for their natural ability to relieve cold, cough, and nasal congestion while also creating a calming and refreshing atmosphere. The concept of aromatherapy has evolved as an alternative healing practice that utilizes the aromatic properties of essential oils to promote physical and mental well-being. Eucalyptus oil plays a central role in this discipline due to its distinctive camphor us scent and its scientifically proven effects on the respiratory system. When inhaled through vapor, the active compounds in eucalyptus oil act as natural decongestants that help clear nasal passages, ease breathing difficulties, and reduce symptoms of sinusitis, bronchitis, and common colds. The gentle diffusion of eucalyptus aroma through a burning candle provides an effortless and continuous method of inhalation therapy, offering both therapeutic benefits and a pleasant sensory experience. The eucalyptus oil candle is a simple yet effective innovation designed to merge the curative essence of essential oils with the calming aesthetics of candlelight. Unlike synthetic candles that rely on artificial fragrances, eucalyptus candles use natural waxes such as soy or beeswax blended with pure eucalyptus essential oil. When lit, the candle releases microscopic aromatic molecules into the air, which are inhaled and absorbed through the respiratory tract, providing relief from congestion, sore throat, and blocked sinuses. The warmth generated from the candle flame also aids in dispersing the aroma more effectively throughout the space, ensuring uniform inhalation and relaxation. From a scientific perspective, the inhalation of eucalyptus vapor stimulates the olfactory system, which is directly linked to the brain's limbic system the center responsible for emotions, memory, and behavior. This explains why eucalyptus oil not only helps alleviate physical discomfort but also enhances mood, reduces stress, and promotes mental clarity. Its crisp, cooling fragrance refreshes the senses and combats fatigue, making eucalyptus candles especially beneficial during seasonal changes or in times of illness when the body feels weak and congested. Historically, eucalyptus oil was first used by Australian Aboriginal communities for treating wounds, infections, and respiratory ailments. Over time, it became a widely accepted natural remedy across the world for relieving cold symptoms and purifying indoor air. Today, with growing interest in eco-friendly and holistic wellness products, eucalyptus oil candles have become a sustainable and therapeutic alternative to chemical-based air fresheners and vaporizers. They not only serve as natural air purifiers but also add an aesthetic and aromatic touch to modern living spaces. In addition to respiratory relief, the use of eucalyptus oil candles also contributes to overall wellness. The oil's antimicrobial properties help disinfect the air by reducing airborne bacteria and allergens, which can be particularly beneficial during the winter season when colds and flu are prevalent. The mild warmth and light from the candle create a cozy environment that encourages relaxation, meditation, and improved sleep quality. Combining eucalyptus with 2 complementary essential oils such as peppermint, rosemary, or lavender further enhances its therapeutic potential, resulting in candles that soothe the body and mind simultaneously. In conclusion, the eucalyptus oil candle represents a harmonious blend of natural science and holistic health. Its ability to relieve cold and congestion while providing emotional balance exemplifies the growing shift toward natural, plant-based wellness solutions. As people increasingly seek ways to maintain respiratory health and reduce stress in daily life, eucalyptus candles offer a simple, safe, and aromatic remedy that bridges the gap between traditional healing and modern aromatherapy. This natural innovation continues to illuminate homes and heal bodies, proving that sometimes, the smallest flame can offer the greatest comfort.

II. MATERIALS AND METHODS

The conventional electric-powered steam distillation system comprised an electric boiler, extraction column, condenser, and oil-water separator. The photograph and schematic diagram of the unit are shown in Fig. 1a, b. The electric boiler had a power rating of 2000 W and was used to heat 40 L of water. It served as the source of steam for the distillation process. The extractor column could store 5 kg of raw material and 25 l of water. It was made from food grade stainless steel with an opening of 0.012 m for drainage. A 0.003 m nozzle was installed inside the extractor for sparing. At the bottom of the extractor, column was a 0.005 m perforated stainless steel wire mesh to hold the raw material during the steam distillation process. The separator was a glass tube with a capacity of 100 ml. It was used to separate the extracted oil from the condensate water. The condenser was a shell and tube type made from stainless steel. It was used to condense the steam vapor back into liquid form during the distillation process. The condenser was sealed to prevent any leaks using gaskets and silicone sealants. Solar steam distillation system The solar steam distillation system consisted of a solar baby boiler with a capacity of 4 L. It was designed to collect solar energy efficiently and then used to generate steam for the distillation process. The Schaffer concentrator was mounted on a two-axis tracking system that allowed it to follow the sun's movement throughout the day. This tracking system ensured the concentrator remained oriented towards the sun, maximizing the sun- light it captured. As the concentrator tracked the sun, it reflected and concentrated sunlight onto the solar boiler, which was placed at the focal point. The Schaffer concentrator had an aperture area of 2.5 m2. The solar steam distillation system was integrated with the distillation assembly, as in to extract the oil. The photograph and schematic diagram of the integrated system are shown in Experimental procedure Fresh leaves Eucalyptus leaves (E. hybrid) were collected from Ambaji (24° 33 N, 72°0.850 E') in the northern part of Gujarat, a state in western India. Eucalyptus hybrid (E. hybrid) was introduced in Gujarat, India in 1961. This tree species is known for its rapid growth, which allows it to overtop and out compete weeds, ensuring its dominance in various environments. It can Renfrew from its stump after being cut, which makes it sustainable for repeated harvesting. The species can thrive in a wide range of soil and climatic conditions, making it a versatile option for various regions. These characteristics make E. hybrid a valuable tree for a forestation, land rehabilitation, and sustainable forestry practices. In addition, the species contains significant amounts of 1–8 cineole or eucalyptol, which is highly valued for its medicinal and antimicrobial properties, making the oil ideal for pharmaceutical, cosmetic, and the rape tic applications. In addition, it contains α-Pinene, a compound known for its anti-inflammatory and bronchodilator effects, enhancing the oil's utility in respiratory treatments. The output oil quantity through conventional steam distillation ensures that the extraction processes economically viable and can reliably meet industrial standards. The species is well-adapted to various climates, facilitating extensive cultivation. Using solar thermal energy for the extraction process further aligns with sustainable practices, reducing the carbon footprint compared to conventional methods. From other species of Eucalyptus, e.g., E. camaldulensis and E. citriodora leaves essential oil yields of 0.61% and 1.16% were obtained using a solar distillation system. In addition, 16.2% of 1, 8- cineole and 15.6% of α-Pinene were identified in E. camaldulensis In Eucalyptus camaldulensis leaves, 1,8-cineole (eucalyptol) was found to be 50.9% The leaves were thoroughly washed with water, and Diagram of conventional electric-powered steam distillation system the cleaned leaves were then kept at room temperature for 2–3 h, partially air drying them before further processing. The leaves were then sorted according to their size, this ensured uniformity and consistency in the experimental setup, as leaves of different sizes have varying characteristics that could affect the results. The organized leaves of the same size were then used for the experiments.

Experiments with conventional electric-powered steam distillation system

According to the run-sheet of RSM, Eucalyptus leaves were prepared for the 27 runs. The independent variables (input parameters) were selected as implemented by other researchers as well as trial runs were performed to decide the range of independent variables for better outcomes. The ranges of input parameters were Leaf Size: Ranging from 0.02 to 0.05 m.

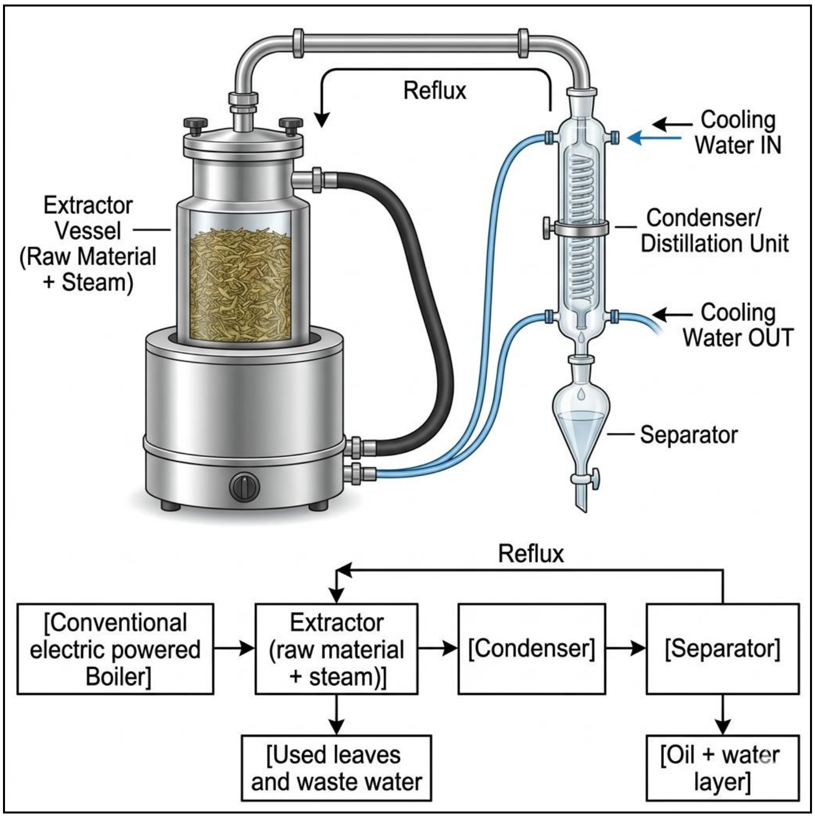

Fig1. A. Conventional electric-powered steam distillation system.

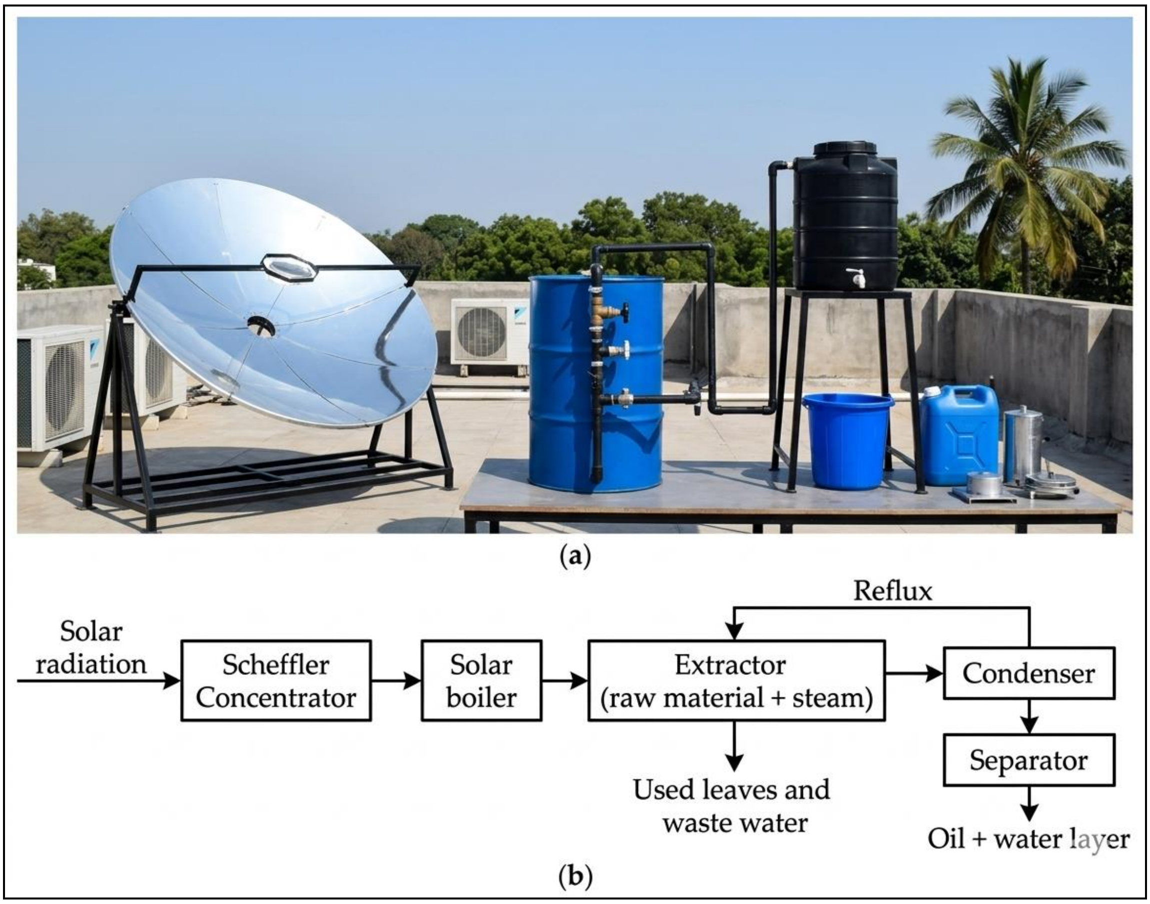

Fig.2 (a) Solar steam distillation system. (b) Schematic diagram of solar steam distillation

Extraction Temperature: Ranging from 92 °C to 98 °C. Solid/Solvent Ratio: Ranging from 0.4545 to 0.6250. Extraction Time: Ranging from 150 to 210 min. The selected range for leaf size ensured an optimal balance between exposing enough surface area and maintaining ease of handling. The temperature range of 92-98 °C was chosen with the aim to maximize the efficiency of steam generation and oil extraction without degrading heat-sensitive components of the essential oil. Temperatures below 92 °C might not produce sufficient steam for effective distillation, while temperatures above 98 °C risk degrading valuable oil constituents. The solid/ solvent ratio of 0.4545-0.6250 ratio reflected the quantity of leaves in relation to the water used in the extraction process. A lower ratio might have resulted in insufficient steam for efficient extraction, while a higher ratio could have led to saturation, reducing extraction efficiency. The range for an extraction time of 150-210 min was to ensure thorough oil extraction. Shorter times might not have allowed for complete extraction, while excessively long times might have led to unnecessary energy use. For each experimental run, 2.5 kg of Eucalyptus leaves was used. The leaves were kept on the wire mesh installed at the bottom of the extractor. To reach the extraction temperature range, the steam from the boiler was introduced to the extractor through a sparer the sparer ensured equal steam distribution on leaves throughout the experimental run.

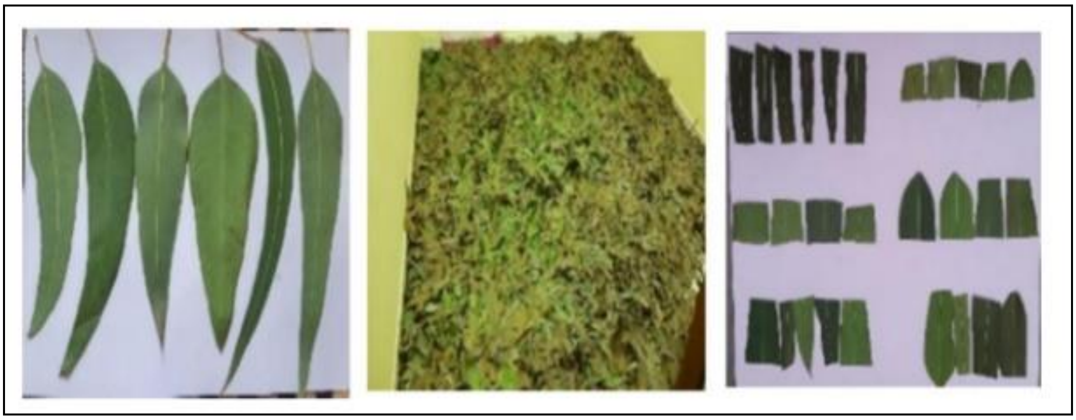

Fig. 3 Eucalyptus leaves with normal and different sizes.

Electric powered conventional steam distillation system to keep it within the intended temperature range of 92-98 °C. Throughout the experimental runs, temperature sensors and control systems were used to monitor and modify the heaters to reach and maintain the desired temperature. The first drop of oil was collected after an hour, 7 and the quantity of the collected oil was recorded at regular intervals. The water vapors and the volatile essence of the leaves flowed through the extractor and were then condensed. Oil samples were separated from the water layer in the separator based on their density. The separated oil samples were filtered and dried for 12 h using anhydrous sodium sulphate (Na2SO4). The dried samples were stored in are frigate at 4 °C. The characteristics of the oil samples were determined through qualitative analysis by gas chromatography mass spectrometry (GC-MS). A similar procedure was followed for all 27 runs. The rated power of the electric boiler was 2000 W. The total run time for each run was observed and found to be 3.5 h. These experiments aimed to optimize the conventional electric-powered steam distillation process and identify the best combination of input parameters that lead to a higher oil yield from the Eucalyptus leaves.

Formulation and Ingredients used for candle preparation

A typical cold-relief aromatherapy candle is formulated with the following components:

1**. Wax Base**

- Soy wax or beeswax is preferred due to its clean burning nature and ability to

Hold essential oils effectively.

2. **Essential Oils**

- Eucalyptus Oil: Acts as an excellent decongestant and antiseptic, helping clear nasal passages.
- Peppermint Oil: Contains menthol, which provides a cooling and soothing effect on the respiratory tract.
- Camphor Oil: Helps relieve chest congestion and acts as a mild expectorant.
- Tea Tree Oil: Possesses antimicrobial and antiviral properties, preventing secondary infections.

3. **Wick**

- Cotton wick ensures even burning and minimal soot production.

4. **Additives (Optional)**

- Natural colorants or dried herbs like rosemary and thyme may be added for enhanced aesthetic and therapeutic appeal.

Preparation Method

- Melt the wax base using a double boiler until it reaches around 70-75°C.
- Once melted, remove from heat and allow the temperature to drop to about 60°C.
- Add measured essential oils (around 6-8% of total wax weight) and mix thoroughly.
- Pour the mixture into a pre-set container with a centered wick.
- Allow it to cool and solidify for 24-48 hours.

Mechanism of Action

When the candle is lit, the heat gently vaporizes the essential oils, dispersing their aromatic molecules into the air. Inhalation of these vapors helps:

- Open blocked nasal passages by loosening mucus.
- Reduce inflammation in respiratory pathways.
- Kill airborne pathogens due to antimicrobial properties.
- Soothe the nervous system, promoting relaxation and better sleep during illness.

Benefits

- Provides natural and non-invasive relief from cold, cough, and sinus congestion.
- Improves air quality and offers a pleasant aroma.
- Reduces dependence on synthetic vapor rubs or nasal sprays.
- Supports respiratory comfort and enhances mood simultaneously.

III. Evaluation Tests of Eucalyptus Oil Candle

A. Physical Evaluation

The prepared eucalyptus oil candle was physically evaluated to assess its overall appearance and quality. The candle was observed for parameters such as color, surface smoothness, presence of cracks, and uniformity. A good quality candle should possess a smooth surface with uniform color distribution and should not show any air bubbles, cracks, or uneven texture. Proper physical appearance indicates successful formulation and appropriate mixing of ingredients.

B. Odor Evaluation

Odor evaluation was carried out by smelling the candle before and after burning. The presence of a strong and pleasant eucalyptus aroma indicates proper incorporation and retention of eucalyptus oil within the wax base. A refreshing and soothing aroma is preferred because it contributes to the aromatherapy effect and enhances the user's comfort during cold and congestion conditions.

C. Burning Time Test

The burning characteristics of the candle were evaluated by measuring its total burning time. Initially, the candle was weighed and then ignited. The total duration for complete burning was recorded using a stopwatch. A slow, steady, and uniform burning pattern is considered ideal for aromatherapy candles because it ensures gradual release of eucalyptus vapors and prolonged therapeutic effect.

D. Melting Point Test

The melting point of the candle wax was determined using the capillary tube method. A small quantity of wax was filled into a capillary tube and heated slowly while observing the temperature at which melting began. Aromatherapy candles generally show a melting point in the range of 50-65°C. Appropriate melting temperature ensures proper burning behavior and controlled release of essential oil vapors.

E. Smoke Test

The smoke produced during candle burning was carefully observed. Excessive smoke formation indicates incomplete combustion or improper formulation of the candle. An ideal eucalyptus oil candle should produce minimal smoke during burning, ensuring safer indoor use and better air quality.

F. Aroma Diffusion Test

The aroma diffusion property of the candle was tested by burning it in a closed room and recording the time required for the eucalyptus fragrance to spread throughout the room. An effective aromatherapy candle should diffuse its aroma within approximately 3–5 minutes. Good aroma diffusion indicates efficient vaporization of eucalyptus oil and satisfactory aromatherapy performance.

G. Congestion Relief Sensory Test

A simple human volunteer study was conducted to evaluate the perceived congestion relief effect of the candle. Approximately 5-10 volunteers with mild cold or nasal congestion were selected. The candle was burned in a room for about 10-15 minutes, after which volunteers were asked to rate the level of relief experienced.

The relief was assessed using the following scale:

Score	Relief Level
0	No relief
1	Mild relief
2	Moderate relief
3	Excellent relief

Studies on eucalyptus inhalation products suggest that eucalyptus vapors may improve breathing comfort and provide a sensation of nasal clearance during congestion.

Stability Study

The stability of the eucalyptus oil candle was evaluated by storing the candle under room temperature and warm conditions for a period of 15–30 days. During storage, the candle was observed for changes such as oil leakage, color variation, aroma loss, or cracking. A stable candle formulation should maintain its physical appearance, fragrance, and structural integrity throughout the storage period.

Safety Evaluation

A simple safety evaluation was performed to assess possible irritation caused by exposure to eucalyptus vapors. Skin exposed near the burning candle vapors was observed for redness, itching, or irritation. Although eucalyptus oil is commonly used in aromatherapy, excessive exposure may cause irritation in sensitive individuals. Therefore, careful and moderate use is recommended. Aromatherapy candles are gaining immense popularity as natural remedies for respiratory ailments such as cold, cough, and nasal congestion. These candles are formulated using essential oils that possess decongestant, antiseptic, and soothing properties. The warmth of the candle helps release the therapeutic aroma of essential oils into the air, providing relief from blocked sinuses and promoting relaxation. Among the commonly used oils, Eucalyptus, Peppermint, Camphor, and Tea Tree Oil are highly effective for cold and congestion relief.

IV. RESULTS AND DISCUSSION

The eucalyptus oil candle was successfully formulated using a suitable wax base and eucalyptus essential oil intended to provide a decongestant effect during common cold conditions. The prepared candle exhibited satisfactory physical appearance and demonstrated desirable characteristics for aromatherapy applications. The formulation process resulted in a smooth, uniform candle without visible cracks, air bubbles, or surface irregularities, indicating proper blending of ingredients and successful solidification of the wax matrix.

Physical evaluation showed that the candle possessed a pleasant appearance with uniform color distribution and good structural integrity. The texture remained smooth throughout the surface, suggesting compatibility between the wax base and eucalyptus oil. No phase separation or oil leakage was observed after preparation, confirming effective incorporation of the essential oil into the formulation.

Odor evaluation revealed a strong, refreshing, and characteristic eucalyptus aroma before ignition as well as during burning. The fragrance remained consistent throughout the burning period, indicating good retention of volatile constituents within the candle matrix. The aromatic profile produced a soothing and refreshing sensation, which is considered beneficial for aromatherapy and respiratory comfort.

The burning characteristics of the formulated candle were found to be satisfactory. The candle burned with a stable flame and showed uniform wax consumption without excessive dripping or tunneling. The gradual burning pattern facilitated the continuous release of eucalyptus vapors into the surrounding environment, which is desirable for prolonged aromatherapeutic action. Minimal smoke generation was observed during combustion, suggesting efficient burning behavior and suitability for indoor use.

The melting behavior of the candle was also found to be appropriate. The candle softened and melted uniformly when exposed to heat, allowing controlled volatilization of eucalyptus oil. Proper melting characteristics are important for ensuring sustained fragrance release and maintaining the therapeutic effectiveness of the formulation during use.

The aroma diffusion study demonstrated efficient distribution of eucalyptus fragrance throughout the test area within a short period after ignition. The released vapors dispersed evenly in the room and created a pleasant aromatic environment. Effective diffusion of eucalyptus vapors is essential because inhalation of these vapors is responsible for the desired decongestant effect associated with aromatherapy.

A sensory evaluation was performed to assess the perceived relief from nasal congestion. Volunteers exposed to the burning candle reported noticeable improvement in breathing comfort and a feeling of nasal freshness. Most participants experienced mild to moderate relief from congestion symptoms, while some reported greater comfort and easier breathing after exposure. These observations may be attributed to the presence of eucalyptus oil, which is widely recognized for its aromatic and soothing effects on the respiratory tract.

The stability study indicated that the candle maintained its physical appearance, fragrance, and structural integrity throughout the observation period. No significant changes in color, odor, texture, or shape were detected during storage. Furthermore, no oil seepage, cracking, or deterioration of the formulation was observed, demonstrating good stability of the prepared candle under normal storage conditions.

Safety assessment showed that the candle was generally well tolerated during use. No significant irritation, discomfort, or adverse effects were reported by the volunteers during the evaluation period. The pleasant aroma and clean burning properties contributed to a comfortable user experience. Overall, the developed eucalyptus oil candle demonstrated satisfactory physical quality, good burning characteristics, effective aroma diffusion, acceptable stability, and promising decongestant activity, supporting its potential application as a natural aromatherapy product for providing comfort during common cold and nasal congestion.

V. CONCLUSIONS

The present study successfully formulated and evaluated a eucalyptus oil candle intended for providing decongestant effects during common cold conditions. The prepared candle exhibited desirable physical characteristics, including uniform appearance, smooth texture, pleasant aroma, good structural integrity, and satisfactory burning behavior. The formulation demonstrated efficient retention and release of eucalyptus essential oil, allowing continuous diffusion of aromatic vapors during combustion.

Evaluation studies confirmed that the candle possessed suitable melting properties, minimal smoke production, effective fragrance diffusion, and good storage stability. The aroma generated by the burning candle created a refreshing environment and contributed to respiratory comfort. Sensory evaluation further suggested that inhalation of eucalyptus vapors may help provide relief from nasal congestion and improve breathing comfort in individuals experiencing symptoms associated with common cold.

The stability studies indicated that the formulation remained physically stable without significant changes in appearance, fragrance, or consistency during storage. Safety observations also showed that the candle was well tolerated under normal conditions of use, with no significant adverse effects reported during the study period.

Based on the findings, eucalyptus oil candles can be considered a simple, natural, and user-friendly aromatherapy product for supportive management of cold-related discomfort and nasal congestion. The formulation combines the therapeutic benefits of eucalyptus oil with the convenience of candle-based delivery, offering an attractive alternative to synthetic room fresheners and conventional inhalation products. Further studies involving a larger number of volunteers and extended clinical evaluation may provide additional evidence regarding the effectiveness of eucalyptus oil candles in respiratory wellness and aromatherapy applications.

ACKNOWLEDGMENTS

The authors extend their profound and sincere gratitude to Er. Sanjeev Agrawal (Hon'able Chairman, Sage Group International) and Dr. Prashant Jain (Hon'able Vice-Chairman, SGI) for providing a state-of-the-art research infrastructure and fostering a progressive academic environment. Special professional appreciation is formally expressed to Dr. R. B. Goswami (Director, SIRTS-Pharmacy) and Dr. Neelima Goswami (Professor) for their constant scientific encouragement, expert guidance, and institutional support throughout this formulation study.

Finally, the primary author expresses deep gratitude to research supervisor Dr. Swati Rathore for her expert academic direction, methodical review, and invaluable analytical insights during the execution of this project.

REFERENCES

1. Abdul-Majeed, B. A., Hassan, A. A., & Kurji, B. M. (2013). Extraction of oil from Eucalyptus Camadulensis using water distillation method". Iraqi Journal of Chemical and Petroleum Engineering., 14, 7–12.
2. Afzal, A., Alvarado, J., Munir, J., & Ghafoor, A. (2017). Income generation of rural community by using solar distillation system. Renewable Energy and Power Quality Journal,1(179), 183. https://doi.org/10.2084/repqj15.265
3. Afzal, A., Munir, A., Ghafoor, A & Alvarado J. L. (2017). Development of hybrid sola distillation system for essential oil extraction. Renewable Energy, 113, 22–29. https://doi.org/10.1016/j.renene.2017.05.027
4. Ait Nouth, F. Saidi, S. Janah, Y. Mandi, L. & Kettab, A. (2017). Experimental study of a distillation unit by the use of a Sheffler solar Parabola. Algerian Journal of Environmental Science and Technology., 3, 342–346
5. Anand, U. Jacobo Herrera, N., Altemimi, A., & Lakhssassi, N. (2019). A comprehensive review on medicinal plants as antimicrobial therapeutics: potential avenues of biocompatible drug discovery. Metabolites, 9, 258. https://doi.org/10.3390/metabo9110258
6. Andharia, J. K., Bhattacharya, P., & Maiti, S. (2020). Development and performance analysis of a mixed mode solar thermal dryer for drying of natural rubber sheets in the north-eastern part of India. Solar Energy, 208, 1091–1102. https://doi.org/10.1016/j.solener.2020.08.051
7. Boukhatem, M. N., Ferhat, M. A., Kameli, A., Saidi, F., Walid, K., & Mohamed, S. B. (2014). Quality assessment of the essential oil from Eucalyptus globules Labill of Blida (Algeria) origin. International Letters of Chemistry Physics and Astronomy, 36, 303–315. https://doi.org/10.18052/www.scipr ess.com/ILCPA.36.303
8. Damayanti, A., & Setyawan, E. (2012). Essential oil extraction of fennel seed (Foeniculumvulgare) using steam distillation. International Journal of Sci- ence and Engineering. https://doi.org/10.2777/ijse.3.2.12-14
9. Dung, D. (2018). experimental and modeling studies of vietnam lemongrass essential oil extraction process using response surface methodology. Vietnam J Sci Technol, 56, 11-16.
10. Gakuubi, M. M. (2016). Steam distillation extraction and chemical composition of essential oils of Toddalia Asiatica L and Eucalyptus camaldulensis Dehn. Journal of Pharmacognosy and Phytochemistry., 5(2), 99–104.

11. Galadima, M. S., Ahmed, A. S., Olawale, A. S., & Bugaje, I. M. (2012). Optimization of steam distillation of essential oil of eucalyptus tereticornis by response surface methodology. Nigerian Journal of Basic and Applied Science., 20(4), 368–372.
12. Hassani Moghaddam, E., Karamian, R., Shaaban, M., & Mohammadian, A. (2020). Identification and Comparison of some essential oils compo- nents in seven Eucalyptus species cultivated in Khoramabad. Journal of Medicinal Plants and by-Product, 9, 59–66. https://doi.org/10.22092/jmpb. 2020.121751
13. Jabbar, S., Abid, M., Wu, T., Hashim, M. M., Saeeduddin, M., Hu, B., Lei, S., & Zeng, X. (2015). Ultrasound-assisted extraction of bioactive compounds and antioxidants from carrot pomace: a response surface approach. Journal of Food Processing and Preservation, 39, 1878–1888. https://doi.org/10.1111/ jfpp.12425
14. James, S. A., & Bell, D. T. (2001). Leaf morphological and anatomical characteris- tics of heteroblastic Eucalyptus globulus ssp globulus (Myrtaceae). Austral- ian Journal of Botany,49, 259. https://doi.org/10.1071/BT99044
15. Juergens, U. R., Engelen, T., Racké, K., Stöber, M., Gillissen, A., & Vetter, H. (2004). Inhibitory activity of 1,8-cineol (eucalyptol) on cytokine production in cultured human lymphocytes and monocytes. Pulmonary Pharmacology & Therapeutics, 17, 281–287. https://doi.org/10.1016/j.pupt.2004.06.002
16. Kabuba, J. T. (2009). Steam extrcation of essential oils Investigation of process parameters a dissertation report. Canadian Journal of Chemical Engineering. https://doi.org/10.1002/cjce.20236
17. Kanyowa, T., Victor Nyakujara, G., Ndala, E., & Das, S. (2021). Performance analysis of Scheffler dish type solar thermal cooking system cooking 6000 meals per day. Solar Energy,218, 563–570. https://doi.org/10.1016/j.solen er.2021.03.019
18. Kostić, M. D., Joković, N M. Stamenković, O. S., Rajković, K. M., Milić, P. S., & Veljković, V. B. (2013). Optimization of hempseed oil extraction byorg/10.1002/wics.73 n-hexane. Industrial Crops and Products, 48, 133–143. https://doi.org/10.1016/j.indcrop.2013.04.028
19. Kültürel, Y., & Tarhan, S. (2016). Birleşik parabolik toplaçlı (BPT) güneş enerjili uçucu yağ damıtma sistemi. Anadolu Journal of Agricultural Sciences, 31, 72. https://doi.org/10.7161/anajas.2016.31.1.72-83
20. Liu, S., Yang, F., Zhang, C., Ji, H., Hong, P., & Deng, C. (2009). Optimization of pro- cess parameters for supercritical carbon dioxide extraction of Passiflora seed oil by

response surface methodology. Journal of Supercritical Fluids, 48, 9–14. https://doi.org/10.1016/j.supflu.2008.09.013

21. Munir, A., & Hensal, O. (2009). Biomass energy utilization in solar distillation sys- tem forn essential oils extraction from herbs on international research confer- ence on food security natural resource management and rural development. University of Hamburg.
22. Munir, A., & Hensal, O. (2010). Investigation of optimal thermal parameters for essential oils extraction using laboratory and solar distillation systems. Agricultural Engineering International the CIGR Ejournal, 12, 1–13.
23. Munir, A., & Hensel, O. (2010). On-farm processing of medicinal and aromatic plants by solar distillation system. Biosystems Engineering, 106, 268–277. https://doi.org/10.1016/j.biosystemseng.2010.03.016
24. Munir, A., Hensel, O., & Scheffler, W. (2010). Design principle and calculations of a Scheffler fixed focus concentrator for medium temperature applica- tions. Solar Energy, 84, 1490–1502. https://doi.org/10.1016/j.solener.2010
25. Munir, A., Hensel, O., Scheffler, W., Hoedt, H., Amjad, W., & Ghafoor, A. (2014). Design,development and experimental results of a solar distillery for the essential oils extraction from 36 medicinal and aromatic plants. Solar Energy, 108, 548–559. https://doi.org/10.1016/j.solener.2014.07.028
26. Patel, H., Rajai, V., Das, P., Charola, S., Mudgal, A., & Maiti, S. (2018). Study of Jatropha curcas shell bio-oil-diesel blend in VCR CI engine using RSM. Renewable Energy, 122, 310–322. https://doi.org/10.1016/j.renene.2018.01.071