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SELECTIVE COATING ON ABSORBER PLATES FOR STEAM DISTILLATION OF MINT OIL

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Abstract: Mint distillation, a common method for extracting essential oils from mint, traditionally relies on steam distillation, which is both energy-intensive and water-consuming. To address these sustainability concerns, we propose an innovative approach to enhance the solar thermal efficiency of mint oil distillation systems. Our method involves using selective coatings on the absorber plates. These coatings are designed to absorb solar radiation efficiently and convert it into heat while minimizing thermal losses. The absorber plate, integrated with a copper tube network, is coated with a selective material that has shown a temperature increase of 15-20°C compared to conventional black coatings. This improvement in temperature not only boosts the yield and quality of mint oil but also reduces water usage and environmental impact. Selective coatings manipulate the absorption and emissivity properties of the absorber plate, tailoring them specifically to the distillation process.

Keywords: Mint Distillation, Steam Distillation, Solar Thermal Efficiency, Solar Radiation, Distillation Process.

I. INTRODUCTION

The energy sustainability of any country has a strong correlation with its social and economic development. The rapidly increasing world population has led to adverse effects on ageing infrastructure and increased energy consumption. The limited availability of primary energy sources isposing a severe threat to the continuous energy supply in many developing countries. Many developing countries have been facing severe energy crises, specifically in the last few decades which have adversely affected their domestic, commercial, industrial and agriculture sectors. Furthermore, the environmental consequences associated with energy production including climate change continue to be a challenge for the world.

In this regard, the developed countries have already taken initiatives to explore alternative sources of energy for sustainable energy supply in the future. Natural resources such as water for hydroelectric power, solar energy, wind energy, biogas production, biomass resources and biofuel crops, could potentially meet the demand of developing countries around the world.

Therefore, it is appropriate to increase the reliance on renewable sources of energy in developing countries to cope with environmental challenges caused by the production of energy associated with conventional means. Fortunately, many developed countries have already started working on the exploration, development and direct implementation of renewable energy sources. Out of these renewable energy sources, solar energy is abundantly available in many countries and can be used for thermal energy and electricity generation. The mean total irradiation falling near the equator is about 200–250 W m^−2 day^−1. This amount is about 1500–3000 sunlight hours or 1.9–2.3 MW^-hr per year. It is worth mentioning that most of industrial processes like pasteurization, extraction, sterilization, drying, hydrolyzing, distillation, evaporation, washing andpolymerization operate in the medium temperature range.

The temperature ranges for all these processes lie between 60 and 280 °C. One key process commonly used within the same temperature range is distillation, which is used for extracting clean and refined oil from plant materials by evaporating the volatile compounds, which have many useful applications.The majority of distillation processes are carried out using conventional energy sources requiring significant amounts of energy. Fortunately, solar-based distillation processes can be used as attractive alternatives to meet energy demand in medium-temperature applications. Solar-based distillation has clearly shown that lower operating costs are possible, thus increasing the net revenue by producing essential oils and minimizing crop and fruit waste. Out of various types of distillation processes used worldwide for extracting essential oils from plant materials, the commonly used processes include water or hydro distillation, steam distillation and water-cum-steam distillation, with steam distillation being considered to be the most favorable process.

Koul conducted a study on the steam distillation of essential oil extraction from lemon grass. For the study, a kinetic model was developed for the 100–1000 kg batch process. It was concluded that oil yield could be increased by increasing the steam injection rate in the still.

Sengar conducted a study on the design and development of a solar distillation system for the distillation of water. The system was tested in winter and summer against different inclination angles of the solar distillation system. Water in the amount of 2300 and 3400 ml/m2/day was distilled by a solar distillation system in winter and summer, respectively. It was found that in winter at an angle of 40–48°, maximum distillation of water occurred. The efficiency of this system was 47.2% and 56.3% in winter and summer, respectively. It was calculated that its reimbursement or pay-back period was 6 months with a benefit-to-cost ratio of 1.7.

To improve the efficacy of distillation processes when integrated with solar concentrators, a study has been undertaken, which involves the design, development and experimental investigation of a newly designed steam receiver capable of producing steam using a Scheffler reflector for the distillation process. To complement scarce radiation during cloudy days or nighttime, a backup energy source was used to reliably and continuously power the distillation process.

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II. LITERATURE SURVEY

Ravi Kant and Anil Kumar et. al. The numerous advancements conducted experimentally to improve the efficiency of steam desalination systems to extract the essential oil from the peppermint plant are presented in this article. Peppermint oil is important for human life because of its health benefits. It is used in the medical sector and food industry as an herb and fragrance, respectively. In this study, two types of distillation systems, namely the solar distillation system and the electrical energy-based distillation system, are discussed. The major factors that lead to increased system efficiency, such as the mass flow rate of heat transfer fluid, inlet water flow rate to boiler and batch size of peppermint, are addressed [1].

Nasr, Mona & Morad, M.M. &علي, محمود&Wasfy, Kamal et. al. The main objective of the present work is to construct a simple steam distillation system for extracting volatile oil from peppermint plant. The constructed extraction system consists of the following main parts: electric heater, boiler, extracting unit, condenser and connection hoses. Experiments were carried out to study the effect of boiler inlet water flow rates (1.00, 1.25 and 1.50 l/h) and batch size of whole peppermint plant (300, 500 and 700 g) on system productivity, extraction efficiency, essential oil yield, power and energy requirements. Results indicated that the constructed extraction system using steam distillation technique gave the optimum conditions of system productivity (6.2 ml), extraction efficiency (88.57 %), essential oil yield (0.797 % (w/w)) and energy requirements (0.475 kW.h/ml) under 1.5 l/h boiler inlet water flow rate and 700 g batch size [2].

A. Justiniano-Medina, J. Arrieta-Conde, A. L. Torres-Taipe, J. A. Cruz-Anchiraico and D. Huamanchahua et. al. The extraction of essential oils is a process widely used around the world, and part of its main ingredients consists of a natural base. Also, Peru is one of the 15 most biologically diverse countries in the world, maintaining approximately 10% of world flora and endless endemic species, valuing those citrus fruit products such as orange, lime, lemon, and grapefruit. Therefore, the process and development of a model of a grapefruit essential oil distiller are analyzed through the design of an essential oil extractor on an industrial scale by steam dragging, thus establishing the automation and monitoring of the extractor machine through a mobile device that will present the status of the various actuators and sensors implemented showing the status of the parameters in the module, with this it is intended that the operator can be aware of the extraction at any time of the day. Finally, an approximate result was obtained in the distillation of 1,338% of Grapefruit essential oil and the efficiency of remote control was also demonstrated through a Telegram application using Python software for its programming [3].

T. Thanh Son and P. Qui Tra et. al. Melaleuca oil is one of the most powerful immune system stimulants, which is capable of quickly eliminating most viral, bacterial, and fungal infections. Melaleuca oil in Vietnam is only produced on a small-scale using outdated technology. In this study, the materials were firstly processed with the steam explosion method before being put into the distillation pot. This pretreatment process helps to break down the structure of the materials and extract the essential oil efficiently. In the scope of this study, many different experiments had been done such as changing of heating time, pressure, and the number of steam explosions. The main purpose of the study is to find parameters suitable for oil dissociation regarding oil color and quantity. Research results show that the essential oil yield depends on explosion pressure, explosion time, and the number of explosions. In the scope of this study, it shows that for every 3 kg of raw melaleuca, about 10.2 ml of essential oil is extracted, which is almost twice as high as traditional methods without steam explosion. This process also saves 60% more time than the traditional method. These preliminary results demonstrate that pretreatment is an important part of improving the efficiency of essential oil extraction both in terms of essential oil yield and energy consumption [4].

N. Kasuan, N. Ismail, M. N. Taib and M. H. FazalulRahiman et. al. In this paper, recurrent adaptive neuro-fuzzy inference system (RANFIS) structure has been proposed to solve approximation problem in identifying a global model of steam temperature of packed distillation column in steam distillation essential oil extraction process. The input-output data is acquired from field experimentation via MATLAB Real-time Workshop (RTW) integrated to the plant. The derived RANFIS model is optimized in order to get the optimum ANFIS structure that includes the optimal number of membership function, fuzzy rules, data selection, epoch which gives low computation time and root means squared error (RMSE). Several experiments were carried out using both pseudo random binary sequence (PRBS) and noise as perturbation signals. Performance comparison of RANFIS with ARX model shows that RANFIS identification gives an excellent global modeling method with RMSE of 0.1778 and consumed less computation or training time [5].

III. METHODOLOGY

Mint or Mentha are aromatic herbs belonging to the genus Mentha and the family Lamiaceae. Globally, the genus Mentha comprises more than 30 species distributed mainly in temperate and tropical/subtropical regions. Most species are perennials with leafy runners, stolons or underground rootstocks. There are several species and varieties of mint oil which are cultivated in one or the other parts of the world, five of them are grown on a commercial scale in India, these are Mentha arvensis, Mentha-piperita, Mentha-spicata, Mentha-veridish and Mentha-citrata. Menthol is a unique and valuable component of plants, which gives the typical minty smell to plants.

Mint is mostly found in tropical regions which have hot and humid climates and receive plenty of rainfall. Mint is easy to cultivate with minimum care and attention. The mint plant also requires very little or no fertilizers and pesticides as it can grow in any type of soil and is resistant to most diseases and pests. Mint oil is present in the bottom part of mint leaves in very small quantities.

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 Journal Volume 13, Iss 4 2024

Mint oil is obtained from the leaves of the peppermint plant which is a hybrid of spearmint and water-mint. The peppermint plant is mainly found in tropical regions having wet climates. It is cultivated in the states of Kerala and Karnataka in southern India and the states of Assam, Mizoram, Nagaland and Sikkim in north-eastern India. Peppermint is also cultivated in Bhutan, Nepal, China, Sri Lanka, Vietnam, Thailand, Malaysia, Mexico and Indonesia. India is the largest exporter of mint oil followed by Thailand and Vietnam. Mint oil is stored in the glands present at the bottom of the leaves. It is extracted by first crushing the leaves to maximize the surface area for extraction and expose the stored oil in the leaves. By passing steam or methanol through the leaves, the cell walls get softened and oil gets extracted.

Mints have been popularly cultivated in India for more than 50 years. In the last few years, India has emerged as the largest producer and export hub for Mentha oil and its derivatives. The country contributes around 80% to the total global Mentha oil production followed by China (9%), Brazil (7%) and the USA (4 %). 7 It exports different types of mint oil to China, the UK, France, the US, the Netherlands, Germany, Brazil, Singapore, and Japan, among others.

In similar ways, India (with a 33% share in world exports) maintains its position as the world's largest exporter of menthol, despite the fluctuations over the years.

India is closely followed by China (22%), Germany (22%) and Japan (9%) as the major exporters of menthol in the world.8 The area under mint cultivation in India is 0.3 M ha which produces nearly 30,000 MT of Mentha oil annually, 75% of which is exported by the country.9 It is primarily grown in Uttar Pradesh, Punjab, Haryana, Madhya Pradesh and Bihar. Uttar Pradesh is the largest producer of Mentha oil, accounting for 90% of the country's total Mentha production, followed by Punjab, Haryana, Bihar, and Madhya Pradesh Bihar and Madhya Pradesh.

Fig. 1: Mentha Arvensis Plant

Fig. 2: Mentha Piperita Plant

The genus Mentha is part of the Lamiaceae family and consists of a wide range variety of species, one of them is M. piperita. This species is herbaceous; the essential oil composition depends on the type of verities at different stages of its production and extraction conditions, however, the major component is menthol (70% - 90%). The vital components found in Mentha piperita oil other than menthol are menthone, iso menthone, limonene, neomenthol, methyl acetate, beta-caryophyllene, piperitone, alpha- and beta-pipene, tannins, flavonoids, esters, menthyl acetate, ketones, phellandrene, cineol piperitone and sesquiterpene. The components of Mentha piperita oils especially menthol and menthone are valuable due to their refreshing minty flavour and odour which they give to plants. Among all of the components of the Mentha genus, menthol plays a very important and vital role due to its large number of health-related activities such as antioxidant, antimicrobial, anticancer and anti-inflammatory activities. Menthol has a significant role in medicine for the treatment of stomach problems and also in the relief of headaches. Because of its wide range of antiseptic and anti-bacterial properties, it plays an important role in the treatment of puffiness of gums, breath freshers, oral herpes and odontalgia.

Fig. 3: Mentha Spicata plant (Spearmint)

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, Journal Volume 13, Iss 4 2024

Applications

Mint oil has a lowering effect on the heart rate and the systolic pressure. Relaxation of bronchial smooth muscles and an increase in ventilation are also other cardiovascular effects of peppermint oil. Inhalation of peppermint oil increases the nasal air force and thus supplies more air into the lungs.

In a few studies, it was also claimed that it makes the lung surfactant more efficient enabling better pulmonary function. Peppermint is used in making oral dentifrices as it can provide overall freshness in breath and also keep away bad breath. It improves the gastric emptying rate. There is a significant antiemetic effect of peppermint in reducing postoperative nausea for patients with very sensitive gag reflexes. Peppermint is said to be a good analgesic to be applied topically and also a coolant for the skin. Peppermint oil stimulates cold receptors on the skin and dilates blood vessels, causing a sensation of coldness and an analgesic effect.

Solar Cell: Considering the ever-increasing energy needs of the modern world, the diminishing conventional fossil-based sources of energy would need to be switched to sustainable and renewable sources. In this regard, there are a few options to look into, which include, wind, tidal, hydro, biomass, atomic and solar energy. Solar cells/photovoltaic cells provide an efficient route to utilize ample solar energy. Solar energy is radiant light and heat from the Sun that is harnessed using a range of technologies such as solar power to generate electricity. If suitably harnessed, this highly diffused source has the potential to satisfy all future energy needs. In the 21st century, solar energy is expected to become increasingly attractive as a renewable energy source because of its inexhaustible supply and its nonpolluting character, in stark contrast to the finite fossil fuels coal, petroleum, and natural gas.

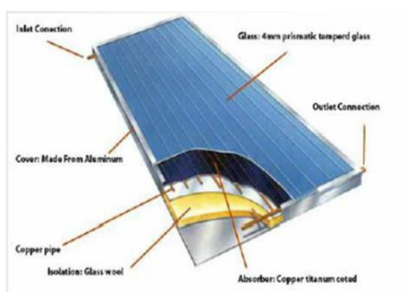

Fig. 4: Schematic of solar cell

The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by Earth, but its intensity at Earth's surface is quite low. This is essentially because of the enormous radial spreading of radiation from the distant Sun. One such approach is our Solar panel made from Aluminum sheets covered with Glass wool. On that sheet number of copper pipes are arranged for the flow of electrons coated with absorber coating with Titanium dioxide covered with a 4mm prismatic tempered glass sheet where the Panel is provided with an Inlet and outlet of copper pipes. When kept under the SUN radiation, power generation of 600 millivolts is observed with dimensions of Aluminum plate 25cm*25cm*6mm thick. Study of various factors such as the activity life of aluminium plate, electrochemical rate kinetics, material being used for coating, etc. that affect the amount of power generation is being done. Such a system can supply a home with hot water drawn from the storage tank, or, with the warmed water flowing through tubes in floors and ceilings, it can provide space heating. Flat-plate collectors typically heat carrier fluids to temperatures ranging from 66 to 93 °C (150 to 200 °F). The efficiency of such collectors (i.e., the proportion of the energy received that they convert into usable energy) ranges from 20 to 80 per cent, depending on the design of the collector. Solar energy is commonly used for solar water heaters and house heating. The heat from solar ponds enables the production of chemicals, food, textiles, warm greenhouses, swimming pools, and livestock buildings. Cooking and providing a power source for electronic devices can also be achieved by using solar energy.

Although the efficiency of our solar cells does not match the efficiency of presently applied solar cells, our solar cells might compete with presently applied solar cells economically, especially when considering factors such as production and maintenance costs and efficiency.

Steam distillation: Steam distillation is a separation process that consists of distilling water together with other volatile and non-volatile components. The steam from the boiling water carries the vapor of the volatiles to a condenser; both are cooled and return to the liquid or solid state, while the non-volatile residues remain behind in the boiling container.

If, as is usually the case, the volatiles are not miscible with water, they will spontaneously form a distinct phase after condensation, allowing them to be separated by decantation or with a separatory funnel.

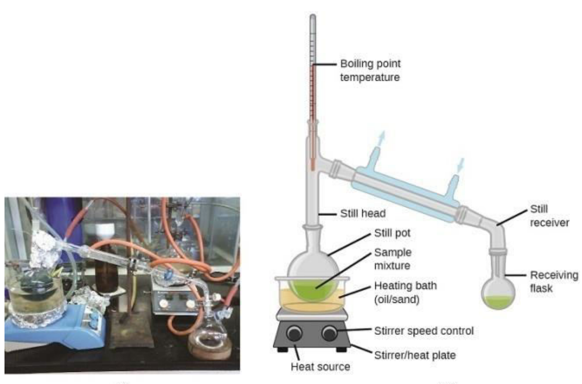

Fig. 5: General setup of steam distillation columns

Steam distillation can be used when the boiling point of the substance to be extracted is higher than that of water, and the starting material cannot be heated to that temperature because of decomposition or other unwanted reactions. It may also be useful when the amount of the desired substance is small compared to that of the non-volatile residues. It is often used to separate volatile essential oils from plant material—for example, to extract limonene (boiling point 176 °C) from orange peels.

Steam distillation once was a popular laboratory method for the purification of organic compounds, but it has been replaced in many such uses by vacuum distillation and supercritical fluid extraction. It is however much simpler and more economical than those alternatives and remains important in certain industrial sectors.

METHODS OF EXTRACTION

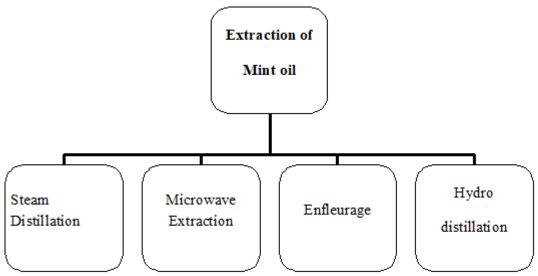

Fig. 6: Different Extraction Methods

Microwave-assisted extraction (MAE) or simply microwave extraction is a relatively new extraction technique that combines microwave and traditional solvent extraction. The application of microwaves for heating the solvents and plant tissues in extraction process, which increases the kinetic of extraction, is called microwave-assisted extraction. MAE has several advantages, e.g., shorter extraction time, less solvent, higher extraction rate and lower cost, over traditional methods of extraction of compounds from various matrices, especially natural products. The use of MAE in natural products extraction started in the late 1980s, and through technological developments, it has now become one of the most popular and cost-effective extraction methods available today, and several advanced MAE instrumentations and methodologies have become available, e.g., pressurized microwave-assisted extraction (PMAE) and solvent-free microwave-assisted extraction (SFMAE).

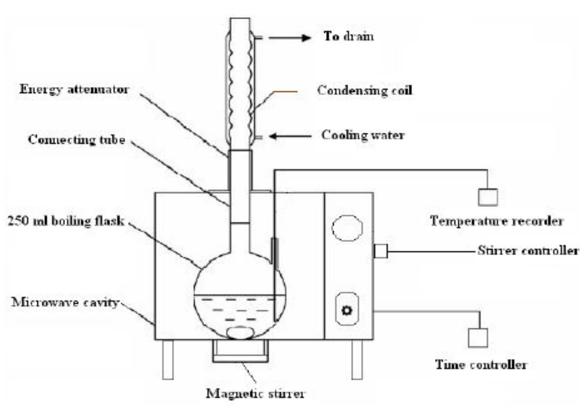

Fig. 7: Microwave assisted extraction diagram

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Hydro-distillation uses water (steam) as an extraction solvent to recover volatile or polar components of plant materials. Hydro-distillation is often carried out using a setup known as Clevenger apparatus or simple steam distillation. In the Clevenger apparatus, sample mixed water is boiled to evaporate volatile components while in the steam distillation approach, steam is passed through a bed of the sample. In both approaches, two layers (aqueous and oil-rich) are obtained and oil can be further separated via separating funnels. In this technique, the separation of aroma compounds from water, particularly polar ones, is a challenging task and perhaps the greatest limitation of hydro-distillation type extraction.

IV. RESULTS

The use of solar panels with selective coatings on absorber plates can significantly enhance the efficiency of steam distillation processes for extracting essential oils, such as mint oil. Selective coatings are designed to have high absorptance in the solar spectrum and low thermal emittance in the infrared region, which means they can effectively convert UV-VIS part of solar radiation into heat while minimizing heat loss.

For the steam distillation of mint oil, specifically from Mentha piperita, the yield percentage can vary based on several factors, including the distillation setup, the condition of the mint plants, and the duration of the distillation process. However, the experimental studies have done shown that the optimum yield for steam distillation of mint oil can be around 1.36% of essential oil at 80°C from a 70g sample of Mentha piperita.

The energy obtained from solar cell for 10 minutes under the sunlight is 571 milliamperes. After keeping the cell under the sun for thirty days the wattage increased to 430 watts from 0.571 watts.

After the analysis the properties were calculated as

Table 1: Properties of Mint oil

Sr No	Properties	Values
1	Molecular Weight	965.51672 g/mol
2	Density	0.896 - 0.908 g/cm^3 (at 25?)
3	Molecular Formula	C10H20O
4	Boiling Point	215 ?
5	Solubility	Insoluble in water and soluble in ethanol and organic solvents.
6	Specific Gravity	0.90 g/mL at 20 ?
7	Refractive Index	1.421
8	Flash Point	66 ?
9	Acid Value	1.54 mg/g
10	Odour	Strong Mint Odour
11	Colour	Pale Yellow

V. CONCLUSION

In summary, employing solar panels with selective coatings on absorber plates for the steam distillation of mint oil offers a promising path towards more sustainable and efficient extraction methods. By harnessing solar energy, this approach improves the overall energy efficiency of the distillation process, reducing dependence on fossil fuels and decreasing environmental impact. The selective coatings enhance solar radiation absorption while minimizing heat loss, which boosts heat transfer efficiency crucial for effective steam distillation. This innovation not only makes mint oil production more sustainable but also supports the broader shift toward renewable energy sources in industrial applications. However, additional research and development are necessary to refine the design, efficiency, and scalability of these systems to fully realize their commercial potential.

VI. REFERENCES

[1] Ravi Kant and Anil Kumar, Advancements in steam distillation system for oil extraction from peppermint leaves, Materials Today: Proceedings, Volume 47, Part 17, 2021, Pages 5794-5799, doi. 10.1016/j.matpr.2021.04.123

[2] Nasr, Mona & Morad, M.M. &علی, محمود&Wasfy, Kamal. (2020). Extraction Of Peppermint Volatile Oil Using A Simple Constructed Steam Distillation System. Plant Archives. 20. 1487-1491.

[3] A. Justiniano-Medina, J. Arrieta-Conde, A. L. Torres-Taipe, J. A. Cruz-Anchiraico and D. Huamanchahua, "Design of a Steam Distillation of Essential Oils from Grapefruit Peel with Raspberry Pi B+ Using Telegram Connection," 2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, NY, USA, 2022, pp. 0132-0137, doi: 10.1109/UEMCON54665.2022.9965707.

[4] T. Thanh Son and P. Qui Tra, "Research on melaleuca oil production by steam explosion method," 2020 Applying New Technology in Green Buildings (ATiGB), Da Nang, Vietnam, 2021, pp. 100-104, doi: 10.1109/ATiGB50996.2021.9423324.

[5] N. Kasuan, N. Ismail, M. N. Taib and M. H. FazalulRahiman, "Recurrent adaptive neuro-fuzzy inference system for steam temperature estimation in distillation of essential oil extraction process," 2011 IEEE 7th International Colloquium on Signal Processing and its Applications, Penang, Malaysia, 2011, pp. 1-6, doi: 10.1109/CSPA.2011.5759831.

[6] J. Ranjitha and S. Vijiyalakshmi, "Facile Methods for the Extraction of Essential Oil From the Plant Species-a Review", Int. J. Pharm. Sci. Res., vol. 5, no. 4, pp. 1107, 2014.

[7] S. Thompson, "Spiritual practice and essential oil therapy: Exploring the history and individual preferences among specific plant sources", Int. J. Aromather., vol. 13, no. 2–3, pp. 108-113, 2003.

[8] Z. M. Yusoff, Z. Muhammad, M. H. F. Rahiman and M. N. Taib, "PRBS perturbation and modeling of hydro-diffusion steam distillation essential oil extraction system under feed-in disturbance", Proc. - 2012 IEEE 8th Int. Colloq. Signal Process. Its Appl. CSPA 2012, pp. 480-484, 2012.

[9] Z. Liu et al., "Cinnamomum camphora fruit peel as a source of essential oil extracted using the solvent-free microwave-assisted method compared with conventional hydrodistillation", Lwt, vol. 153, pp. 112549, 2022.

[10] A. Farhat, A. S. Fabiano-Tixier, M. El Maataoui, J. F. Maingonnat, M. Romdhane and F. Chemat, "Microwave steam diffusion for extraction of essential oil from orange peel: Kinetic data extract's global yield and mechanism", Food Chem., vol. 125, no. 1, pp. 255-261, 2011.

[11] N. J. Sadgrove, G. F. Padilla-González and M. Phumthum, "Fundamental Chemistry of Essential Oils and Volatile Organic Compounds Methods of Analysis and Authentication", Plants, vol. 11, no. 6, 2022.

[12] U. Acar, O. S. Kesbiç, S. Yilmaz, N. Gültepe and A. Türker, "Evaluation of the effects of essential oil extracted from sweet orange peel (Citrus sinensis) on the growth rate of tilapia (Oreochromis mossambicus) and possible disease resistance against Streptococcus iniae", Aquaculture, vol. 437, pp. 282-286, 2015.

[13] S. Moradi, A. Fazlali and H. Hamedi, "Microwave-assisted hydro-distillation of essential oil from rosemary: Comparison with traditional distillation", Avicenna J. Med. Biotechnol., vol. 10, no. 1, pp. 22-28, 2018.

[14] M. A. Hanif et al., "Raman spectroscopy for the characterization of different fractions of hemp essential oil extracted at 130 °C using steam distillation method", Spectrochim. Acta - Part A Mol. Biomol. Spectrosc., vol. 182, pp. 168-174, 2017.

[15] C. A. Calderon, J. P. Gutierrez, L. Alvarez, D. Granda, E. Valarezo and C. Ramirez, "PLC-based temperature controller applied to a distiller of essential oils by water-steam drag", Iber. Conf. Inf. Syst. Technol. Cist, pp. 1-7, 2018.

[16] N. Kasuan, M. Yunus, M. H. F. Rahiman, S. R. A. Aris and M. N. Taib, "Essential oil composition of Kaffir lime: Comparative analysis between controlled steam distillation and hydrodistillation extraction process", SCOReD2009 - Proc. 2009 IEEE Student Conf. Res. Dev., pp. 479-482, 2009.

[17] N. Ismail, N. Tajjudin, M. H. F. Rahiman and M. N. Taib, "Modeling of dynamic response of essential oil extraction process", Proc. 2009 5th Int. Colloq. Signal Process. Its Appl. CSPA 2009, pp. 298-301, 2009.

[18] N. Tajjudin, M. Tajjudin, M. H. F. Rahiman and M. N. Taib, "Model predictive control for steam distillation essential oil extraction process", SCOReD2009 - Proc. 2009 IEEE Student Conf. Res. Dev., pp. 446-449, 2009.

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 13, Iss 4 2024

[19] X. Chen, L. Zhang, C. Qian, Z. Du, P. Xu and Z. Xiang, "Chemical compositions of essential oil extracted from Lavandula angustifolia and its prevention of TPA-induced inflammation", Microchem. J., vol. 153, pp. 104458, 2020.

[20] L. Soto, G. O. De Rodriguez, L. Rojas and B. Sulbarán, "Caracterizaciónquímica del aceiteesencial de toronja (Citrus paradisi L.) Chemical characterization of essential oils of grapefruit (Citrus paradisi L.)", pp. 266-283, 2013.