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COMPARISON BETWEEN EXTRACTION ESSENTIAL OIL BY STEAM DISTILLATION AND MICROWAVE ASSISTED EXTRACTION PROCESSES

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ABSTRACT

Extraction processes have been developed to be more eco-friendly applied processes, the most popular conventional method to extract essential oils is a steam distillation (SD), whereas a new technic to heat the plants faster is to use microwave cavity. This work is aimed to compare two extraction methods scaled up based on the experimental results obtained using microwave assisted extraction (MAE) for essential oil extraction from lavender flowers. The results proved that the capital cost for MAE mainly increased by microwave cavity and microwave generator, their cost were 8 times higher than that of conventional method steam distillation, while the operating cost for both of them are almost the same. However, MAE over short time and small area to be applied, to extract an essential oil from Lavender flowers. Whereas the SD has an important advantage over the microwave assisted extraction in terms of safety and cost.

***Keywords**:*
Extraction processes.
Microwave Assisted Extraction.
Steam Distillation (SD).
Essential Oil.

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1 INTRODUCTION

Several types of fragrant herb such as lavender flower, that contain a valuable volatile oil [1]. The essential oil from lavender is used widely especially in cosmetics, soaps and fragrances. The annual growth rate of essential oil approximately 7.5% of its global mark about \$2.61 billion dollars [2]. Steam distillation uses thermal energy in the extraction process and it is a well-known technology method [3]. Steam is produced by a boiler and fed to extractors where the biomaterial, flowers, will be boiled to extract the oil inside exploiting the volume proportionated by the extractors. After it, the vapour will be cooled by a condenser [3, 4]. Based on density difference method is used to separate the liquid mixture (water and oil) in the separator. Due to the nature of the boiler, thermal degradation of oil is avoided which is a common problem in the other production methods [5]. The thermal energy supply can be controlled according to the type of oil to be distilled. It is also the best way for energy efficiency which is one of the main costly inputs in the essential oil industry for mass production [2, 5].

This paper illustrates an evaluation of a theoretical design of a mobile unit, which scaled up for essential oil extraction from flowers on the basis of experimental results obtained using microwave assisted extraction (MAE). Higher microwave in MAE has the advantages of short extraction time and less energy consumption, consequently a smaller area is required for the mobile unit [3, 6-9]. Based on these hypotheses, the objective of the study was to evaluate SD and MAE methods to extract the volatile oil from the lavender in aspects of scaling up, cost and safety on the basis of plant design rules and experimental results.

2 MATERIALS AND METHODS

The mobile unit was designed to process (1 ton/h) of fresh lavender by steam distillation (SD) method. The MAE was scaled up to process (1 ton/h) on the basis of laboratory experiments in order to be an alternative to the SD method. The microwave extraction experiment was conducted using a Miniflow 200SS instrument “AET company, Kanagawa, Japan”[10] at optimum conditions of distillate water to lavender flowers 1:2 respectively and temperature of 100°C, microwave power 175W and approximately 15 g of lavender. The processes to extract the essential oil are shown in figure 1below.

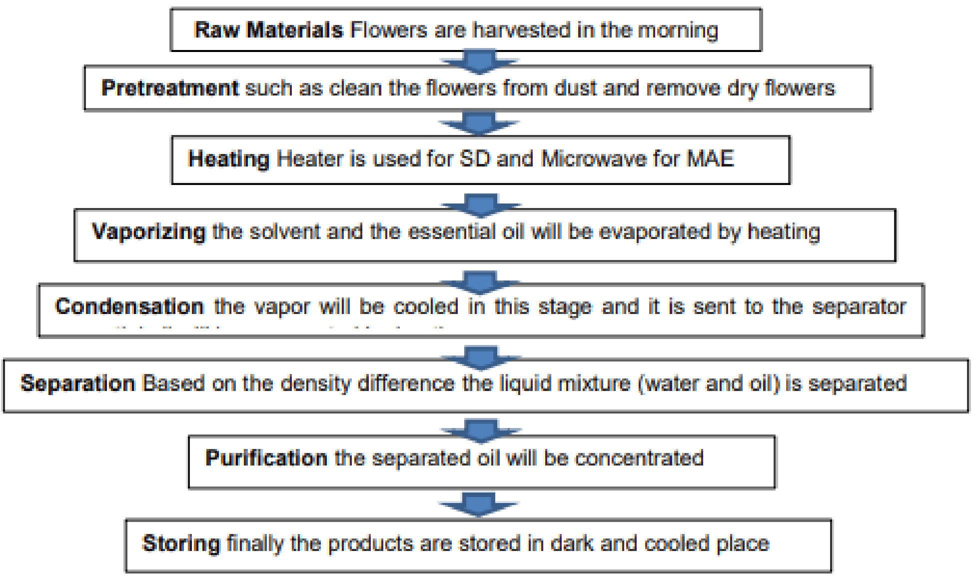

Figure 1. The process of extraction essential oil.

3 RESULTS AND DISCUSSION

In MAE much shorter time is needed to dissipate the same energy in compared to other conventional methods [4, 11]. In this work there was a small improvement in the yield at higher microwave power (above 150 W). The yield was reported to be smaller (1.8673%±0.054) than what was expected (above 8%) [12]. Another noticeable point is that the reflected power was unstable and difficult to be controlled in order to consume the same energy by the samples. Moreover, density calibration curve was used to obtain the yield, due to the limited amount of oil that was extracted. Despite all of these challenges, the study agrees with *Thirugnanasambandham* and others higher microwave power can reduce the extractor volume by reducing the extraction time [12].

3.1 The Impact of Research Findings on the Design

In the continuous extraction process SD's extractors were replaced by the continuous microwave cavity, the boiler was replaced by the microwave generator. Based on the experimental data Figure 2. was created to predict the yield at higher microwave power. It demonstrates that the yield should be above 7% at 1000 W. Similarly, found that the yield of essential oil from lavender was 8.86% at power of 1000 W (4 W/g). This data appears to support the assumption that the optimum power density is around 4 W/g.

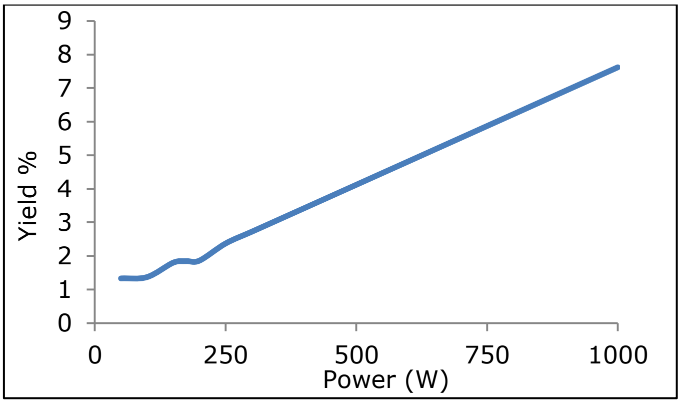

Figure 2. The effect of microwave power on the yield

Since higher microwave power reduces extraction time, increasing the number of batches results in minimizing the extraction cavity size. The extraction time was fixed in order to induce sufficient energy to the samples. Higher microwave power has a dramatic impact on improving productivity and minimizing extractor volume resulting in small area is needed for the mobile unit. The effect of microwave power on the extraction time and extractor volume is presented in Figures 3. and 4, respectively.

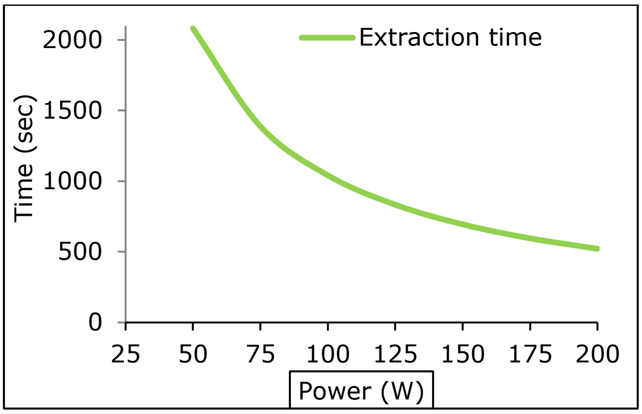

Figure 3. The effect of microwave power on the extraction time

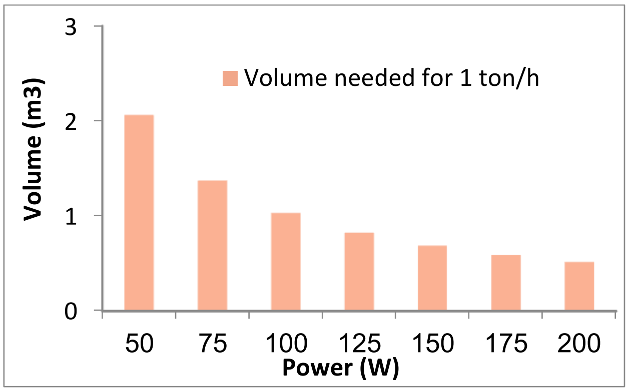

Figure 4. The effect of microwave power on extractor volume

Increasing solvent (water) ratio will reduce the annual profit by increasing the annual operating cost without any significant change in the yield. It increases the extractor volume resulting in a bigger carbon footprint as it is shown in figure 5. Based on these hypotheses the optimum water to lavender ratio should be 1:1.

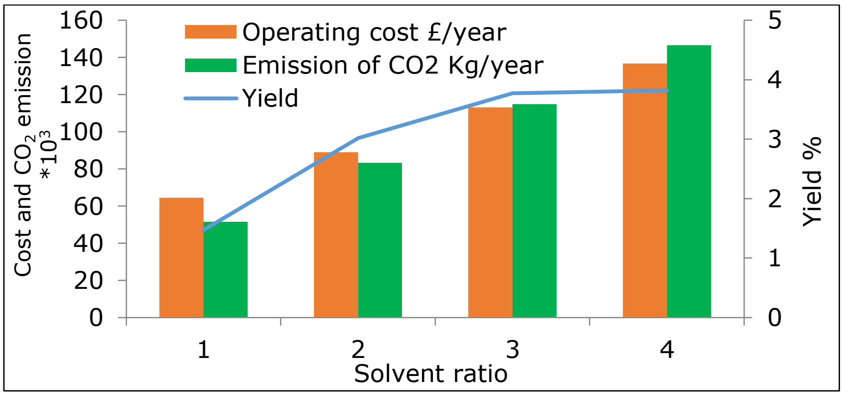

Figure 5. The effect of solvent ratio on yield, CO_2 emission and operating cost

As for the pre-treatment to raw materials, the chopped flower indicated an effect on the yield compared to whole plant as they are shown in Figure 6. However, the whole plant should be used because the stripping and chopping need more time reducing the flow rate of fresh material. In addition, the operating cost increases and more personnel are needed.

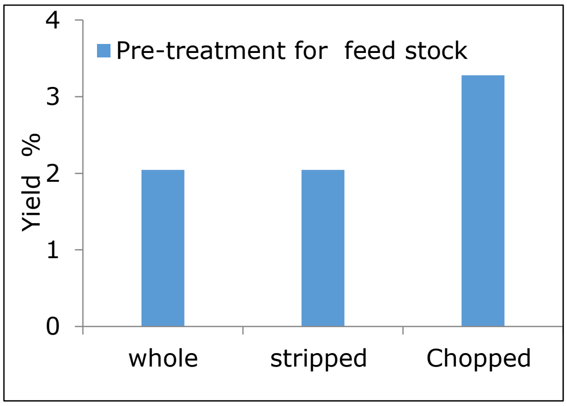

Figure 6. The effect of pre-treatment of the feed stock on the yield

The extraction at higher temperature showed a small change in the yield. Therefore, the temperature should be just above the boiling point (above 98.6^{o}C) in order to evaporate the oil and the water from the plants. The effect of higher temperature on the design by causing a fire will be discussed in the next section 3.2.

Microwave assisted extraction cavity was redesigned and scaled up on the basis of the assumption made above. Applied microwave power was 100 kW (4 W/g). The microwave generator has 90% electrical conversion efficiency. The microwave operates at a typical commercial frequency of 915 MHz.

The major drawback of applying the open end in industrial microwave is a large amount of heat loss. Additionally, it introduces the air to the flowers during the extraction process. The air makes an isolating layer inside the heat exchanger and thus reduces its efficiency. That is why the shell and tube condenser should be replaced with a direct contact condenser.

3.2 The Impact of Research Findings on Safety

In microwave assisted extraction processes the most important thing is the safety of employees. This was ensured by revising the initial HAZOP for the new method (MAE). The SD hazards were the possibility of explosion and potential burning during discharging the vessels after every batch, whereas the major hazards associated with MAE, which must be taken into account in microwave extraction, include microwave leakage and radiation exposure, arcing and firing.

The main hazard to operators from microwave extraction processes is the microwave irradiation exposure which can increase the blood temperature. Therefore, microwave leakage must be monitored by setting appropriate sensors in order to take immediate corrective actions.

There is a possibility of arcing during the extraction process indicating a very serious impact of electrical contact arcing on operators' lives. This is due to condensing the vapour inside cavity wall. Thus, safety shut-off switches must be used. In addition, the conveyor belt is made from non-conductor material polyethylene (PE).

Firing is another hazard might be occurred during microwave assisted extraction process. During the extraction process some raw material might get burnt inducing fire inside the cavity. This challenge can be overcome with water sprays just above the conveyor belt and they must be made of non-conducting material (PE). Also, enough fire extinguishers must be provided.

3.3 The Impact of Research Findings on Cost

The comparison between the steam distillation method and microwave assisted extraction method in terms of capital and operating costs are shown in Figure 7. The capital cost for MAE increased by microwave cavity and microwave generator. It was 8 times higher than that of SD, while the operating cost for both of them are almost the same.

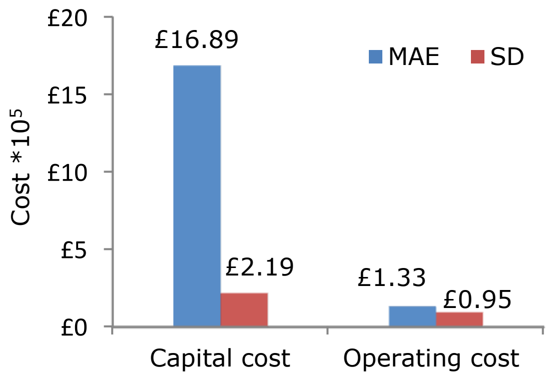

Figure 7. Break Even Point analysis for both in terms of capital and operating costs

The breakeven point (BEP) analysis is illustrated in Figure 8. It is clear from both figures (red and blue) that SD is much more cost effective than MAE. The first needs just a year for reaching the BEP whereas the MAE needs more than 6 years.

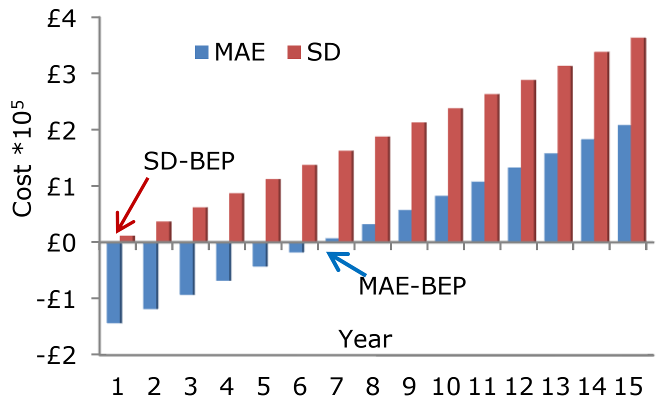

Figure 8. Comparison between SD and MAE methods

4 CONCLUSION

Microwave extraction has been compared with a conventional technique SD, for the extraction of essential oil from lavender flowers. From the analyses undertaken in this study, SD was found much better than microwave extraction in terms of plant economy and safety. The SD seems to be safer than MAE for the personnel. In conclusion SD is recommended to be applied for the extraction of essential oil from lavender.

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REFERENCES

[1] S. J. Enna and S. Norton, *Herbal supplements and the brain: understanding their health benefits and hazards*. FT Press, 2012.

[2] A. & H. Kebede. The design and manufacturing of essential oil distillation plant for rural poverty alleviation in ethiopia. *J. Environ. Stud. Manag*,2008, **1**, p. 81–91.

[3] Ma, C. H., Liu, T. T., Yang, L., Zu, Y. G., Chen, X., Zhang, L. Zhao,. Ionic liquid-based microwave-assisted extraction of essential oil and biphenyl cyclooctene lignans from Schisandra chinensis baill fruits. *Journal of Chromatography a*, 2011 ,**48**, p.8573-8580.

[4] K. A. Abed, . Effect of microwave power on the yield of essential oil from lavender. *J. Al asmarya Univ.*, 2020, **2** (2).

[5] A. N. Afoakwah, J. Owusu, C. Adomako, and E. Teye,. Microwave assisted extraction (mae) of antioxidant constituent in plant materials,. *Glob. J. Bio-Science Biotechnol.*, 2012.

[6] Y. L. Wang, G. S. Xi, Y. C. Zheng, and F. S. Miao,. Microwave-assisted extraction of flavonoids from chinese herb radix puerariae (Ge Gen). *J. Med. Plants Res.*, 2010, doi: 10.5897/JMPR09.426.

[7] Li, J., Zu, Y. G., Fu, Y. J., Yang, Y. C., Li, S. M., Li, Z. N., & Wink, M. (2010). Optimization of microwave-assisted extraction of triterpene saponins from defatted residue of yellow horn (Xanthoceras sorbifolia Bunge.) kernel and evaluation of its antioxidant activity. *Innovative Food Science & Emerging Technologies*, **11**(4), P.637-643.

[8] X. Liu, J. H. Park, A. M. Abd El-Aty, M. E. Assayed, M. Shimoda, and J. H. Shim, "Isolation of volatiles from nigella sativa seeds using microwave-assisted extraction: Effect of whole extracts on canine and murine CYP1A. *Biomed. Chromatogr.*, 2013, doi: 10.1002/bmc.2887.

[9] C. H. Chan, R. Yusoff, G. C. Ngoh, and F. W. L. Kung. Microwave-assisted extractions of active ingredients from plants. *Journal of Chromatography A*. 2011, doi: 10.1016/j.chroma.2011.07.040.

[10] Holmes. Modeling-Based Scale-Up of reactors in Microwave-Assisted chemistry. *WORCESTER POLYTECHNIC*, 2013.

[11] A. Filly, X. Fernandez, M. Minuti, F. Visinoni, G. Cravotto, and F. Chemat, "Solvent-free microwave extraction of essential oil from aromatic herbs: From laboratory to pilot and

industrial scale," *Food Chem.*, 2014, doi: 10.1016/j.foodchem.2013.10.139.

[12] M. Lis-Balchin. Lavender: the genus Lavandula. *CRC press*, 2002.

مقارنة لإستخلاص الزيت العطري باستخدام عملية التقطير بالبخار وعملية الاستخلاص بمساعدة الميكروويف

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الملخص

عمليات الاستخلاص تطورت لتصبح من العمليات الأكثر محافظة على البيئة، يعتبر التقطير باستخدام البخار من العمليات التقطير التقليدية الاكثر استخداماً في عمليات استخراج الزيوت الأساسية "العطرية" من النباتات. مؤخراً تم تطوير عملية التسخين خلال عملية الاستخلاص باستخدام الميكروويف. هدفت هده الدراسة إلى عمل مقارنة بين عملية الاستخلاص التقليدية باستخدام البخار وعملية الاستخلاص باستخدام الميكروويف من زهور الخزامي. أثبت النتائج من هده الدراسة أن التكلفة باستخدام الميكروويف ارتفعت بشكل كبير جداً مقارنة بعملية التقطير بالبخار ويرجع السبب في ذلك إلى تكلفة المولد والمفاعل وقد كانت ثمانية أضعاف تكلفة عملية الاستخلاص بالطريقة الاعتيادية في حين كانت التكلفة التشغيلية للعمليتين متساوية. بالرغم من أن تقنية الميكروويف تحتاج إلى وقت قصير وحجم مفاعل أقل لتطبيقها، فعملية الاستخلاص التقليدية كانت هي الأفضل من حيث السلامة من المخاطر التشغيلية والتكلفة الثابتة.

الكلمات الدالة:

عمليات الاستخلاص.

الاستخلاص بمساعدة الميكروويف.

التقطير بالبخار.

الزيوت الاساسية.

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