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The extraction of essential oil from patchouli leaves (*Pogostemon cablin* Benth) using microwave hydrodistillation and solvent-free microwave extraction methods

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Abstract. Patchouli plant (*Pogostemon cablin* Benth) is one of the important essential oil-producing plant, contributes more than 50% of total exports of Indonesia's essential oil. However, the extraction of patchouli oil that has been done in Indonesia is generally still used conventional methods that require enormous amount of energy, high solvent usage, and long time of extraction. Therefore, in this study, patchouli oil extraction was carried out by using microwave hydrodistillation and solvent-free microwave extraction methods. Based on this research, it is known that the extraction of patchouli oil using microwave hydrodistillation method with longer extraction time (240 min) only produced patchouli oil's yield 1.2 times greater than solvent-free microwave extraction method which require faster extraction time (120 min). Otherwise the analysis of electric consumption and the environmental impact, the solvent-free microwave extraction method showed a smaller amount when compared with microwave hydrodistillation method. It is conclude that the use of solvent-free microwave extraction method for patchouli oil extraction is suitably method as a new green technique.

1. Introduction

Essential oil is one of the potential agroindustry export commodities that can be income for Indonesia . World export -import statistic shows that the average growth of essential oil consumption and its derivatives of 5-10% per year. The increase was mainly driven by the growing need for food flavoring, cosmetic, and fragrance industries [1].

Pogostemon cablin Benth., known as patchouli, from southeast Asia has been extensively cultivated in Indonesia, Philippines, Malaysia, China, and Brazil. Essential oil produced by patchouli are one of the most important natural ingredients used in the perfume industry [2]. Patchouli plant (*Pogostemon cablin* Benth) is one of the important essential oil-producing plant, contributes more than 50% of total exports of Indonesia's essential oil. Almost all patchouli cultivation in Indonesia is a community crop involving approximately 36,461 farmers. In Indonesia, patchouli production centers are located in Bengkulu, West Sumatra, North Sumatra and Nanggroe Aceh Darussalam, and then spread to Lampung, West Java, Central Java, East Java and other provinces. The area of patchouli cultivation in 2002 was about 21,602 ha, but the oil productivity was still low with an average of 97.53 kg / ha / year. Nevertheless, Indonesia is the largest supplier of patchouli oil in the world market with a contribution of about 90%. Besides Indonesia's competitors as a supplier of patchouli oil in the world market is Malaysia, Filiphina, India, and China [3].

In the case of distillation technology it can be seen that the extraction of patchouli oil done by patchouli farmer group in Kuningan, West Java, used steam distillation system with capacity of 100 kg per boiler. The result of this distillation is 2.2 kg to 2.8 kg of patchouli oil for one patchouli oil extraction for eight hours. For once patchouli oil extraction by the steam distillation method it consumes 40 liters of kerosene [4].

Therefore, new green techniques should be considered in the extraction of essential oils with the minimum use of energy, solvent, and time. Several new methods have been developed to extract essential oils, one of these methods is using microwave (microwave-assisted extraction).

Previous research has shown that extraction with microwave is an alternative that can be developed more than conventional methods, due to high levels of product purity, minimal solvent usage, and short processing times [5]. Some extraction methods with microwave have been developed were microwave hydrodistillation method which combine hydrodistillation with microwave heating [6] and microwave steam distillation method which combine steam distillation with microwave heating [7]. Based on previous research, the extraction of essential oil from patchouli leaves has also been done by using microwave hydrodistillation method [8].

Further development of microwave hydrodistillation method is solvent-free microwave extraction method. This method has advantages over conventional methods such as have a faster extraction rate, yield, and also higher purity of extract because it does not require a solvent so it does not contact with chemicals. Based on the GC/MS (Gas Chromatography / Mass Spectrometry) analysis, the solvent-free microwave extraction method does not change the chemical components present in essential oils, and this method can be categorized as green technology because it reduces the energy requirement per mL from essential oil extraction [9].

So based on that, patchouli oil will be carried out by using microwave hydrodistillation and solvent-free microwave extraction method, which will then be compared to yield obtained, the necessary costs and the environmental impact of the extraction process from both methods.

2. Material and methods

2.1 Materials and chemicals

The materials used in this research were patchouli leaves (*Pogostemon cablin* Benth) obtained from Tulungagung, East Java, Indonesia. All samples were air dried with moisture content of 16.4%, intact size and stored at room temperature until required. The distilled water and anhydrous sodium sulphate used in the experimental work were all of analytical grade.

2.2 Solvent-free microwave extraction method

In employing solvent-free microwave extraction, we used a domestic microwave oven (EMM-2308X, Electrolux, maximum delivered power of 800 W) with wave frequency of 2450 MHz. The dimensions of the PTFE-coated cavity of the microwave oven were 48.5 cm × 37.0 cm × 29.25 cm. The microwave oven was modified by drilling a hole at the top. A round bottom flask with a capacity of 1000 mL was placed inside the oven and was connected to the three-way adapter and liebig condenser through the hole. Then, the hole was closed with PTFE to prevent any loss of the heat inside. The schematic tool can be seen on figure 1.

In the patchouli oil extraction using solvent-free microwave extraction, patchouli leaves were soaked in water for 30 min, and then removed the excess water. The wetted leaves (moisture content = 87.4%) were put in a series of round bottom flasks (1000 mL) with ratio of feed to distiller was 0.06 $g.mL^{-1}$. The extraction was carried out for 120 min under microwave power 450 W. The extraction time shall be computed from the first drop out of the condenser. The essential oils were separated using a separating funnel. To remove water, the extracted essential oils were then dried over anhydrous sodium sulphate, weighed and stored in amber vials at 4ºC until they were used for analysis. The yield of patchouli oil was found by taking into moisture content factors by the following equation [10]:

$$\text{Extraction yield } (\%, w/w) = \frac{\text{Mass of extracted essential oil}}{\text{Mass of material } (1 - \text{moisture content factors})} \times 100\,\% \quad (1)$$

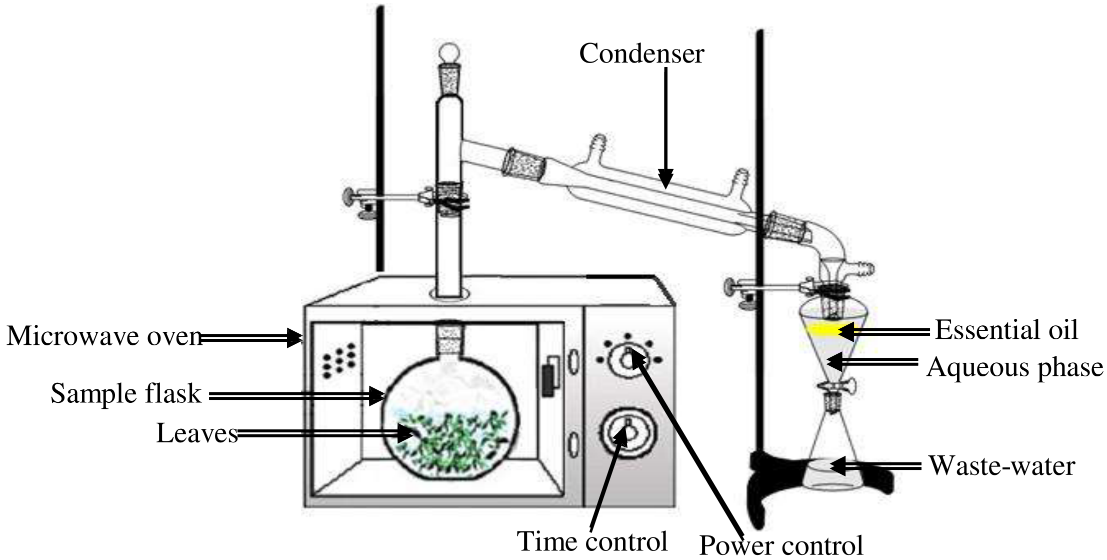

Figure 1. Schematic tool for extraction of patchouli oil using solvent-free microwave extraction method

2.3 Microwave hydrodistillation method

Patchouli leaves (60 g) were placed in a 1 L flask containing deionized water (200 mL). The flask was setup within the microwave oven cavity and a condenser was used on the top (outside the oven) to collect the extracted essential oils (figure 2). The microwave oven was operated at power 450 W for a period of 240 min. This period was sufficient to extract all the essential oils from the sample. The essential oils were separated using a separating funnel. To remove water, the extracted essential oils were then dried over anhydrous sodium sulphate, weighed and stored in amber vials at 4 °C until they were used for analysis.

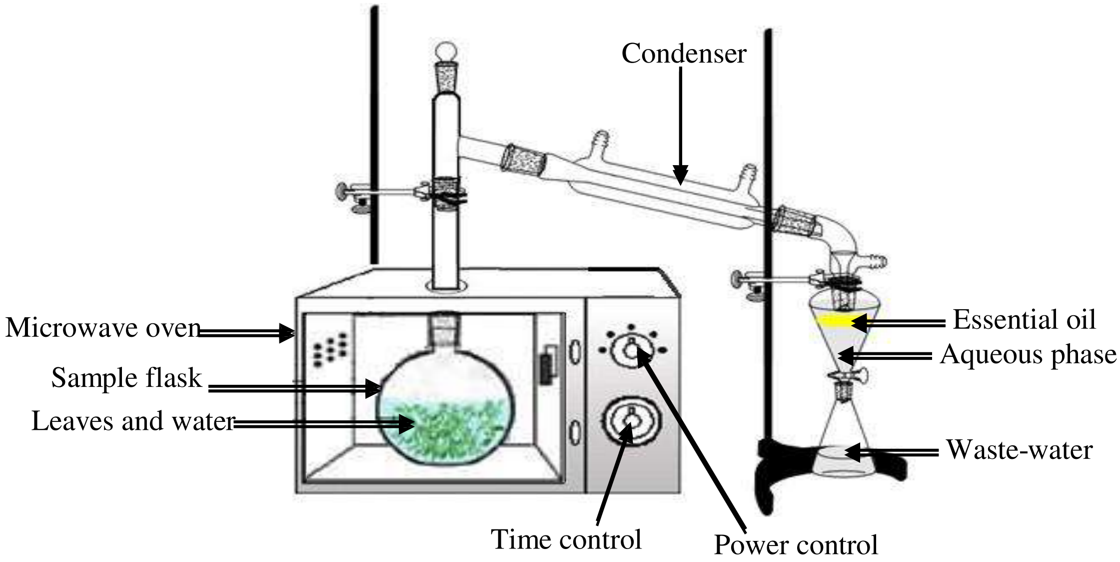

Figure 2. Schematic tool for extraction of patchouli oil using microwave hydrodistillation method

2.4 Electric consumption

The electric consumption of the different extraction methods was calculated based on the infuence of power consumption and extraction time . The general equation for electric consumption is described by equation (2):

$$E_c = \frac{Pt}{3\,600\,000} \quad (2)$$

where E_c is electric consumption (kW h), P is power consumption (W) and t is time (s).
Additionally, the relative electric consumption of the different extraction methods could be expressed by equation (3):

$$E_c^* = \frac{E_c}{m} \quad (3)$$

where E_c^* is relative electric consumption (kW h g^{-1}) and m is the mass of obtained essential oil (g) [11].

2.5 CO_2 emission

The measurements of CO_2 emitted were carried out based on the procedures mentioned in previous studies: to obtain 1 kWh of energy from coal or fossil fuels, 800 g of CO_2 will be released into the atmosphere during combustion [5]. Thus CO_2 emission is described by equation (4):

$$E_{CO_2} = \frac{E_c 800}{1000} \quad (4)$$

where E_{CO_2} is CO_2 emission (g) and E_c is electric consumption (kW h).
The relative CO_2 emission of the different extraction methods was calculated according to equation (5):

$$E_{CO_2}^* = \frac{E_{CO_2}}{m} \quad (5)$$

where $E_{CO_2}^*$ is the relative CO_2 emission (kg g^{-1}) and m is the mass of obtained essential oil (g) [11].

3. Results and discussion

3.1 Comparison of yield in patchouli oil extraction using microwave hydrodistillation and solvent-free microwave extraction methods

In general, with the longer extraction time, the yield obtained also will be greater. However, with the longer extraction time, increasing of the yield become smaller [12]. Based on figure 3, the extraction of patchouli oil by microwave hydrodistillation method has the higher yield than solvent- free microwave extraction method. This is due to the amount of water in the distiller in the microwave hydrodistillation method is less when compared with the solvent-free microwave extraction method using a soaked dry material. Where the amount of water in the distiller in microwave hydrodistillation method is about 210 mL, whereas in the the solvent -free microwave extraction method is about 260 mL. With the small amount of water in the distiller it will accelerate the temperature rising and then it will accelerate the opening of oil glands and also cause the rate of increase in yield will be faster. So the yield produced on the patchouli oil extraction by solvent-free microwave extraction method can be smaller when compared with microwave hydrodistillation method.

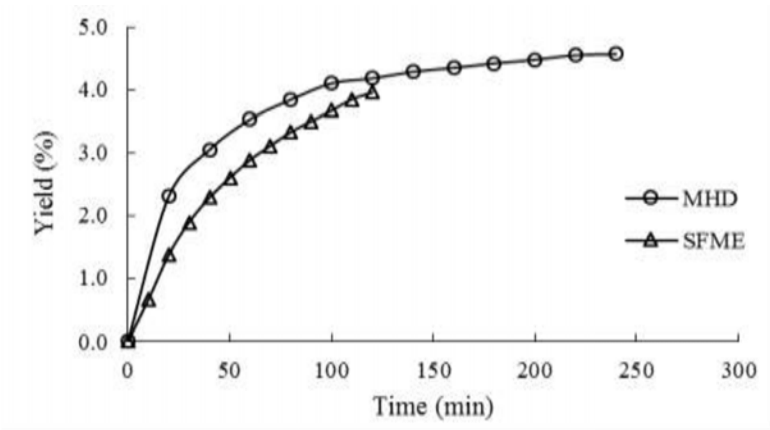

Figure 3. Comparison between the yields of patchouli oil obtained by microwave hydrodistillation (ratio of feed to solvent=0.3 gmL^{-1}, time=240 min) and solvent-free microwave extraction (ratio of feed to distiller=0.06 gmL^{-1}, time=120 min) at the microwave power was 450 W.

In the patchouli oil extraction with microwave hydrodistillation method obtained a yield of 4.6%, while the solvent-free microwave extraction method obtained a yield of 4.0%. From these data it can be seen that the difference in yield obtained between microwave hydrodistillation and solvent-free microwave extraction method is less significant, whereas in microwave hydrodistillation method with longer extraction time (240 min) only produced yield 1.2 times greater when compared with solvent-free microwave extraction method that requires faster extraction time (120 min).

3.2 Analysis of electric consumption and environmental impact of patchouli oil extraction using microwave hydrodistillation and solvent-free microwave extraction methods

In the patchouli oil extraction by the solvent-free microwave extraction method takes relatively faster than the microwave hydrodistillation method. This extraction time is related to the cost and energy required. So to know it, we conducted an analysis of electric consumption and the environmental impact of patchouli oil extraction using solvent-free microwave extraction method and microwave hydrodistillation method. An analysis of electric consumption and the environmental impact of patchouli oil extraction with both methods can be seen in figure 4.

In this study, the electric consumption requirements for patchouli oil extraction by microwave hydrodistillation method was 1.8 kWh, while for solvent-free microwave extraction method was 0.9 kWh. So it can be said that using microwave hydrodistillation method requires 2 times more electricity consumption than the solvent-free microwave extraction method. The electric consumption to obtain1 g of patchouli oil from extraction using microwave hydrodistillation method was equal to 0.8 kWh, while for solvent-free microwave extraction method was 0.5 kWh. So it can also be said that with the microwave hydrodistillation method requires an electric consumption that is 1.7 times higher when compared with the solvent-free microwave extraction method. Thus it can be assumed that the extraction of patchouli oil using solvent-free microwave extraction method requires lower operating cost when compared with microwave hydrodistillation method [8].

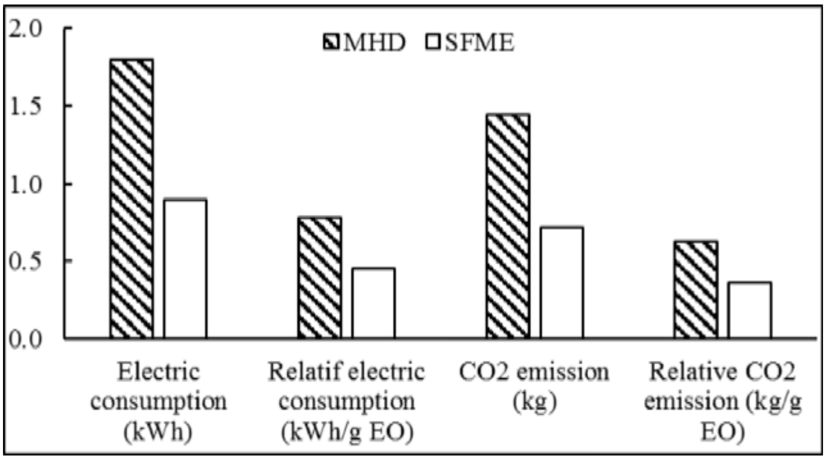

Figure 4. The electric consumption and environmental impact (CO_2 emissions) for the extraction of patchouli oil by the microwave hydrodistillation (ratio of feed to solvent=0.3 gmL^{-1}, time=240 min) and solvent-free microwave extraction method (ratio of feed to distiller=0.06 gmL^{-1}, time=120 min) at the microwave power was 450 W.

The environmental impact of the essential oil extraction can be known from the amount of CO_2 emissions produced. If 1 kWh of energy from coal or fossil fuels, 800 g of CO_2 will be released into the atmosphere during combustion [5]. The CO_2 emissions produced from patchouli oil extraction with microwave hydrodistillation method of 1.4 kg, while the solvent-free microwave extraction method was equal to 0.7 kg. It can be said that the extraction of patchouli oil by microwave hydrodistillation method produces a greater amount of CO_2 emissions than the solvent-free microwave extraction method. And to obtain 1 g of patchouli oil, CO_2 emissions produced by microwave hydrodistillation and solvent-free microwave extraction methods were 0.6 and 0.4 kg. So it can be concluded that patchouli oil extraction using microwave hydrodistillation method produces greater CO_2 emission when compared with by using solvent-free microwave extraction method. Therefore, the use of solvent-free microwave extraction method for patchouli oil extraction is suitably method as a new green technique.

4. Conclusion

Patchouli oil extraction using the solvent-free microwave extraction method is a new green technique which is better than the microwave hydrodistillation method. Where to obtain the yield, the microwave hydrodistillation method with longer extraction time (240 min) only produces yield 1.2 times greater when compared with the solvent-free microwave extraction method that requires faster extraction time (120 min). Whereas based on the analysis of electric consumption and the environmental impact, the extraction of patchouli oil with solvent-free microwave extraction method requires lower electric consumption and CO_2 emissions production is also lower when compared with microwave hydrodistillation method. So, it can be said that the use of solvent-free microwave extraction method for patchouli oil extraction is suitably method as a new green technique.

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