The Comparison of Essential Oil Extraction from Citronella Grass (*Cymbopogon nardus L.*) Using Solvent-Free Microwave Extraction and Microwave Hydrodistillation Methods

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Abstract. Indonesia is a country that has 40–50 types of essential oil-producing plants out of a total of 80 types of essential oils that enter the world market. There are several essential oil-producing plants that until now have not been used optimally. However, the extraction method of citronella oil in Indonesia generally uses conventional methods so that which requires high costs and take a long time. Therefore, it is necessary to develop a more effective and efficient method of citronella oil extraction. One of them uses the Microwave Hydrodistillation (MHD) and Solvent-Free Microwave Extraction (SFME) methods. Based on the results of the study, it showed that the extraction of citronella oil using the SFME method resulted in the yield of citronella oil of 1.0969% with a time of 60 min, and when compared with the MHD method with the extraction time of 90 min, the citronella oil yield is 0.8407%. The results of the analysis of electricity consumption and the environmental impact of the MHD method produced a larger amount than the SFME method. Thus, the SFME method is a more effective and efficient method for citronella oil extraction and a suitable method as a new green technique.

Keywords: citronella oil · Cymbopogon nardus L. · MHD · SFME

1 Introduction

Indonesia as a tropical country has very diverse biological resources. There are several essential oil-producing plants in Indonesia which until now have not been used optimally. Indonesia is a country that has 40–50 types of essential oil-producing plants out of a total of 80 types of essential oils that enter the world market, including vetiver, patchouli, sandalwood, citronella, ylang and eucalyptus [1].

The citronella plant is a type of aromatic grass in the genus Cymbopogon that contains essential oils with a subtle lemon flavor. The world's production of citronella oil is around 4,000 tons with the main producers being China and Indonesia, which produce 40% of the world's supply. Citronella oil is obtained from the leaves and stems [2]. Chemical characterization of essential oils is generally carried out using GC-MS. Citral is one of the

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essential ingredients of the oil found in several species of Cymbopogon with very large modern uses, for example as a simple ingredient for vitamin A, sugar and perfume. In traditional medicine, citronella has a function for headaches, insect repellent, fatigue and oily skin. In addition, these chemicals are widely used in the soap, cosmetic, fragrance and flavoring industries [3].

In microwave distillation, the material to be extracted is placed in a flask so that it can be penetrated by microwave radiation. Microwave extraction provides a rapid transfer of energy in water (solvent) to the extracted material, which then heats the water and the material matrix. This energy transfer takes place efficiently and homogeneously. The absorption of microwave energy by water and matrix material causes cells to rupture due to internal overheating, which will facilitate the diffusion of chemical constituents in the material out of the matrix. This event generates heat so that the cell wall will break and the essential oil can be released freely [4].

This research will use Solvent Free Microwave Extraction (SFME) and Microwave Hydrodistillation (MHD) methods. The SFME method is a method that does not use solvents in the extraction process and the extraction process will run faster with good quality. The MHD method is a method that combines hydro distillation and microwave heating using aquadest as a solvent [5]. The purpose of this study was to compare the effect of using the SFME and MHD methods on the yield of citronella oil produced and the environmental impact of the extraction process as well as the costs required for both methods.

2 Material and Methods

2.1 Material

In this study, the materials used were citronella grass (*Cymbopogon nardus* L.) obtained from Kemuning Lor Village, Arjasa District, Jember Regency in the form of fresh leaves with a moisture content of $> 49.00\%$ after being harvested directly from the fields.

2.2 Microwave Hydrodistillation (MHD) Method

In the microwave hydrodistillation (MHD) method, the instrument used is an Electrolux microwave model EMM2308X with a maximum power of 880 W and a wave frequency of 2450 MHz (2.45 GHz). The microwave used has dimensions of 48.5 cm x 37.0 cm x 29.25 cm. Microwave are adapted by production to form at the apex of the microwave. A 1000 mL round bottom flask was placed in the oven where the neck was then connected to a three-way adapter and condenser through the top hole of the microwave. To prevent heat loss in the microwave, the holes are covered with PTFE. The schematic of the citronella oil extraction equipment using the MHD method can be seen in Fig. 1.

In extraction of citronella oil using the MHD method, citronella grass (100g) was put into a 1000 mL round bottom flask filled with water (200 mL) water functions as a catalyst, where water vapor is used to remove the oil in citronella. Based on several experiments that have been carried out, the best results were obtained at the extraction time of 90 min and a power of 450 W. The extraction time was determined from the first

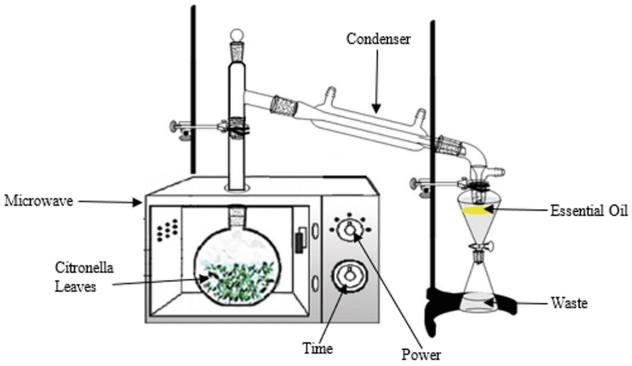

Fig. 1. Citronella oil extraction equipment design using the MHD and SFME methods [5].

drop of the condenser. The essential oil is separated using a separating funnel and then weighed and stored in a bottle vial. The yield of citronella oil can be obtained by the following equation [6]:

$$\text{Yield}\,(\%) = \frac{\text{Mass of extracted essential oil}}{\text{Mass of material}} \times 100\% \tag{1}$$

2.3 Solvent-Free Microwave Extraction (SFME) Method

Citronella grass (100g) were put into a 1000 mL round bottom flask in the SFME method. The flask was connected to a condenser placed outside the microwave to collect the extracted essential oil (Fig. 1). Based on several experiments that have been carried out, the best results were obtained at the extraction time of 90 min and a power of 450 W. The essential oil is separated by a separating funnel and then weighed and stored in a vial.

2.4 Electric Consumption

The electrical energy consumption for each extraction method is different and is calculated based on the extraction time and the effect of power consumption. The equation for electricity consumption is shown on Eq. (2)

$$E_c = \frac{P_t}{3600000} \tag{2}$$

where:

E_c = Electricity consumption (kWh)
P = Power consumption (W)
t = Extraction time (s)

2.5 CO_2 Emission

In previous studies, the measurement of CO_2 emissions was carried out on the basis that 1 kWh of coal or fossil fuel energy would be obtained by releasing 800g of CO_2 into the atmosphere during combustion [7]. For the calculation of CO_2 gas emissions, it is explained by the equation

$$E_{CO2} = \frac{E_c}{1000} \tag{3}$$

Notes:
$E_{CO2} = CO_2$ emission (g)
E_c = electric consumption (kWh)

3 Result and Discussion

3.1 Comparison of the Yield of Citronella Oil Extraction Using SFME and MHD Methods

The results of the analysis show that the extraction method will affects the yield obtained. The comparison of each method can be seen from the yield of citronella oil produced, in Table 1.

In the MHD method, the yield of citronella oil is 0.84067%. Meanwhile, the SFME method is 1.0969%. Compared to the MHD method, SFME method is much faster in terms of extraction time (60 min) and has a high yield of 1.0969%.

The longer the extraction time, the higher the yield produced until it reaches the optimum extraction point. After reaching the optimum point, the resulting yield will decrease. Extraction time that passes the optimum point will damage the dissolved substances in the material and potentially lose compounds in the solution due to evaporation [8].

As can be seen from the table, the power consumption of the MHD method is 0.68 kWh, and the relative power consumption is 0.567 kWh/g EO. While the SFME method is 0.45 kWh, the relative power consumption is 0.493 kWh/g EO. The CO_2 emission produced by the MHD method is 0.54 kg, and the relative CO_2 emission is 0.642 kg/g EO. The CO_2 emission in the SFME method is 0.36 kg and the relative CO^2 emission is 0.328 kg/g EO. These results indicate that the electricity consumption and the environmental impact resulting from the MHD method is greater than the SFME method.

Table 1. Obtaining citronella oil yield using the MHD method and the SFME method

Method	Duration	Yield (%)
Microwave Hydrodistillation (MHD)	90 Min	0.84067
Solvent-free Microwave Extraction (SFME)	60 Min	1.0969

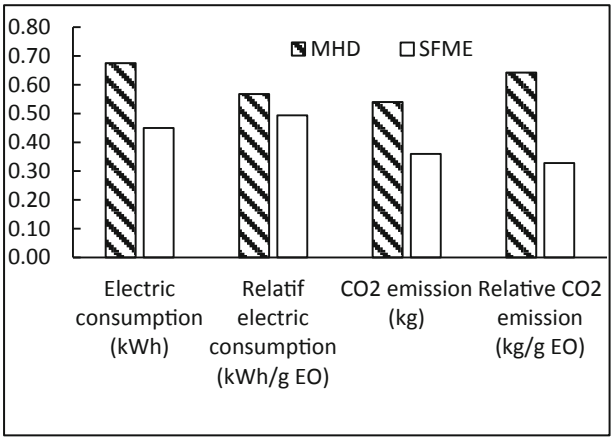

Fig. 2. The electric consumption and environmental impact (CO_2 emissions) for the extraction of citronella oil by the microwave hydrodistillation (ratio of feed to solvent = 0.5 gmL^{-1}, time = 90 min) and solvent-free microwave extraction method (ratio of feed to distiller = 0.1 gmL^{-1}, time = 60 min) at the microwave power was 450 W.

3.2 Analysis of Electric Consumption and Environmental Impact of Citronella Oil Extraction Using SFME and MHD Methods

The results of the analysis show that the extraction method affects the extraction result. In the MHD method, the yield of citronella oil was 0.84067%. While the SFME method is 1.0969%. Compared to the MHD method, the SFME method is much faster in terms of extraction time (60 min) and yields up to 1.0969%. As well as for the electricity consumption and the environmental impact resulting from the MHD method is greater than the SFME method. So, from the research that has been done, these results show that the SFME method is more attractive than the MHD method and a suitable method as a new green technique (Fig. 2).

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Authors' Contributions. DKYP conceived the original idea, ATA and SF screened and summarized all obtained literatures. BAF evaluated the generation of tables and schemes, as well as analysed the bias of the study. The main text was written by DKYP. The manuscript was initially written by ATA, and the improved and revised by DKYP.

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