Essential oil extraction from citronella grass by microwave-assisted hydro-distillation technique: a preliminary study

M Sarah¹,²* and D Estherina¹
¹Department of Chemical Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jl. Almamater Kampus USU Medan 20155
²Centre of Excellence for Sustainable Energy and Materials, Universitas Sumatera Utara, Jl. Almamater Kampus USU Medan 20155

*Email: mayasharid@yahoo.com

Abstract. This study evaluates potency of microwave hydro-distillation method to yield citronella oil from citronella grass. The presence of microwave energy provides sufficient thermal heat to accelerate extraction process. Penetration of microwave energy into citronella grass sample facilitates temperature increment inside-out from the sample which enhance citronella oil released from cell wall immediately. Parameters to be evaluated in this study are temperature profile during extraction process and citronella oil yield. The variables observed in this study were power (300 Watt, 450 Watt and 600 Watt) and time (30 minutes, 45 minutes and 60 minutes). This study observed the effect of power and time to the yield of essential oils. In this study, it was observed that the highest yield obtained during extraction using power of 600 Watt for about 60 minutes that yielded 9.7% citronella oil. The results indicate potency of microwaves as a heating medium for extracting essential oils as an effective method with respect to their efficient time feature.

1. Introduction

*Cymbopogon nardus* (*L*.), popularly known as citronella grass, is a grass cultivated in subtropical and tropical regions in America, Africa, and Asia, including Indonesia. Indonesia is one of the world's major producers of essential oils that supply approximately 85% world's demand. Citronella grass is an abundant plant in Indonesia because it is easy to grow in a variety of soils that have sufficient fertility. In the area of North Sumatra province, the existence of citronella grass is relatively abundant, but their market and utilization are low. Local people only use limited citronella as animal feed, traditional drinks, anti-mosquito additives or soap additives.

Citronella grass plants have the following characteristics such as grow clumps with fibrous roots that able to absorb nutrient elements in the soil effectively, it has elongated flat leaves resembling reeds with their normal length approximately 1 meter curved with their width ranged between 1-2 cm. The leaves color is light green to bluish green – blue while the stems are green and purplish red. The sharp aroma of citronella grass smells will release as the leaves are squeezed. The essential oil produced from of *C. nardus* is commonly used for perfumes and cosmetics, so as an insect repellent. The major chemical constituents in *C. nardus* are geraniol, citral, citronellal, and citronellol.

Several studies have reported and demonstrated the antiviral, antibacterial, and antifungal activities of this oil [1]. The common methods to extract essential oil from medicinal plant, including for lemon grass (*Cymbopogon citratus*), are hydro distillation (HD), steam distillation, and solvent extraction. It is proved through a number of studies, that the quality of essential oil mainly depends on its constituents which is primarily influenced by their extraction procedures [2].
In addition, the oil obtained through solvent aided extraction contains residues that pollute the foods fragrances to which they are added. As a means to overcome this sort of drawbacks, an advance and improved method such as microwave-assisted extraction, subcritical water extraction and ultrasound-assisted extraction have been applied to shorten extraction time, improve the extraction yield and reduce the operational costs. Recently, microwave-assisted hydro-distillation (MAHD) procedures for isolating essential oils have become attractive for use in laboratories and industry due to its effective heating, fast energy transfers and friendly environmental extraction technique. Its acceptance as potential and powerful alternative for conventional extraction techniques has been proved through several research [2]. Several studies reported utilization of microwave energy to assist chemical processing such as for sterilization [3, 4, 5, 6, 7], reaction [8], and extraction as well for various dielectric materials [9].

Therefore, as a preliminary study, the aim of the present study is to investigate the applicability of the method to extract oils from citronella grass with MAHD technique with respect to extraction yield and constituents of oils obtained under various condition. The effect of operational parameter such as extraction time and power microwave are evaluated to identify suitable process condition for extraction of citronella grass by microwave irradiation.

2. Method

The main material used in this study is citronella grass obtained from local community field located at Tarutung, northern part of Tapanuli, North Sumatra province and distill water produced from Research Laboratory Chemical Engineering Department of Universitas Sumatera Utara. The main equipment used is a microwave domestic oven (Samsung MS23K3515ASR, 230 V, 23 L) with frequency of 2450 MHz that modified with 500 mL distillation flask connected with condenser and separating funnel (500 mL).

![Figure 1](image-url) Experimental rigs modified with connector (1), condenser (2), distillation flask (3), timer (4), temperature controller (5), separating funnel (6), erlenmeyer (7) and microwave oven (8).

Temperature during extraction process is measured using a thermocouple type K (Krupp and Closs size diameter of 3 x 300 mm (Mineral Insulated) C/w Cable 2 m) connected with thermo controller (Shimaden). Temperature monitored using Arduino software to obtain their profile during extraction process.

2.1. Material preparation

Fresh citronella grass was washed from dirt, placed in an open area and dried under the sun for a certain time until homogenized moisture obtained. It cut into 1 cm pieces, wrapped by aluminum foil and
weighed for 1-2 grams sample prior moisture content determination. The wrapped citronella grass sample dried in an oven (Memmert, 230 V) at 40 °C for approximately 2 hours, put it in a desiccator until cooled wrapped sample is obtained and re-weighed the sample. Repeat this procedure until a constant weight is obtained. Water content is calculated as ratio of vaporized water to their initial content. The average water content of sample is approximately 75.23%.

2.2. Extraction process and yield calculation
Extraction of citronella essential oils with MAHD was carried out at various combination of mass (30 grams, 40 grams and 50 grams), time (30 minutes, 45 minutes and 60 minutes) and microwave power with constant H$_2$O volume of 400 ml. Time variation is conducted to find the optimal oil yield. The extraction process is carried out by varying the power of the microwave oven of 300, 450 and 600 Watt respectively. Oil is taken after extraction is stopped in accordance with each predetermined variable. Each essential oil product was evaluated their quality parameters such as density, citronella content and geraniol content. During extraction process, temperature was measured and monitored regularly.

3. Results and discussions

3.1. Effect of citronella grass and H$_2$O ratio on yield of essential oil
Figure 2 shows yield of citronella oil obtained from experimental work at various sample’s weight using constant solvent volume. The ratio between citronella grass sample to H$_2$O as solvent was varied approximately 3:40; 4:40 and 5:40 (w/v) respectively. The results of the extraction of essential oils from the citronella raw material using MAHD obtained the highest yield of 9.7% after 50 g material irradiated for 60 minutes using 600 Watt of microwave power.

Evaluation on raw material to solvent ratio in this study indicates their relationship with citronella yield. Increment of the ratio from 3:40 to 4:40 and 5:40 increases the yield from 1.1 to 1.6 and 1.9% respectively after extraction by microwave energy for 30 minutes using similar microwave power of 300 Watt. Similar results observed also from extraction of citronella grass sample carried out approximately 45 and 60 minutes respectively using power of 300 Watt. Yield of citronella grass at various materials ratio as describe above for each 45 and 60 minutes are 3.3; 3.6 and 4.5% respectively and 5.8; 6.3 and 7.7% respectively. Overall, material ratio in this study influences the yield but less significant for extraction with ratio of 3:40 (w/v). In this study, similar phenomena observed from extraction with higher level of microwave power (450 and 600 Watt).

Fundamental microwave energy dissipating concept basically rely on level of power used to emit microwave energy and mass of target material. Relationship between power and mass always represent as power density. Power density is number of microwave energy applied per kg sample during irradiation period. Power density in this study is listed in Table 1.

| Citronella Grass (g) | H$_2$O (mL) | Power Density (Watt/kg) |
|----------------------|-------------|------------------------|
|                      |             | 300 (Watt) | 450 (Watt) | 600 (Watt) |
| 30                   | 400         | 10,000     | 15,000     | 20,000     |
| 40                   | 400         | 7,500      | 11,250     | 15,000     |
| 50                   | 400         | 6,000      | 9,000      | 12,000     |

During irradiation period, extraction with less citronella grass had higher power density as compared to the one with large citronella grass sample, but as explained in Figure 2, citronella oil yielded from this particular extraction is lower as compared to the one with lower power density or extraction of large number of citronella grass. High power density usually enhances chemical processing such as extraction to obtain high temperature process. Maximum temperature attained at the end of extraction process is listed in Table 2. High temperature actually performs fast extraction, but Figure 2, Table 1 and Table 2 explains that high temperature during extraction on the other side also promotes some part of the
citronella oil dissolved into water to be taken out from the extractor during vaporization which resulting low citronella oil yield at the end of irradiation process. If compare to less sample, large sample irradiation process resulting lower power density so as lower maximum temperature attained during extraction with this MAHD technique. This situation able to retain as much as possible citronella oil product during extraction and water vaporization process resulting higher citronella oil yield.

**Table 2. Max extraction temperature of citronella grass by microwave energy at constant H₂O volume.**

| Mass (g) | Microwave Power (Watt) | Irradiation Time (minutes) | Temperature (°C) |
|----------|------------------------|----------------------------|------------------|
| 30       | 300                    | 30                         | 103              |
|          |                        | 45                         | 101              |
|          |                        | 60                         | 91               |
|          | 450                    | 30                         | 105              |
|          |                        | 45                         | 104.5            |
|          |                        | 60                         | 103              |
|          | 600                    | 30                         | 104              |
|          |                        | 45                         | 103              |
|          |                        | 60                         | 102              |
| 40       | 300                    | 30                         | 104              |
|          |                        | 45                         | 98               |
|          |                        | 60                         | 87               |
|          | 450                    | 30                         | 102              |
|          |                        | 45                         | 95               |
|          |                        | 60                         | 76               |
|          | 600                    | 30                         | 93.5             |
|          |                        | 45                         | NA               |
|          |                        | 60                         | NA               |
| 5        | 300                    | 30                         | 89               |
|          |                        | 45                         | NA               |
|          |                        | 60                         | 89               |
|          | 450                    | 30                         | 102              |
|          |                        | 45                         | 90               |
|          |                        | 60                         | 67.5             |
|          | 600                    | 30                         | 103              |
|          |                        | 45                         | 102.9            |
|          |                        | 60                         | 102.7            |

NA: Data is not available

3.2. Effect of mass, microwave power and time on yield of essential oil

This study observed citronella oil that resulted from extraction of approximately 30, 40 and 50 g of citronella grass sample increase significantly at increment of microwave power from 300 to 600 Watt. Extraction carried out with microwave energy of 600 Watt for 30 minutes yielded maximum citronella oil of 35% and 70% higher as citronella grass sample mass increases from 30 to 40 and 50 g respectively. Similar situation observed for extraction period longer than 30 minutes using constant microwave power of 600 Watt. The effect of microwave power to citronella oil yield is shown in Figure 2. Overall, increment of extraction time from 30 minutes to 45 and 60 minutes decreases the yield approximately 45% and 28% lower as compared to the one obtained at 30 minutes extraction process respectively at constant microwave power of 600 Watt.
Power increment from 300 to 450 and 600 Watt did not significantly improved the yield of oil. The citronella oil yield only increased 5.5% and 3% after extraction for 45 minutes if power increased from 300 to 450 Watt and from 450 to 600 Watt respectively. This is due to lower power density obtained for extraction with higher power at constant mass. Extraction using power of 300, 450 and 600 Watt at constant mass of 50 g for 45 minutes each obtained power density of 20,000; 15,000 and 12,000 Watt/kg respectively. On the contrary, extraction for 30 and 60 minutes indicates different results especially for treatment using power of 450 Watt. In this case, power increment from 300 to 450 Watt decreased the citronella oil yield as low as 26% and 8% after irradiated for 30 and 60 minutes respectively during extraction process. This was due to inappropriate amount of microwave energy penetrates into raw material using both 30 and 50 g samples. The sample of 30 g received excess microwave energy (10,000 to 20,000 Watt/kg) especially for extraction using microwave power of 600 Watt as shown in Table 1. Nevertheless, Table 1 shows microwave energy was not sufficient for the sample of 50 g, especially for extraction using 300 Watt of power (6,000 to 12,000 Watt/kg). Over all, prolong extraction time yielded

**Figure 2.** Yield of oil at various microwave power and citronella grass (● 30g, x 40g, ● 50g).
citronella oil higher than the one obtained from extraction for 30 minutes. Material ratio less affected the

growth yield of citronella oil. In this study time increment to extract 30 g sample from 30 to 45 and 60 minutes yielded citronella oil as much as 1, 3 and 6% respectively. It can be concluded that irradiation period is directly proportional to yield [10]. The oil yield increase with time extraction, microwave power and temperature. The distillation assisted by microwave is more efficient than conventional distillation, because we can increase the oil yield with shorter extraction time [11].

4. Conclusions

The citronella oil yielded from microwave-assisted hydro-distillation influenced by material to solvent ratio, mass, microwave power and irradiation time. This method has proven to be highly effective for citronella oil extraction due to their interesting features such as fast process with low energy. The highly efficient microwave-assisted hydro-distillation method is used for extraction of citronella oil in a short time. The highest yield in this study is the mass of material 50 g when the power is 600 Watts in 60 minutes, that is 9.7%. Overall, the effect of power and time on citronella oil yield is directly proportional.

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