Distillation of Essential Oils from the Leaves and Stems of Citronella (Cymbopogon winterianus) Utilizing a Solar Energy-Based Steam Distillation Unit with a Photovoltaic Method

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Abstract. The photovoltaic method with solar panel modules with a capacity of 100 Wp can absorb heat and convert it into electrical energy up to 100 watts/hour. It is used for the citronella oil refining process which requires 57,550 Kj of energy. By using 4 solar cell panels, within 4 hours the power generated can meet these energy needs. Based on the test results of the design of the distillation device using solar cells, the efficiency of energy absorption cannot be absorbed up to 100%, due to the occurrence of lost energy but this can be overcome with a longer absorption time. In testing citronella oil with variations in drying time and distillation time, it was found that the optimum time to produce the highest percentage of citronella oil yield was at a drying time of 18 hours with a distillation time of 6 hours, which is 1.20%. From the laboratory tests produced, citronella oil with variations in drying time and operating time has a density value ranging from 0.8751gr/ml to 0.8831gr/ml and the best GC-MS test results obtained the amount of citronellol in the sample as much as 15.73% and the amount of geraniol as much as 28.57% have met the Indonesian National Standard (SNI) 2385-2006.

Keywords: Solar Cell, Photovoltaic, Citronella Oil, Solar Panel.

1. Introduction

Indonesia is one of the countries that produces the largest essential oil in the world. Essential oil is also a foreign exchange earning commodity and one of the essential commodities that has a very high prospect is citronella oil among the 12 essential oils exported by Indonesia. Demand for citronella oil is high and tends to increase, but the price remains stable. The development of citronella oil exports is high enough to range from 9-10% where BPS (Central Bureau of Statistics) export data shows that the contribution of citronella oil to revenue in essential oil exports is around 6.89%, the third largest after patchouli oil (patchouli oil) around 60% and vetiver oil (vetiver oil) around 12.47%."[1]
Generally, citronella oil is produced by 3 methods, which are distillation, extraction, and pressing. The distillation method is used here because the distillation method is a simple and cheap technology to apply, especially for farmers from North Aceh and

M. U. H. Al Rasyid and M. R. Mufid (eds.), *Proceedings of the International Conference on Applied Science and Technology on Engineering Science 2023 (iCAST-ES 2023)*, Advances in Engineering Research 230,
https://doi.org/10.2991/978-94-6463-364-1_71

Lhokseumawe. The distillation method uses a solvent medium of water, steam, or steam-water mixture. The steam distillation method is the most widely used process. Solar Cell is a renewable energy source that is rapidly increasing its energy source to become more powerful. This system converts sunlight directly to produce electricity immediately hence it is said to be renewable energy. During periods of lower temperatures the energy produced by the panels (Photovoltaic) will also have favorable consequences for the surrounding air[2]. This energy also has the potential to address several social, economic, and environmental issues through this renewable energy. Therefore from ancient times, some humans have utilized solar energy, radiant light, and heat from the sun and the technology continues to develop at this time[3].

Solar-based distillation is possible to operate with lower operating costs, thus increasing revenue, especially in producing essential oils that require high operating costs. Of the various types of distillation processes used worldwide to extract essential oils from plant materials, commonly used processes include hydro distillation, steam distillation, and water distillation, steam distillation is considered the most profitable process[4].

This research was conducted to determine the drying time on the yield and quality of citronella oil in the distillation process (distillation), determine the effect of distillation time (distillation) on the yield and quality of citronella oil produced, and determine the capacity of the solar cell and the amount of power consumption used for the distillation process (distillation) of citronella oil.

2. Methodology

The research method used is to arrange 100 Wp (Watt Peak) solar panels and assemble then connect them to the SSC (Solar Charger Controller) to convert solar energy into electric current then connect them to the battery for storage of electric current when weather conditions are not sunny (cloudy) then connect to the inverter which is to convert DC into AC then the Heater outlet is connected to the inverter.

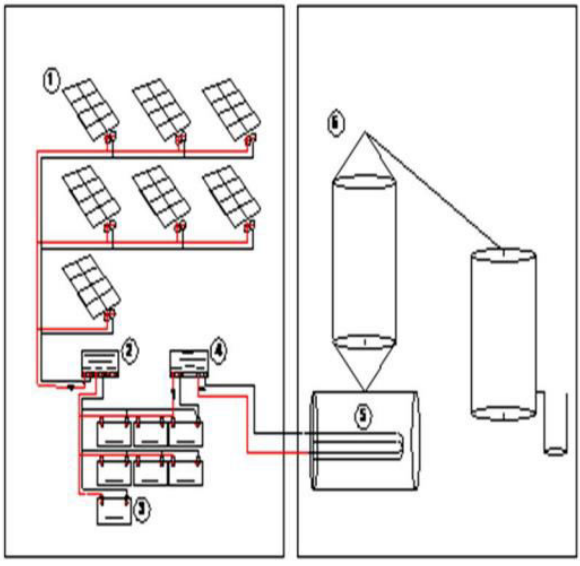

Fig.1. Schematic of Distillation Equipment Using Photovoltaic Technology.

2.1. Maintaining The Integrity Of The Specifications

The tools used are a set of distillation tools, 100ml beaker glass, 100ml measuring cup, pH meter, 100Wp solar panel, 12V 200Ah battery, DC-AC inverter, heating element, alcohol meter, stirrer, and scales. The materials used in this research are citronella, water, and distilled water.

2.2. Water Content (Sni 06-2413-2002)

Testing the water content of the leaves and stems of citronella using the oven method by weighing an empty petri dish so that its weight is obtained and inserting 5 grams of citronella leaves into the petri dish. Then the petri dish and raw citronella were oven to 105 ℃ for 2 hours, then weighed the petri dish and citronella that had dried, so that the weight was obtained, and calculated the water content in citronella with equation (1).

$$\text{Moisture content } \% = (b-(c-a))/(b) \times 100 \quad (1)$$

Description:
a = Weight of a constant dry cup
b = Initial sample weight
c = Weight of cup and dry sample that has been constant

2.3. Yield

Citronella oil that has been separated is transferred in a sample bottle (vial), and each citronella oil obtained is calculated as the yield. According to Rangana (1987), the yield value is the ratio of the mass value between the final product, namely the essential oil produced, and the mass value of the initial raw material, namely citronella stems and leaves [5]. The yield is calculated by
using equation (2).

$$\text{Yield } \% = (B-A)/C \times 100 \quad (2)$$

Description:
A = weight of empty erlenmayer
B = weight of erlenmeyer + with sample
C = Initial sample weight

2.4. Density

Density testing is done by cleaning the pycnometer by rinsing it. The pycnometer is then dried and weighed and then filled with the resulting liquid at a temperature of about 25 ° C and the lid is installed. After that, the pycnometer is filled with liquid, and made sure there is no air trapped in the pycnometer then place it on an analytical scale to be weighed [6]. Calculate the density using equation (3).

$$\text{Density } (\rho) = \text{Mass/Volume} \quad (3)$$

2.5. Organic Compound Analysis

The citronella oil obtained is then analyzed using GC-MS equipment to determine the components of the constituent chemical group compounds contained in citronella plants (Cymbopogon winterianus) and the mass spectrum obtained from citronella plants (Cymbopogon winterianus) can be compared with the mass spectrum of the comparator compounds listed in the database that has been programmed on the GC-MS tool [7].

2.6. Data Analysis

Data analysis in this study was carried out by ANOVA (Analysis of Variance) statistical test using IBM SPSS Statistic version 29 application with 95% confidence level for yield and density parameters. The ANOVA statistical test in this study used a significance value of <0.05 [8].

3. Result And Discussion

In this study, the energy required to heat water in a tank weighing 25 kg is 57,559 kJ, for energy output consists of an electric element (heater) which has an energy absorption capacity of 2,000 watts/hour which means it takes 6 hours to meet power needs, while the distillation time varies at 4; 4.5; 5; 5.5; and 6 hours. The heat absorption capacity of 1 solar cell panel is 100 Wp which in this design there are 4 panels which means that in one hour it can absorb the heat of 1,440 kJ, based on theoretical calculations at the maximum time of 6 hours the panel can absorb the heat of 8,640 kJ.

3.1. The Ability To Absorb Solar Heat With Solar Cells Theoretically And Actual

Before the research is done first calculate the ability of solar cells to absorb the heat used to heat the distillation kettle, The following graph is the relationship between the efficiency of heat absorption against time.

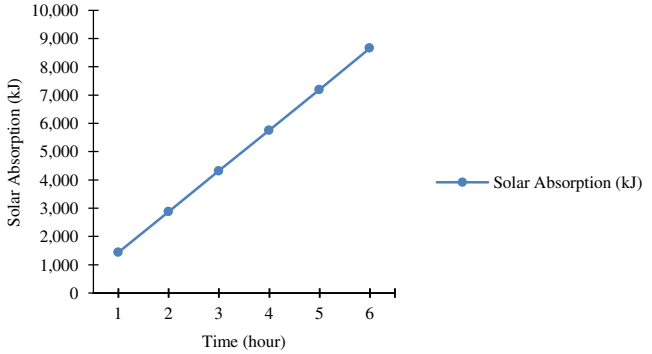

Fig.2. Relationship curve of heat absorption efficiency against time theoretically.

Based on the curve, it can be seen that the longer the absorption time, the more heat energy is absorbed by the solar cell which will be converted into a source of electricity and is directly proportional. This is by the expected goal where the power needed for boiler heating can be supplied properly.

However, in reality, it does not work that way, unfavorable weather often affects the process of absorbing solar heat to be not optimal, Below is the heat absorption curve that is measured in the field, considering that the weather in recent months tends to be cloudy and rainy, so that absorption is not maximized according to the theoretical calculations that we expect. Actual Solar Heat Absorption Capability with solar cells.

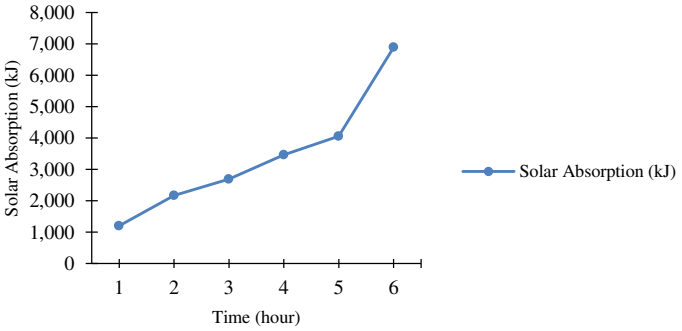

Fig.3. Relationship curve of heat absorption efficiency to actual time.

Based on the curve above, it can be seen that the absorption of solar heat tends to be unstable, It is caused by the weather and can also be caused by lost energy, not all energy absorbed can be stored properly and maximally.

During the distillation process to control excessive electric current or disconnect the distribution of electrical energy generated by solar cells stored into batteries, the Controller is used as a safety against damage to solar cells and battery damage due to excessive electrical energy supply. One of the stages is to extend the life of photovoltaic devices. In this case by the calculations contained in the journal

Experimental Study of photovoltaic panel mounting configurations for lighting structures written by Kulturela Y, et al [9].

3.2. Yield Analysis

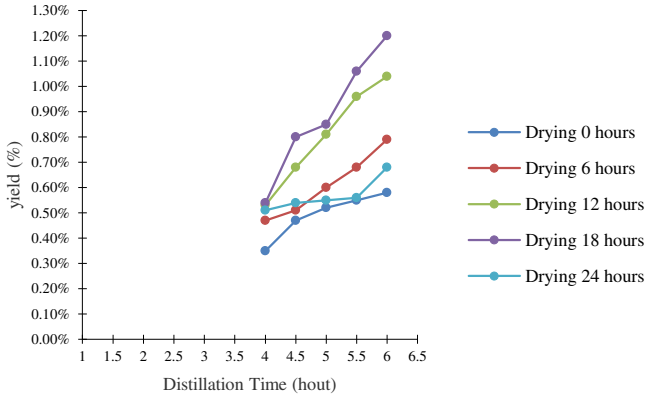

Fig. 4. Graph of the effect of operating time using solar distillation on citronella oil yield.

From the graph above, it can be seen that the amount of yield produced fluctuates. The highest yield was obtained as much as 1.20% with a distillation process of 6 hours and a drying time of 18 hours. From the data, it can be seen that the efficient drying time for citronella is 18 hours because if the drying is done for less than 18 hours, the water content in the yield is more than the oil and if the drying is done for more than 18 hours, the oil in the citronella leaves will evaporate due to too long exposure to the sun. The best distillation time is 6 hours, this happens because the longer a material receives solar heat, the more evenly the diffusion process in the material causes the distillation process to be more efficient.

Table 1. ANOVA statistical test results of yield.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Drying time	0,579	4	0,144	16,379	1,636 x10^{-5}
Distillation time	0,388	4	0,097	10,988	1,765 x10^{-4}
Error	0,141	16	0,008		
Total	1,108	24			

Source of Variation	*SS*	*df*	*MS*	*F*	*P-Value*
Waktu Penjemuran	$5{,}818 \times 10^{-6}$	4	$1{,}454 \times 10^{-6}$	25,14434	$9{,}949 \times 10^{-7}$
Waktu Distilasi	$1{,}655 \times 10^{-4}$	4	$0{,}413 \times 10^{-4}$	715,3086	$8{,}189 \times 10^{-18}$

The ANOVA statistical test results show a significant value at a drying time of 1.636x10-5 and a significant value at an operating time of 0.000176584. Both values are smaller than the significance level of 0.05 so it can be concluded that there is a significant difference between drying time and operating time on the percentage yield produced in citronella oil distillation.

3.3. Density Analysis

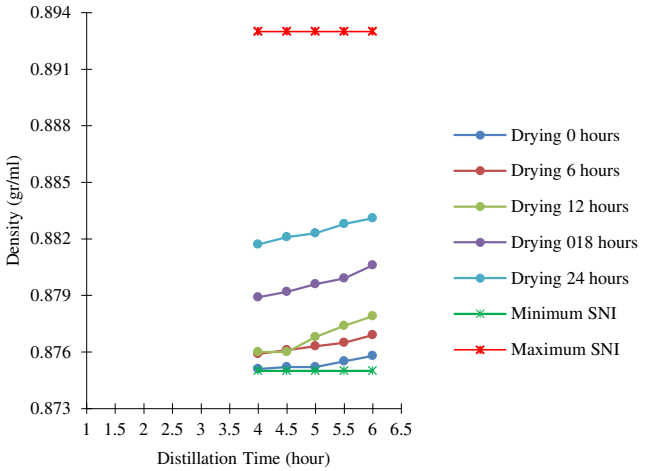

Fig.5. Graph of density value against distillation time.

From the Fig.5, it can be seen that the density value does not exceed the SNI (Indonesian National Standard) range value and the density value above is very influential on distillation time and drying time. The highest density value of citronella oil obtained is at a drying time of 24 hours with an operating time of 6 hours. The lowest citronella oil density value obtained is at 0 hours drying time at 4 hours operating time.

Table 2. ANOVA statistical test results of density.

Error	$9{,}255x10^{-7}$	16	$5{,}784x10^{-8}$
Total	$1{,}722x10^{-4}$	24	

The ANOVA statistical test results showed a significant value at a drying time of 9.949x10-7 and a significant value at an operating time of 8.189x10-18. Both values are smaller than the significance level of 0.05 so it can be concluded that there is a significant difference between drying time and operating time on the density produced in citronella oil distillation.

3.4. Compound Analysis Using GC-MS

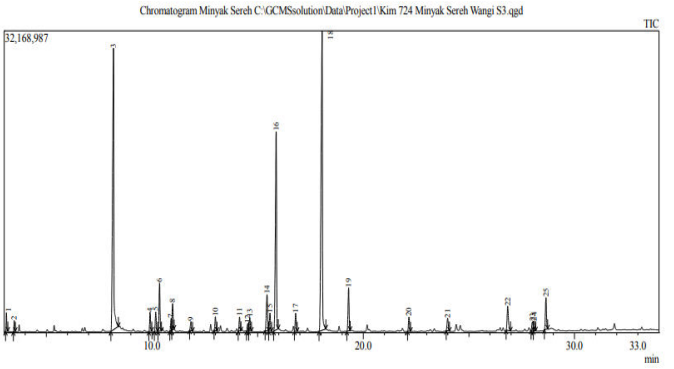

Fig. 6. GC-MS graph of citronella oil distillation results.

The results of analysis using GC-MS, it show that there are chemical compounds identified by GC-MS tools including Citronellal, Geraniol and several other compounds in citronellal, based on the results of GC-MS obtained Citronellol 15.73%, and Geraniol by 28.57%.

Conclusions

1. Drying time has an influence on the yield produced where the less drying time, the less yield is produced and the longer the drying time, the more yield is produced.

2. Distillation time influences the yield produced where the faster the distillation time is carried out, the less yield is produced and the longer the distillation time is carried out, the more yield is obtained.

3. The heating capacity of 5 kg of citronella raw materials requires 57,559 kJ of electrical energy. By using 4 solar cell panels, within 4 hours the power generated can meet these energy needs.

4. In the results of citronella oil distillation, the lowest yield obtained was 0.35% at 0 hours drying time and 4 hours distillation time and the highest yield obtained was 1.20% at 18 hours drying time and 6 hours distillation time.

Acknowledgment

The authors would like to thank the Politeknik Negeri Lhokseumawe which has funded this article and submit to ICAST 2023,.

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