Distillation of Patchouli Oil Using Firewood and Liquefied Petroleum Gas as Fuel: Effects of Yield, Quality and Cost Analyses

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Abstract. This research aimed to examine the distillation of patchouli oil using firewood (FW) and Liquefied Petroleum Gas (LPG) as fuel. The effects of yield, patchouli oil quality and cost analyses had been observed. The results showed that distillation of patchouli oil using FW obtained a higher yield than LPG. Physical-chemical properties test (color, specific gravity, refractive index and optical rotation) showed no significant difference of value and still met the requirements parameters in SNI 06-2385-2006. Meanwhile, chemical component analysis by GC-MS showed that the patchouli alcohol using FW and LPG has not met the requirement parameters in SNI. Cost analysis indicated that the distillation of patchouli oil using LPG was not profitable because of higher cost and lower yield than FW.

Keywords: patchouli oil, firewood, liquefied petroleum gas, distillation

1. Introduction

Indonesia is one of the largest essential oil exporting countries in the world. Here, there are 40 types of essential oils trades where 12 types of which have long been grown and exported to Europe, America, Australia, Africa, China, India and ASEAN countries [1]. One of the major essential oils from Indonesia is Patchouli oil (Pogostemon cablin) which is recognized to have the best quality and high oil content. It is an aromatic material of plant origin, which is widely appreciated because of its value in perfumery industry, medicine, toiletries, insecticides, anti-bacterial agent and flavoring [2]. Every year, the world’s consumption of patchouli oil and its derivatives keeps increasing. It is trigged by the increased demands from various industries. Commonly, there are three types of patchouli plant being cultivated in Indonesia: Acehnese patchouli (Pogostemon cablin), Javanese patchouli (Pogostemon hortensis) and thin patchouli (Pogostemon heyneanus). Among these types, Acehnese patchouli is the best type since it has the highest content of patchouli oil (2,5-5%) while other types only contain 0,5% of patchouli oil [3]. Patchouli oil is obtained through steam distillation from shade dried of leaves, stems and branches of patchouli plant. The leaves have the highest oil content with patchouli alcohol (Pa) being the major content between 30-50% [3]. The patchouli oil has a fresh and distinct aroma with strong fixation force which cannot be replaced by synthetic material.
Steam distillation is one of ancient technology and official approved methods for extraction of essential oil from plant materials. The plant materials charged in the alembic are subjected to the steam without maceration in water in which the steam functions as agents that break up the pores of the raw material and release the essential oil from it [4]. Generally, traditional steam distillation unit in Indonesia still uses firewood (FW) as a major fuel by reason of locally available, cheaper and can be directly used as fuel. The use of firewood for sources of energy can have negative environmental impact in term of deforestation, loss of biodiversity, soil erosion and air pollution which would contribute to environmental damage and global warming. To address these challenges, it requires effort for conversion of firewood to other sources of clear energy. Liquified Petroleum Gas (LPG) is one of fuel substituted alternatives to FW for distillation of patchouli oil. Over FW, LPG has a higher heating value, cleaner, safely stored and burned, doesn’t contain sulphur and could help reduce the negative health impacts. The objective of this study was to observe the effects of processing time, yield, quality and cost analyses of patchouli oil using steam distillation with FW and LPG as fuel. The physicochemical parameters of the patchouli oil, such as color, density, optical rotation and refractive index were analyzed and compare with SNI 06-2385-2006 standards. Meanwhile, the chemical component of patchouli oil was analyzed using Gas Chromatography-Mass Spectrometry (GC-MS).

2. Materials and Methods

Patchouli plants were collected from Desa Panga in Aceh Jaya district, Aceh Province, Indonesia. After shade dried, the patchouli plant was prepared into two samples. The first sample was distilled using FW, another sample was distilled using LPG as fuel. 50 kgs of shade dried Patchouli plant were cut into 3-4 cm pieces and placed in steam distillation unit and the system was run at temperature of 100°C, distillation time of 1-5 hours at atmospheric pressure. The extracted patchouli oil was then analyzed for physicochemical based on SNI 06-2385-2006 i.e. color, density, optical rotation and refractive index. The chemical composition of patchouli oil product was analyzed using Gas Chromatography Mass-Spectrometer (Shimadzu GCMS-QP2010).

Figure 1 shows the flow diagram of the experimental conducted in the study.

![Flow diagram of distillation patchouli by steam distillation using FW and LPG](image-url)

**Figure 1.** Flow diagram of distillation patchouli by steam distillation using FW and LPG
3. Result And Discussion

3.1 The Effect of Fuel Type and Distillation Time Toward Yield

Figure 2 presents the effects of fuel type and distillation time toward the yield of patchouli oil. The patchouli oil distillation using FW obtained a total yield of 2.64%, while distillation using LPG obtained a total yield of 1.4% in the same distillation time (five hours).

![Figure 2](image)

**Figure 2.** The effect of fuel and distillation time toward yield of patchouli oil

From Figure 2, it can be seen that the different type of fuel and distillation time have significant effects on the yield of patchouli oil. The higher yield of patchouli oil using FW as energy resources, the higher temperature in the boiler unit. In addition, it can affect the temperature of the system to increase rapidly and cause the patchouli oil to be extracted more optimally if compared to LPG. Based on the distillation time (measured from the beginning of the distillation, at the moment when the first drop of patchouli oil), it can be seen that the first distillation time obtained greater yield. However, longer distillation time obtained less patchouli oil yield. The rapid increase in the yield during the first step distillation suggested that the patchouli oil is easily accessible by the steam, the steam passes easily through the sample, evaporate and carries the patchouli oil to the cooling condenser [5].

3.2 Patchouli Oil Quality

3.2.1 Patchouli oil color

Figure 3 presents the effects of FW and LPG toward patchouli oil color. Test results by visual observation show that the different fuel leads to a significant effect to the color of patchouli oil. The dark brown color is found in the patchouli oil that has been distilled by using FW as fuel, while the light brown color is the one that has been distilled by using LPG. This is presumably due to the different temperature in system. Using FW made temperature in the system higher than using LPG. The higher temperature made darker color caused by the effect of decomposition of hydrocarbon components [6]. Compared to SNI 06-2385-2006, the change of patchouli oil color to be dark brown was still within the range of SNI 06-2385-2006 quality requirement, while in SNI standards, patchouli oil color is standardized to be yellow to reddish brown. Moreover, the differences in color also occur
due higher temperature, causing the oil that is close to the wall of the kettle become easily damaged [7].

Figure 3. The different color of patchouli oil

3.2.2 Specific Gravity

The specific gravity is an important parameter in determining the purity and quality of patchouli oil products. The specific gravity is associated with weight fraction of the compounds contained in patchouli oil. The heavier the weight fraction contained in the oil, the greater the specific gravity value [8]. Figure 4 presents the specific gravity of patchouli oil distillated with FW and LPG.

Figure 4. Specific gravity of patchouli oil distillated using FW and LPG

The specific gravity using FW (0.954) has a bit higher than specific gravity using LPG (0.952). Its means that there are many weight fraction/compounds in patchouli oil and the weight fraction to be
semi polar compounds. Moreover, based on the Figure 4, the specific gravity value of FW and LPG was still within the range of SNI 06-2385-2006 quality requirement.

3.2.3 Refractive Index
The refractive index of patchouli oils is a unique number that designates how the oil responds to and bends light. It is a test how the speed of light is altered when passing through the oil. The refractive index value is closely linked with the components arranged in the patchouli oil. The more long-chain components such as sesquiterpenes or group function that contain oxygen, the light that comes will be more difficult to be refracted [8]. In laboratories, the refractive index of patchouli oil can be analyzed using spectrometer using hollow prism. Figure 5 presents the refractive index of patchouli oil distilled using FW and LPG. From the data, it is found that there is no different value of refractive index of both patchouli oil distilled using FW and LPG where the refractive index of patchouli oil in both samples are 1.511. Referring to SNI 06-2385-2006, the quality requirements of patchouli oil refractive index range from 1.507 to 1.515. It means that the refractive index of patchouli oil distilled using FW and LPG is still within the range of SNI 06-2385-2006 quality requirement.

![Refractive Index of Patchouli Oil Distillated by FW and LPG](image)

**Figure 5.** Refractive index of patchouli oil distillated by FW and LPG

3.2.4 Optical Rotation
Commonly, when essential oil is placed in a beam of polarized light, it will have the property of rotating the plane of polarization to the right (dextrorotatory) or to the left (levorotatory). The extent of the optical activity of an oil is determined by polarimeter and measured in degrees of rotation. Both the direction and degree of rotation are as important as criteria of essential oil purity. In patchouli oil, optical rotation indicates a high patchoulol content and consequently a lower hydrocarbon content, which will provide a more pleasant aroma [9]. Figure 6 presents the optical rotation of patchouli oil distilled using FW and LPG as fuel. From the data, it is found that the different type of fuel has significant effects on optical rotation of patchouli oil products. The optical rotation value using FW (-) 52.5 was higher than optical rotation value with LPG (-) 48.2. Referring to SNI 06-2385-2006, the quality requirements of patchouli oil optical rotation range from (-) 48 – (-) 65. Therefore, the optical rotation value of patchouli oil products distilled using FW and LPG meet SNI standards.

![Optical Rotation of Patchouli Oil Distillated by FW and LPG](image)
Figure 6. Optical rotation of patchouli oil distillated with FW and LPG.

3.2.5 Chemical Component

The chemical component of the distilled patchouli oil with FW and LPG were analyzed using Gas Chromatography-Mass Spectrometer (GC-MS). The results of GC-MS analysis are shown in Table 1. It shows the number of compounds of patchouli oil distilled with FW has 15 compounds, meanwhile the component of patchouli oil with LPG has the same compounds and there are no significant differences of the main compounds content in patchouli oil.

Table 1. Chemical component analysis of patchouli oil by GC-MS

| Peak | Compound            | Retention Time (FW) | Area (%)  | Retention Time (LPG) | Area (%) |
|------|---------------------|---------------------|-----------|----------------------|----------|
| 1    | beta-Patchoulene    | 12,507              | 2.78      | 15,517               | 3.02     |
| 2    | beta elemene        | 12,719              | 1.74      | 15,723               | 1.42     |
| 3    | trans-Caryophyllene | 13,519              | 3.49      | 16,533               | 3.43     |
| 4    | alpha-Guaiene       | 14,113              | 1.57      | 16,138               | 1.45     |
| 5    | Seychellene (CAS)   | 14,283              | 6.90      | 16,309               | 7.19     |
| 6    | alpha-Patchoulene   | 14,595              | 6.52      | 16,623               | 7.30     |
| 7    | gamma-Gurjumene     | 14,670              | 2.41      | 16,695               | 2.87     |
| 8    | alpha-Guaiene       | 15,003              | 0.43      | 15,019               | 0.86     |
| 9    | alpha-Guaiene       | 15,330              | 0.74      | 15,335               | 0.82     |
| 10   | Aciphyllene         | 15,611              | 4.65      | 15,635               | 4.94     |
| 11   | delta-Guaieni       | 15,971              | 19.38     | 15,940               | 18.05    |
| 12   | Cyclohexanone       | 17,135              | 0.56      | 17,152               | 0.87     |
| 13   | Caryophyllene oxide | 17,819              | 0.82      | 17,829               | 1.66     |
| 14   | VERDIFLOROL         | 20,184              | 10.62     | 20,213               | 10.26    |
| 15   | Patchouli alcohol   | 20,414              | 23.27     | 20,450               | 21.87    |
Table 1 shows that the number of components of patchouli alcohol (Peak 15) is much higher (23.7%) compared to patchouli alcohol component using LPG (21.87%). Referring to SNI 06-2385-2006, the patchouli alcohol content in patchouli oil was at least 30%, hence the patchouli alcohol produced using FW and LPG has not met SNI standard. Patchouli alcohol is the main component characterizing the essential oil of patchouli. A minimum quality of 30% patchouli alcohol content in patchouli oil is acceptable in the essential oil market. If the quantity of patchouli alcohol exceeds 30%, it indicates even a higher essential oil quality; hence it promises a higher return [2].

3.3 Cost Analysis

In this study, the steam distillation unit for distillate of patchouli oil uses FW and LPG. However, different fuel has different effect to the cost, yield and energy required. It mainly discusses the evaluation of cost analysis of distillation patchouli plant using FW and LPG via commercial steam distillation unit with capacity of 50 kg/process. The comparison of cost analysis between distillation unit using FW and LPG can be shown in Table 2 and 3.

Table 2. Cost analysis of patchouli oil distillation using FW

| Cost Component       | Price (Rp) |
|----------------------|------------|
| Patchouli plant (50 kg x Rp 6,000/kg) | 300,000   |
| FW (1/5 mtr³ x Rp 300,000/mtr³)       | 150,000   |
| Labor cost/process   | 50,000     |
| **Total cost (a)**   | **500,000**|
| Income               |            |
| Patchouli oil (y= 2.64% x 50 kg = 1.23 kg x Rp 600,000/kg) | 738,000   |
| **Total Income (b)** | **738,000**|
| **Benefit (b-a)**    | **238,000**|

Table 3. Cost analysis of patchouli oil distillation using LPG

| Cost Component       | Price (Rp) |
|----------------------|------------|
| Patchouli plant (50 kg x Rp 6,000/kg) | 300,000   |
| LPG (3 kgs/hour x 6 hours x Rp 12,000/kg) | 216,000   |
| Labor cost/process   | 50,000     |
| **Total cost (a)**   | **566,000**|
| Income               |            |
| Patchouli oil (y= 1.4% x 50 kg = 0.7 kg x Rp 600,000/kg) | 420,000   |
| **Total Income (b)** | **420,000**|
| **Benefit (b-a)**    | **-146,000**|

From the data in Table 2 and 3, it was noted that the cost of patchouli oil distillation using FW is lower than using LPG. By using FW, every 50 kgs of patchouli plant spent the total cost of Rp 500,000 and produced 1.23 kg of patchouli oil or 2.64%; thus, it gained a total income of Rp 738,000 and get total benefit of Rp 238,000. Meanwhile, by using LPG, every 50 kgs of patchouli plant spent total cost of Rp 566,000 and produced 0.7 kg of patchouli oil or 1.4%; thus, it gained a total income of Rp 420,000 or a negative benefit (Rp-146,000). Therefore, it can be concluded that distillation of patchouli oil using LPG was not profitable because of higher cost to LPG consumption and lower yield of patchouli oil.
Conclusion
The distillation of patchouli oil using FW and LPG as fuel has been done. Test result showed distillation of patchouli oil using FW as fuel obtained a total yield of 2.64%; meanwhile using LPG fuel, it only obtained total yield of 1.4% in the same distillation time (five hours). Physical-chemical properties test of the patchouli oil (color, specific gravity, refractive index and optical rotation) indicated that the patchouli oil distilled using FW and LPG has no significant differences of value but still meets the requirements parameters in SNI 06-2385-2006. Meanwhile, chemical component analysis using GC-MS shows that the patchouli alcohol using FW and LPG has not met SNI standard. Cost analysis indicated that the distillation of patchouli oil using LPG was not profitable because of higher cost to LPG consumption and lower yield of patchouli oil.

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