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Purification of West Pasaman Patchouli Oil by Complexometry Methods to Improve the Quality and Feasibility of the Business

L Marlina[1], A Kasim[2] and T Anggraini[2.]

[1] *Agricultural Industrial Technology Department, Faculty of Agricultural Technology, Andalas University, Padang, Indonesia*
[2] *Lecturer of Agricultural Industrial Technology Department, Faculty of Agricultural Technology, Andalas University, Padang, Indonesia*

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CORRESPONDING AUTHOR

*E-mail: marlinalenny209@gmail.com

A B S T R A C T

This study aims to analyze the quality of purified patchouli oil and determine the most effective chelator in complexometric purification, and asses the feasibility of the refining business. Patchouli oil purification was carried out using optimal chelating conditions identified in previous research. The chelators used were EDTA (2.5%), citric acid (2%), and tartaric acid (1.5%). The design used was a Completely Randomized Design (CRD) with one factor, namely three types of chelates with three replications. The results of testing physical and chemical properties were analyzed by ANOVA, followed by DNMRT at the 5% level. The best chelator was selected using the MADM-SAW method. Meanwhile, the business feasibility analysis was conducted using B/C ratio, R/C ratio, BEP, NPV, IRR, and ROI parameters. This research shows that citric acid is the best chelator for refining patchouli oil. The characteristics of the refined oil are reddish yellow, specific gravity of 0.9597 g/ml, solubility in ethanol 1:10, acid number of 2.32 mg KOH/g, ester number of 7.45 mg KOH/g, Fe content 0.94 mg/kg, and patchouli alcohol 29.25%. The business feasibility analysis shows that the patchouli oil refining business is feasible with a Net B/C value of 3.7, R/C of 1.3, product BEP of 849 kg/year, and price BEP of Rp. 913.891,-/kg, NPV of IDR 1.078.107.098, IRR of 177% and ROI of 30.86%.

Contribution to Sustainable Development Goals (SDGs):
SDG 1: No Poverty
SDG 8: Decent Work and Economic Growth
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production
SDG 15: Life on Land

1. INTRODUCTION

1.1. *Research Background*

Indonesia has thousands of plants that are sources of essential oils that can be developed. Essential oils, also known as volatile oils, are aromatic oils extracted from various parts of plants, such as leaves, skin, bark, flowers, buds, seeds, and so on [1]. Essential oils have broad uses in many industrial fields (chemical, cosmetic, food, and medicine) [2]. Patchouli essential oil is obtained by steam distillation or hydrodistillation of the dried leaves of the patchouli plant Pogostemon cablin, *Benth.* [3]. Indonesia is the leading producer of patchouli oil, controlling around 95% of the world market. [4]. In 2022, the area of patchouli planting areas throughout Indonesia will be around 18,076 hectares with a total production of 2,404 tons, while in 2023, the area of patchouli planting will increase to 20,034 hectares with a total production of 3,007 tons. [5].

West Pasaman is the largest patchouli essential oil-producing area in West Sumatra. Patchouli oil production reached 249,93 tons from 2,503.00 ha in 2021 [6]. The history of the patchouli plant began when farmers used this plant as an intercrop on coffee plantations at the foot of Mount Pasaman [7]. All sub-districts in

West Pasaman produce patchouli oil, such as Kinali, Pasaman, Talamau, Gunung Tuleh, Lembah Melintang, Koto Balingka, and Ranah Batahan sub-districts. The patchouli variety developed by farmers is similar to the Aceh patchouli variety: it has thick leaves, purplish green stems, and leaves and does not have flowers.

One problem with the patchouli oil industry in West Pasaman is the use of distilling equipment that still needs to be stainless steel, which has the potential to introduce heavy metals such as iron (Fe) into the oil produced. Meanwhile, patchouli leaves contain essential oils and other organic compounds, such as flavonoids, saponins, tannins, glycosides, terpenoids, and steroids. [8]. Organic compounds such as polyphenols can interact with metals to form complex compounds that give the oil a dark color.

To reduce the dark color of patchouli oil, the purification process can be carried out using chelating agents or the complexometric purification method. Chelating agents are defined as organic or inorganic compounds that can bind metal ions to form complex ring-like structures known as chelates. The chelator will bind the metals in the oil and produce a precipitated complex. Next, filtering is carried out to separate the sediment from the patchouli oil. Chelating agents that can be used in purifying patchouli oil are ethylenediaminetetraacetic acid tetraacetic (EDTA), citric acid, and tartaric acid.

Previous studies have found optimal conditions for chelators in the patchouli oil-refining process. Ma'mun (2020) purifies patchouli oil with EDTA chelator, citric acid, and tartaric acid at a concentration of 1.5%. Patchouli oil underwent a color change from blackish brown to reddish yellow, accompanied by a decrease in Fe content from 400.1 mg/kg to 17.66 mg/kg with EDTA as a chelator, 27.88 mg/kg with citric acid, and 36.47 mg/kg with tartaric acid. [9]. Harunsyah (2011) purified patchouli oil using 0.5% Na-EDTA, 1.0% citric acid, and 1.5% tartaric acid. The results showed a decrease in Fe from 384 ppm to 19.36 mg/kg (EDTA), 36 mg/kg (citric acid), and 42 mg/kg (tartaric acid) [10]. Manalu found that optimal chelation with EDTA was carried out with a concentration of 1.5% and stirring for 90 minutes to obtain a reddish brown patchouli oil color. [11]. Primandari purified patchouli oil with EDTA and citric acid 1.5 %. The results showed that the color of patchouli oil changed from dark brown with an iron (Fe) content of 328 mg/kg to clear yellow with a Fe content of 8.87 mg/kg (EDTA) and 9.30 mg/kg (citric acid), respectively. [12].

Several previous studies have described the optimal conditions for using chelators in refining patchouli oil. However, the economic analysis of the patchouli oil refining business has not yet been explained. The price of patchouli oil tends to be more volatile than the prices of other essential oils on the market, which certainly poses a risk to the patchouli oil refining business. Therefore, conducting a feasibility study on the patchouli oil refining business is essential.

This paper aims to obtain data on the quality of patchouli oil purified using EDTA, citric acid, and tartaric acid as chelating agents. This data was used to select the best chelator in the complexometric purification of patchouli oil using the Multi-Attribute Decision Making-Simple Additive Weighting (MADM-SAW) method. Then, an analysis of the feasibility of refining patchouli oil with selected chelators was carried out. The goal is to determine the most appropriate chelator for purifiying patchouli oil, asses the product quality, and evaluate its business feasibility.

1.2. Literature Review

The patchouli (*Pogostemon cablin*, Benth) is one of the plants that produce an essential oil called patchouli oil. Patchouli oil from Indonesia contains four main compounds such as seychellene (5.3%), β-patchoulene (5.5%), δ-guaiene (16.7%) and patchouli alcohol (32.2%) [13]. Apart from oil, patchouli leaves contain other compounds such as saponins, flavonoids, tannins, glycosides, terpenoids, and steroids [14].

The organic compounds found in patchouli leaves, such as polyphenols (flavonoids), can react with metals to form complex compounds, resulting in the darkening of the oil's color. One method for chemically purifying patchouli oil is through complexometry or chelation. Complexometry involves binding metals by adding a chelating compound, which forms a metal complex with the chelating compound. [15]. Chelating agents are defined as organic or inorganic compounds that can bind metal ions to form complex ring-like structures called chelates. Citric acid, tartaric acid, and EDTA have been researched and identified as effective chelators in refining patchouli oil.

1.3. Research Objective

This paper aims to obtain data on the quality of patchouli oil purified through chelation. This data will be used to identify the most effective chelator for the complexometric purification of patchouli oil. Furthermore, the viability of refining patchouli oil with the selected chelators has been assessed.

2. MATERIALS AND METHOD

2.1. Materials and Tools

This research uses patchouli oil produced by patchouli farmers in West Pasaman. The chelating agents used technical EDTA, citric acid, and tartaric acid. The analytical materials are ethanol 96% (v/v), diethyl ether, acetone, silver nitrate ($AgNO_3$) 0.1 N solution, sodium chloride (NaCl) 0.0002 N solution, dilute nitric acid (HNO_3) (25%), ethanol 95% indicators phenolphthalein (pp), potassium hydroxide (KOH), alkali solution, 0.5 N potassium hydroxide (KOH) solution and 0.5 N hydrochloric acid (HCl).

The tools used are Gas Chromatography-Mass Spectrometry (GC-MS), magnetic stirrer, measuring cup, T180 monyl cloth, measuring flask, stirrer rod, volume pipette, bulb, drop pipette, analytical balance, spatula, stirrer, separating funnel, glass funnel, funnel support, measuring flask, analytical balance, water bath, Erlenmeyer and reagent bottles.

2.2. Analytical methods

The complexometric process was carried out using the optimal chelating conditions from previous research, namely 2.5% EDTA, 2% citric acid, and 1.5% tartaric acid. Patchouli oil was analyzed for yields, as well as its physical and chemical properties using ANOVA (Analysis of variances), followed by the Duncan Multiple Range Test (DNMRT) at the 5% level. The data from the analysis were used to select the best chelator using the Multiple Attribute Decision Making-Simple Additive Weighting (MADM-SAW) method. Meanwhile, the feasibility analysis for the patchouli oil refining business was conducted using BEP, R/C, B/C, NPV, IRR, and ROI parameters.

2.3. 2.3. Research Implementation

2.3.1 Preparation of Chelating Agents

Put the specified amount of chelator into a measuring flask. Then, add a small amount of distilled water and stir until the chelator dissolves (m/v). Once the chelator has dissolved, add the remaining distilled water to the beaker until the total volume reaches 100 ml. Finally, homogenize the chelating solution again.

2.3.2 Purification of Patchouli Oil

A total of 100 ml of patchouli oil was put into a beaker and then added with a chelating solution in a 1:1 ratio. The mixture was stirred using a magnetic stirrer for 90 minutes at a stirring speed of 500 rpm. After the complexometric process ends, the mixture is put into a separating funnel and left until the oil and water layers are separated. The water will be at the bottom and removed slowly. Meanwhile, put the patchouli oil back into the beaker. So that no water residue is left behind, the oil is filtered using a T180 monyl cloth. The filter results were stored in glass bottles for further tests including color, specific gravity, solubility in ethanol, acid number, ester number, Fe content, and patchouli alcohol.

3. RESULT AND DISCUSSION

3.1 Yield of patchouli oil after purification using different chelating agents

The yield test was carried out to determine the percentage of patchouli oil obtained after the refining process by comparing the volume of patchouli oil before and after purification. The yield of each treatment in Table 1.

Table 1. Yield of patchouli oil after purification using different chelating agents

No	Chelator	(%)	Yield (%) ± SD
1	Sitric acid	2	94.67 ± 0.57 [a]
2	Tartaric acid	1.5	95.00 ± 0.57 [a]
3	EDTA	2.5	96.67 ± 2.64 [a]
4	Crude patchouli oil	0	100

Numbers in the same column followed by the same lowercase letters are not significantly different (F count < F table) according to the 5% DNMRT test (Duncan's New Multiple Range Taste).

Based on Table 1, chelating compounds showed yields that were not significantly different at the 5% DNMRT level. 2.5% EDTA produced a yield of 96.66%, 1.5% tartaric acid of 95%, and 2% citric acid of 94.67%. During the chelation process, the chelating compound binds to metals in the oil, forming metal-chelate complexes, also known as flocculation. [16]. The chelation process produces residues in the form of water and sediment, consisting of metals and other unwanted impurities in patchouli oil.

3.2 Results of Patchouli Oil Quality Analysis

The quality of patchouli oil was assessed by Indonesian standards, specifically SNI: 06-2385-2006. The physical quality analysis encompassed color and solubility in ethanol, while the chemical analysis included testing for acid number, ester number, iron content, and patchouli alcohol. The results of the patchouli oil quality analysis in Table 2.

Table 2. The results of the patchouli oil quality analysis

Characteristics	SNI 2006 (06-2385-2006)	Crude patchouli oil	Chelator		
			EDTA 2,5%	Citric acid 2%	Tartaric acid 1,5%
Colors	Light yellow-reddish brown	Murky black	yellowish red	yellowish red	yellowish red
Specific gravity (g/ml)	0.950-0.975	0.9593[a]	0.9587[a]	0.9597[a]	0.9621[b]
Solubility	Soluble ratio 1:10	Soluble ratio 1:14	Soluble ratio 1:10	Soluble ratio 1:10	Soluble ratio 1:10
Acid number (mg KOH/g)	Max. 8	2.96[b]	2.09[a]	2.32[a]	2.19[a]
Ester number (mg KOH/g)	Max. 20	7.82[d]	6.37[b]	7.45[c]	4.85[a]
Iron (Fe) mg/kg	Max 25 mg per kg	3.87[b]	0.98[a]	0.99[a]	3.22[b]
Patchouli alcohol (%)	Min. 30	28.82	29.74	29.25	29.80

3.2.1 Colos

The L value represents brightness, ranging from 0 (black) to 100 (white). The a value indicates a mix of red and green. A positive value (a+) from 0-100 indicates a red or reddish color, while a negative value (a-) from 0-80 indicates a green or greenish color. The b value represents a mix of blue and yellow. A positive value (b+) from 0-100 indicates a yellow or yellowish color, and a negative value (b-) from 0-70 indicates a blue or bluish color.

The color of patchouli oil is determined by the a and b parameters through the conversion of the Hue value. The color of patchouli oil falls within the range of 54-90 degrees, indicating a chromaticity in the yellowish-red area. The results of variance testing indicate that the color of patchouli oil is significantly different at the 5% significance level.

The hue degree value for all samples falls within the range of 57.82 to 69.55, indicating that the chromatic value for all samples is yellowish-red. However, patchouli oil purified with

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citric acid exhibited a higher b* value compared to the other samples. This suggests that this sample appears more yellow than the others, resulting in a visually brighter color.

Patchouli oil purified with citric acid also exhibited the highest L* levels, followed by patchouli oil samples purified with tartaric acid and EDTA. This suggests that citric acid effectively reduces metal impurities that contribute to discoloration. The color of patchouli oil can be lightened and brightened by adding a citric acid, which inhibits oxidation reactions. This reaction was caused by the enzyme polyphenol oxidase, a group of copper proteins that catalyze the oxidation of phenolics to quinones, resulting in the production of brown pigments. As a result, the oil darkens due to the oxidation of phenolic compounds [17]. The CIELAB value of patchouli oil in Table 3.

Table 3. CIELAB value of patchouli oil

Treatment	L* ± SD	+a* ± SD	+b* ± SD	°Hue	Colors	Appearance
Crude patchouli oil	6.92 ± 1.52^{a}	1.27 ± 0.60^{a}	0.60 ± 0.40^{a}	65.97 ± 3.96^{bc}	yellowish red	
EDTA 2,5%	8.82 ± 1.11^{a}	1.48 ± 0.14^{a}	0.55 ± 0.04^{a}	69.55 ± 0.49^{c}	yellowish red	
Tartaric acid 1,5%	9.34 ± 0.83^{a}	0.79 ± 0.39^{a}	0.44 ± 0.44^{a}	59.35 ± 5.23^{ab}	yellowish red	
Citric acid 2%	12.79 ± 1.51^{b}	2.57 ± 0.39^{b}	1.64 ± 0.12^{b}	57.82 ± 3.24^{a}	yellowish red	

Numbers in the same column followed by the same lowercase letter indicate significantly different (F count > F table) according to the DNMRT test (Duncan's New Multiple Range Taste) at α=5% level. Information:*) L* = Lightness/brightness, a* = reddish (+)/greenish (-), and b* = yellowish (+)/bluish (-).

(a) (b) (c) (d)

Figure 1. Crude patchouli oil (a) and patchouli oil after purification (b,c,d)

3.2.2 Specific gravity

The specific gravity of patchouli oil was determined by comparing its weight to that of distilled water at the same temperature (25°C) and volume. The results of the variance testing indicate a significant difference in the specific gravity of patchouli oil at a 5% level of significance. Purification of patchouli oil with 1.5% tartaric acid chelation resulted in the highest specific gravity at 0.9621 g/ml, followed by 2.5% EDTA at 0.9593 g/ml, and 2% citric acid at 0.9597 g/ml. The crude patchouli oil exhibited the lowest specific gravity at 0.9587 g/ml. Specific gravity values of patchouli oil in Figure 2.

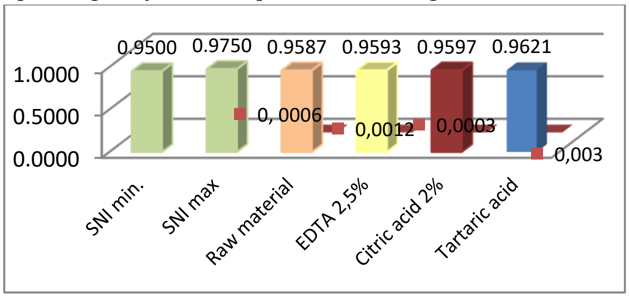

Figure 2. Specific gravity of patchouli oil

The specific gravity of patchouli oil is influenced by its components. If the oil contains a high amount of heavy fractions, its specific gravity will be higher, and vice versa. Examples of heavy fractions in patchouli oil include sesquiterpenes, patchouli alcohol, patchouli, and eugenol benzoate.These heavy fractions consist of long-chain molecules, unsaturated bonds, or numerous oxygen groups due to oxidation reactions [18]. The specific gravity value for patchouli oil in Indonesian National Standards (SNI) is between 0.950 and 0.975 g/ml [19].

3.2.3 Solubility

A significant test for patchouli oil involves measuring its solubility in 90% ethanol. This test is essential for determining the purity of the patchouli oil because the solubility value is affected by its components. According to Table 2, patchouli oil purified with complexometry shows the same solubility. Patchouli oil is soluble and becomes limpid at a ratio of 1:10, meaning 1 ml of oil requires 10 ml of 90% ethanol. In contrast, the solubility value of raw patchouli oil is 1:14, indicating that 1 ml of patchouli oil requires the addition of 14 ml of 90% ethanol to dissolve and become limpid.

The solubility of patchouli oil in ethanol is influenced by its chemical components. Essential oils containing oxygenated terpene compounds are more soluble in alcohol than those containing unoxygenated terpene compounds. The higher the content of unoxygenated terpene, the lower the solubility. Unoxygenated terpene compounds, lacking functional groups, are classified as non-polar compounds. Conversely, higher solubility of the essential oil in ethanol indicates better quality [20].

3.2.4 Acid value

The acid number serves as an indicator of the level of free fatty acids in essential oils. A higher acid number is associated with lower quality as it can negatively impact the distinctive aroma of patchouli oil. The acid compounds in patchouli oil result in an oxidation reaction, which occurs when the oil is exposed to air and is catalyzed by light [18]. The acid value of patchouli oil in Figure 3.

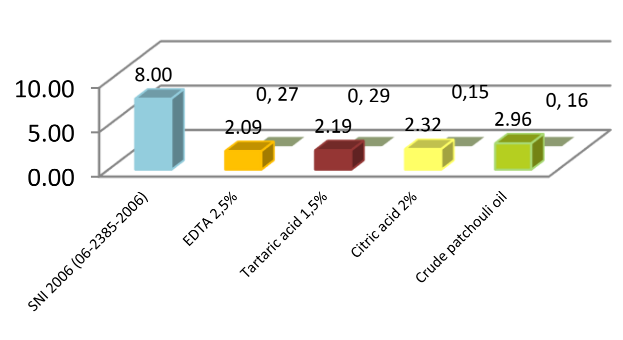

Figure 3. Acid value of patchouli oil

The results of the variance analysis reveal a significant difference in the acid number of patchouli oil at the 5% significance level (α = 5%). The Crude patchouli oil exhibited the highest acid number at 2.96 (mg KOH/gr oil), while the patchouli oil purified with 2.5% EDTA showed the lowest acid numbers. EDTA forms highly stable complexes with metal ions, leading to a reduction in free acid content after the chelation process is complete [9].

3.2.5 Ester number

The purpose of testing the ester number of essential oils is to determine the quantity of esters in patchouli oil. The ester number of patchouli oil indicates the amount of potassium hydroxide (KOH) in milligrams required to saponify the esters in 1 gram of patchouli oil [19]. The high quality of patchouli oil should have a maximum ester content of 20 mg KOH/g. The ester number of patchouli oil is shown in Figure 4.

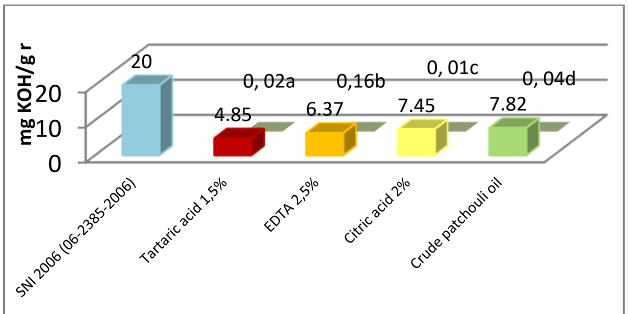

Figure 4. Ester value of patchouli oil

In this study, the results of the variance analysis indicate a significant difference in the ester number of patchouli oil at the 5% significance level ($\alpha = 0.05$). The crude patchouli oil has the highest ester number, suggesting that unrefined patchouli oil underwent more extensive hydrolysis compared to the purified sample. However, the esters in patchouli oil can also form the distinctive aroma of patchouli oil. Patchouli oil contains terpene in combination with alcohols, aldehydes, and esters which interact with each other and provide a unique smell of patchouli oil [21].

3.2.6 Iron content (Fe)

This test aims to determine the iron (Fe) content of patchouli oil Crude patchouli oil and oil purified with 2.5% EDTA, 2% citric acid, and 1.5% tartaric acid. The results of variance analysis show that the ester number of patchouli oil is significantly different at the α = 5% level. The Fe content of the Crude patchouli oil is 4.43 mg/kg. Meanwhile, patchouli oil purified with 2.5% EDTA and 2% citric acid has a Fe content of 0.91 mg/kg and 0.94 mg/kg. In contrast to the two chelators, 1.5% tartaric acid produces more Fe metal, which is 3.43 mg/kg. The difference in metal content resulting from the purification of the three chelators caused the difference in the affinity of the three in forming complexes with metals and other compounds in patchouli oil. The Fe content of patchouli oil is shown in Figure 5.

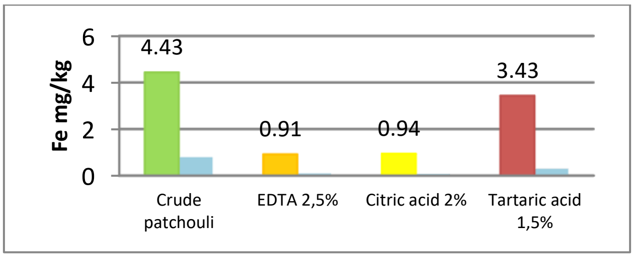

Figure 5. Fe content of patchouli oil

3.2.7 Patchouli alcohol

Patchouli alcohol ($C_{15}H_{26}O$), also known as patchoulol, is one of the main chemical components responsible for the strong, long-lasting fragrant aroma of the oil [22]. According to Table 2, the Crude patchouli oil has the lowest patchouli alcohol content at 28.82%. Patchouli oil with 1.5% tartaric acid exhibits a higher patchouli alcohol content of 29.80% than other chelators. The patchouli alcohol content for EDTA 2.5% is 29.74%, and for citric acid 2% is 29.25%. Chelation leads to an increase in patchouli alcohol content. One of the contributing factors to this increase is the binding of metals by chelating compounds [23]. The chemical components of patchouli oil were read using GCMS and depicted in the form of a chromatogram (Figure 6).

Based on Table 4, there are four largest components in all patchouli oil samples, namely α-guaiene (14.70-15.15%), seychellene (9.22-9.35%), azulene (16.13-16,70%) and patchouli alcohol (28.82-29.74%). These results are consistent with other studies that patchouli oil from Indonesia generally contains four main compounds, namely seychellene (5,3%), β-patchoulene (5,5%), δ-guaiene (16,7%) and patchouli alcohol (32,2%) [13].

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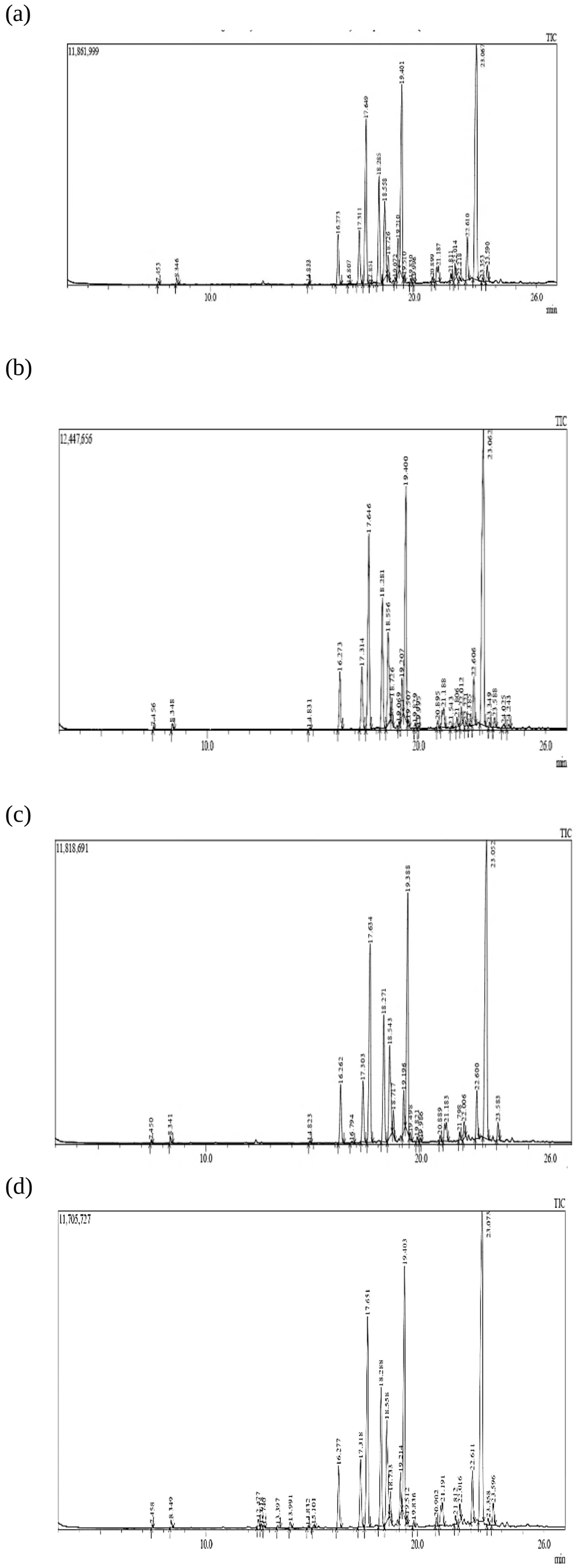

Figure 6. GC-MS chromatogram of patchouli oil: (a) crude patchouli oil, (b) 2,5% EDTA, (c) 1,5 tartaric acid, (d) 2% citric acid.

Other chemical components in patchouli oil samples in Table 4.

Table 4. The chemical components of the patchouli oil

Components	(%)			
	a	b	c	d
(1R)-2,6,6-Trimethylbicyclo [3.1.1]hept-2-ene	0.12	0.08	0.10	0.11
Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene	0.35	0.30	0.34	0.32
Cyclohexene,4-ethenyl-4-methyl-3-(1-methylethenyl	0.10	0.10	0.09	0.10
Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-d	4.18	3.93	3.93	4.05
Caryophyllene	4.82	4.55	4.66	4.53
.alpha.-Guaiene	15.05	14.85	14.70	15.15
Seychellene	9.35	9.22	9.34	9.22
1H-3a,7-Methanoazulene, 2,3,6,7,8,8a-hexahydro	7.89	7.77	7.76	7.82
1H-3a,7-Methanoazulene, octahydro-1,9,9-trim	1.11	1.16	1.21	1.13
Aciphyllene	2.37	2.24	2.23	2.33
Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl	16.48	16.57	16.13	16.70
Copaene	0.30	0.27		0.32
.alpha.-Maaliene	0.25	0.23		0.27
(2R,8R,8aS)-8,8a-Dimethyl-2-(prop-1-en-2-yl)	0.18	0.12		0.16
(E)-5-((1S,5R,8aR)-5-Formyl-5,8a-dimethyl-2-	0.26	0.34		0.28
Caryophyllene oxide	1.95	2.02		2.09
1,1,4,7-Tetramethyldecahydro-1H-cyclopropa[e	0.42	0.48	0.44	0.40
(3aR,4R,7R,7aS)-1,1,3a,7-tetramethyl-2,3,4,5,6	0.93	0.95	0.89	0.90
1,4-Dimethyl-7-(prop-1-en-2-yl)decahydroazule	0.22	0.21		3.08
Patchouli alcohol	28.82	29.74	29.25	29.80
(3S,5R,8S)-3,8-Dimethyl-5-(prop-1-en-2-yl)-2,3,	0.18	0.60	0.32	
4-Hydroxy-6-methyl-3-(4-methylpentanoyl)-2H	1.16	0.64	1.33	1.10
.alpha.-Guaiene	-	0.30		

Notes:
a = Crude patchouli oil
b = EDTA 2,5%
c = Citric acid 2%
d = Tartaric acid 1,5%

3 Determination of the best chelator by MADM-SAW method.

Multi-Attribute Decision Making (MADM) is a method used to evaluate and select a limited number of alternatives to identify the best option from a set of choices [24]. Meanwhile Simple Additive Weighting (SAW) is one of the methods used to solve MADM problems [25]. The process of determining the best chelator in the complexometric purification of patchouli oil using the MADM-SAW method is as follows.

3.1.1. At first, determine the criteria that are used as a reference in decision-making (Ci).

The criteria used in this study are the results of the analysis of the physical and chemical properties of patchouli oil and the prices of each chelator in Table 4.

Table 4. Criteria and the points

Ci	Criteria	Weight	Type
C1	Colors	0.20	*Benefit*
C2	Iron (Fe)	0.20	*Cost*
C3	Patchouli alcohol	0.20	*Benefit*
C4	Acid number	0.15	*Cost*
C5	Solutability	0.10	*Cost*
C6	Chelator price per gram	0.10	*Cost*
C7	Ester number	0.05	*Cost*

3.1.2. The next step is to assign a value to each alternative (Ai) on the criteria (Ci) in Table 5.

Table 5. Suitability Criteria of Alternative

	Ci						
Ai	C1	C2	C3	C4	C5	C6	C7
A1	8.80	0.98	29.74	2.0933	0.1	150	6.34
A2	9.34	0.99	29.25	2.3257	0.1	45	7.44
A3	12.73	3.22	29.80	2.1906	0.1	450	4.86

Description:
A1 = EDTA 2,5%
A2 = Citric acid 2%
A3 = Tartaric acid 1,5%

3.1.3. Create a normalized matrix (rij).

Based on Table 5, normalization is carried out using the following normalization formula.

$$\text{Rij} = \begin{cases} \dfrac{Xij}{Max\ Xij} & \text{(If the criteria attribute is } Benefit\text{)} \\ \dfrac{Min\ Xij}{Xij} & \text{(If the criteria attribute is } Cost\text{)} \end{cases} \quad (1)$$

Rij is the performance rating that has been normalized, Xij is what will be normalized, max {Xij} is the maximum value on the criteria, and min{Xij} is the minimum value on the criteria [26]. The results of the normalization of the decision matrix in Table 6.

Tabel 6. Normalized matrix

	(Ci)						
(Ai)	C1	C2	C3	C4	C5	C6	C7
A1	0.9613	1.0000	0.9980	1.0000	1.0000	0.3000	0.7666
A2	0.7337	0.9899	0.9815	0.9001	1.0000	1.0000	0.6532
A3	1.0000	0.3043	1.0000	0.9556	1.0000	0.1000	1.0000
	0.20	0.20	0.20	0.15	0.15	0.05	0.05

*The red column shows the benefit attribute

3.1.4. Determine the total value of each criterion

To obtain the total normalized value for each index, it is necessary to multiply it by the weighting value. The outcomes of the normalized values multiplied by the criterion weights in Table 7.

Table 7. The result of the normalized value is multiplied by the criterion weights.

	Ci						
Ai	C1	C2	C3	C4	C5	C6	C7
A1	0.1383	0.2000	0.1996	0.1500	0.1000	0.0150	0.0383
A2	0.1467	0.1980	0.1963	0.1350	0.1000	0.0500	0.0327
A3	0.2000	0.0609	0.2000	0.1433	0.1000	0.0050	0.0500

Additionally, based on the results of this study, the effectiveness of each chelator is ranked in Table 8.

Table 8. Table ranking the the effectiveness of each chelator

Chelator	Total value	Rank
EDTA 2,5%	0.8412	2
Citric acid 2%	0.8587	1
Tartaric acid 1,5%	0.7592	3

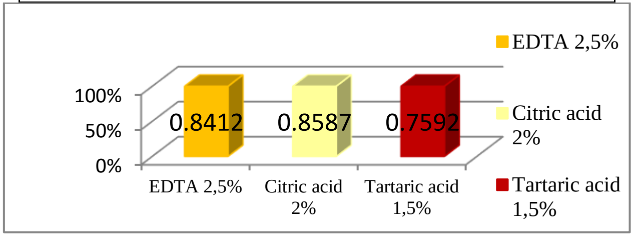

Figure 7. Diagram of selected alternative

Based on to the highest total value calculation, it is evident that 2% citric acid is more effective in refining patchouli oil compared to 2.5% EDTA and 1.5% tartaric acid. Consequently, citric acid has been selected as the best chelator for this research.

4 Economic analysis of patchouli oil refining

The economic analysis method for refining patchouli oil using citric acid is based on certain assumptions. The project is expected to span five years and requires a capital investment of IDR. 162,670,000. In the first year of this project, crude patchouli oil was purchased for IDR. 820,000 per kg. The business can procure 90-100 kg of raw patchouli oil per month.

This business feasibility analysis uses test parameters such as BEP Production, BEP Price, R/C, B/C, NPV, IRR, and ROI. The results of the economic analysis in Table 9.

Table 9. The results of the feasibility analysis of the patchouli oil refining business

No	*Criteria*	*Result*	*Description*
1	BEP production	824	feasible
2	BEP price	IDR 913.891	feasible
3	R/C	1.3	feasible
4	*Net B/C*	7.63	feasible
5	NPV	IDR 1.078.107.098	feasible
6	IRR	177%	feasible
7	ROI	30.00%	feasible
8	Payback period	0.55 years	feasible

After conducting an analysis, it was known that the Break-Even Point (BEP) value for this business's production is 824 kg per year, while the average annual production is 1104 kg per year. The BEP value for pure patchouli oil production is lower than

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the actual production amount, indicating that this business is worth pursuing. The Benefit-Cost (B/C) ratio value is 0.3, meaning that for every Rp. 100,000 incurred in costs, the business makes a profit of IDR 30,000. A business is profitable and feasible if the B/C value is greater than 0 (B/C>0) [27]. The Revenue-Cost (R/C) ratio of the patchouli oil refining business is 1.3, indicating that for every Rp. 100,000 incurred in costs, the business received revenue of IDR 130,000. A business is profitable and feasible if the R/C value is greater than 1 (R/C>1) [12]. The Net Present Value (NPV) for the patchouli oil refining business is IDR 1.078.107.098, and the initial investment value is IDR 162,670,000. The Internal Rate of Return (IRR) of the patchouli oil refining business is 177%, and the Return on Investment (ROI) is 30.86%, indicating that this business is worth pursuing.

4.5 Sensitivity analysis

Sensitivity analysis is a simulation method used to evaluate the ability of patchouli oil-refining businesses to deal with changes in current and future conditions [28]. Another definition of *sensitivity analysis* is a method used to observe the impact of changes in conditions on the results of a feasibility analysis by changing risk variables that are considered important in a business [29]. In this research, sensitivity analysis was carried out by increasing the price of patchouli oil Crude patchouli oil by 10%, 20%, 30%, 40%, and 50%, then comparing the feasibility of the business with normal investment criteria (NPV, R/C, and IRR). From the analysis, it can be seen to what extent this business will survive. Investment criteria values due to increase of patchouli oil prices in Table 10.

Table 10. Investment criteria values due to the increase of patchouli oil prices.

Year -	% *	NPV (IDR)	Net R/C	Net B/C	IRR	ROI
0	0%	1,078,107,098	1.3	3.70	177%	30.86
1	10%	1,184,345,204	1.3	3.86	185%	30.78
2	20%	1,290,583,309	1.3	4.01	193%	30.72
3	30%	1,396,821,414	1.3	4.14	199%	30.67
4	40%	1,503,059,519	1.3	4.26	206%	30.62
5	50%	1,609, 297,624	1.3	4.38	211%	30.58

*%: increase of patchouli oil prices

According to the data in Table 10, even with a price increase in patchouli oil ranging from 10% to 50%, the business still generates positive NPV, Net R/C, Net B/C, and IRR values, all of which exceed the bank interest rate of 7%. Therefore, it is advisable to continue with this business.

4. CONCLUSION

The complexometric purification of patchouli oil resulted in a yellowish-red color and effectively reduced iron (Fe) levels to 0.91 ppm with 2.5% EDTA, 0.94 ppm with 2% citric acid, and 3.43 ppm with 1.5% tartaric acid. In terms of patchouli alcohol content, the use of 1.5% tartaric acid yielded the highest level at 29.80%, followed by 2.5% EDTA 29.74% and 2% citric acid 29.25%, compared to the Crude patchouli oil at 28.82%. Based on the MADM-SAW analysis, 2% citric acid was identified as the most effective chelator for patchouli oil purification. Futhermore, the economic feasibility analysis demonstrated promising results, with B/C ratio of 0.3, R/C ratio of 1.3, BEP price of IDR 913,891,-/kg, NPV of IDR 438,769,019, IRR of 177%, and ROI of 30.86%, indicating that this business is financially viable and sustainable. These findings demonstrate that citric acid is an effective and economically viable chelating agent for refining patchouli oil, enhancing both quality and profitability in the essential oil industry

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