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Distribution and Habitat Characterization of Non-Edible Plants with Potential as Biodiesel Feedstock on Java Island, Indonesia

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ABSTRACT

Global warming, a critical component of climate change, refers to an increase in average temperatures across the atmosphere, oceans, and land. Global warming is primarily caused by the accumulation of greenhouse gases. As an archipelagic nation, Indonesia plays a critical role in mitigating climate change, as outlined in its Nationally Determined Contribution. The Indonesian government announced the B40 policy, requiring a 40% palm oil blend with 60% diesel, effective from 01 January 2025. Indonesia has abundant natural resources, including non-timber forest products from the forestry sector. Among these, oil-producing plants, such as kepuh (*Sterculia foetida*), nyamplung (*Calophyllum inophyllum*), malapari (*Pongamia pinnata*), and jatropha (*Jatropha curcas*) have potential applications in biodiesel. However, these non-edible plants are underutilized and seldom cultivated. This study examined the population distribution and characteristics of these plants to provide baseline data for future development and resource management. The spatial distribution and traits of these non-edible species were assessed, noting that jatropha, malapari, and nyamplung are predominantly found along coastal areas, whereas kepuh is distributed across Java. Clarification of biodiesel characteristics, including yield, viscosity, free fatty acid content, iodine number, and saponification number indicated that each type of oil has unique properties and potential as a bioenergy source.

Keywords: non-edible plants, kepuh, nyamplung, malapari, jatropha, biodiesel

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1. INTRODUCTION

Indonesia has a high demand for fuel oils. Fuel oil consumption is projected to reach 585,514 barrels per day in 2024 and increase to 647,301 barrels per day by 2025. The excessive consumption of fossil fuels has depleted fossil energy reserves. Indonesia has become a net importer of crude oil, as its oil production is no longer sufficient to meet the national demand. However, the use of fossil energy sources is increasing with the growing demand, which is driving the increased atmospheric level of greenhouse gases (GHGs; Wang and Azam, 2024).

A primary goal of the Paris Agreement, adopted at the 2015 Climate Change Conference in Paris (Conference of Parties, COP 21 UNFCCC), is to keep the global temperature increase below 2℃ above pre-industrial levels, with efforts to limit it to 1.5℃. To support this commitment, Indonesia formalized its commitment to the Paris Agreement by enacting Law No. 16 of 2016, which ratified the agreement under the United Nations Framework Convention on Climate Change. To fulfill this commitment, the Indonesian government is working towards achieving a 11% reduction in carbon emissions from the energy sector by 2030 (Kamandika and Dhakal, 2023). The Indonesian government is striving to encourage and promote the transition from fossil fuels to New and Renewable Energy sources as well as low-emission alternatives (Pambudi *et al.*, 2023).

Bioenergy is a viable alternative for meeting Indonesia's energy demands. Utilizing bioenergy from biological sources does not contribute to additional carbon dioxide (CO_2) emissions to the environment, as the CO_2 released is reabsorbed by plants and converted back into glucose through photosynthesis (Ersoy and Ugurlu, 2024). Indonesia has abundant natural resources, including those derived from the forestry sector in the form of non-timber forest products (NTFPs). As defined by Indonesia's Ministry of Forestry Regulations No. P.35/Menhut-II/2007, NTFPs encompass plant- and animal-based biological forest products, along with their derivatives and cultivated products, excluding wood sourced from forests. One such product is oil-producing plants, which can be utilized for bioenergy (Erdiwansyah *et al*., 2024).

Biodiesel is a fuel obtained from oil-seed crops, including palm, coconut, and corn oils. Biodiesel is considered relatively cleaner than fossil diesel in terms of GHG emissions because it utilizes natural raw ingredients (Heo and Choi, 2018; Pratika *et al*., 2024). Biodiesel used as a blended fuel for diesel is referred to as B10, B20, B40, and B100. In Indonesia, biodiesel utilization has reached the B40 level (blending 40% biodiesel and 60% diesel), following the requirement issued on 01 January 2025. This indicates that the demand for biodiesel in Indonesia is increasing. Biodiesel production requires oil with a high concentration of fatty acids. Simultaneously, the use of palm or coconut oil as feedstock for biodiesel production is discouraged because of its necessity as a human dietary component (Pratika *et al*., 2021). This strategy involves employing underutilized non-consumable oils.

Non-edible materials suitable for bioenergy production include kepuh (*Sterculia foetida*), nyamplung (*Calophyllum inophyllum*), malapari (*Pongamia pinnata*), and jarak (*Jatropha curcas)*. These materials offer several advantages as biodiesel feedstock. The oil yields were as follows: *S. foetida* 93.55% (Silitonga *et al*., 2013), *C. inophyllum* 40%–73%, *J. curcas* 40%–60% (Kurniati *et al*., 2019), and *P. pinnata* 30%–40% (Aminah *et al*., 2017). These plants grow rapidly and thrive in various environments. Additionally, they can serve as carbon storage sites and contribute to climate change mitigation programs. The potential of non-edible plants makes them valuable resources for the development of raw bioenergy materials (Erdiwansah *et al*., 2024).

However, knowledge regarding these plants—particularly their energy-related traits—remains scarce. In parts of Java Island where these plants occur naturally, they are becoming increasingly difficult to locate. This highlights the need for a detailed inventory or survey of their current distribution. This study aimed to conduct a preliminary survey through interviews in areas of Java Island believed to be accommodate these plants. Additionally, their bioenergy potential should be investigated to verify whether these plants can be utilized for biodiesel production initiatives on the island.

2. MATERIALS and METHODS

2.1. Sample collection and field survey

This study aimed to identify the locations of non-edible oil-producing plants, in jarak, kepuh, malapari, and nyamplung, by employing purposive sampling to analyze their distribution and potential. Data collection included coordinates, plant counts in various regions, and measurements of diameter, height, and productivity. The samples were collected using the inventory method to measure each plant encountered during the process. The survey and inventory of these species were conducted between 31 May and 20 October 20 2024, across several locations on Java. Jarak, malapari, and nyamplung were inventoried along the southern coastline of Java, whereas kepuh was surveyed in multiple areas spanning from East Java to Banten. The data were analyzed using QGIS to map the distribution of oil-producing plants. The findings are presented descriptively.

2.2. Oil extraction and purification

Oil characterization was performed to examine the quality of the oils extracted from jatropha, kepuh, malapari, and nyamplung. The analysis focused on several quality parameters, including oil yield (proportion of oil weight to seed weight), acid value, iodine value, saponification value, density, kinematic viscosity at 50℃ (in accordance with SNI 7431-2015), free fatty acids (FFAs; as per ASTM D5555-95), and moisture content (using the thermogravimetric method). These tests were performed at the Sub-Laboratory of Non-Timber Forest Products, Faculty of Forestry, Universitas Gadjah Mada. The results were analyzed descriptively to compare the oil quality across different parameters.

Before extracting oil from various plant seeds, the seeds were peeled to obtain kernels and then pretreated. Pretreatment of jarak, nyamplung, and malapari seeds involved oven drying at 100℃ for 1 h. Kepuh seeds were pretreated by steaming at 100℃ for 30 min. A total of 1.5 kg of seeds was prepared for each type, and extraction was performed using an expeller machine in 500-g batches with three repetitions. The extracted oil from each plant type was refined using precipitation and purification processes. The precipitation of jarak, malapari, and nyamplung oils was followed by purification using a combination of degumming and neutralization methods. The degumming process involved using 0.3% v/v of 20% H_3PO_4. The oil was placed in a three-necked flask and heated to 60℃ using a heating mantle. Once the temperature reached 60℃, the H_3PO_4 solution was added, and the mixture was stirred with a magnetic stirrer for 45 min. The oil was then transferred to a separating funnel, left to settle overnight, and washed with distilled water at 60℃. In contrast, the kepuh oil underwent precipitation without degumming.

2.3. Oil quality assessment

The quality of oil derived from the four types of non-edible oil-producing plants involved a quantitative research approach. The data were presented in numerical form as mean ± SD. The data were analyzed descriptively to compare the oil quality across various parameters summarized in section 2.2.

2.4. Fatty acid composition

Fatty acid methyl esters obtained from 0.1 mL of each oil sample diluted with 10 mL of n-hexane were analyzed using gas chromatography-mass spectrometry (GC-MS). The method can identify the chemical composition of biodiesel and quantify fatty acid esters. The analysis utilized an RTX-5MS capillary column (30 m × 0.25 mm, 0.25 μm ID; GL Sciences, Tokyo, Japan), with the column temperature programmed to rise from 70℃ (held for 2 min) to 290℃ at a rate of 5℃/min. The injection temperature was maintained at 200℃ and the detection temperature was set at 285℃ with a mass range of 50–666 m/z. Helium served as the carrier gas at a 1:80 split ratio with internal standards. The retention time comparison range was 25 to 45 min.

Chemical components were quantified using the relative peak area method in chromatography. Compound identification utilized the National Institute of Standards and Technology (NIST) 11 database library. Each oil type was tested in triplicate. The data for the chemical component analysis were summarized as the five main fatty acids, presented in a table with their average percentages ± SD.

3. RESULTS and DISCUSSION

3.1. Distribution of non-edible plants on Java Island

The investigation and identification of the four types of non-edible plants were performed from May 31 to October 20, 2024, at various locations on JavaIsland. Jarak, malapari, and nyamplung were mapped along the southern coast of Java, and kepuh was examined at several locations from East Java to Banten. Field observations revealed jarak (1,546 trees), kepuh (546 trees), malapari (204 trees), and nyamplung (921 trees) in coastal regions and lowland forests across Java Island. These plants with biodiesel potential are distributed from the easternmost to westernmost parts of the island.

The distribution of non-edible plants on Java Island is shown in Fig. 1. Jatropha was mostly found along the island's southern coast. Jatropha was found in four provinces: D.I. Yogyakarta (Bantul and Kulon Progo Regency), Central Java (Purworejo and Cilacap Regency), West Java (Sukabumi Regency), and Banten (Banten Regency). Jatropha plants were cultivated by local residents decades ago in several areas, particularly in Central Java (Purwodadi Regency) and West Java. However, they are no longer found in these cultivated areas. The regeneration of jatropha plants has been discontinued because jatropha is no longer a popular raw material for fuel generation, owing to its high production costs. During the Japanese colonial period, the jatropha plant was plentiful and easily harvested, because it was employed as a weapon lubricant and raw material for fuel during the fuel crisis of the 1940s.

Kepuh plants were identified in Banyuwangi, Jember, Blitar, Kediri, Trenggalek, Nganjuk, Bojonegoro (East Java), Blora, Semarang, Boyolali, Klaten, Pemalang, Brebes (Central Java), Sleman, Kulon Progo, Bantul, Gunung Kidul (D.I. Yogyakarta), Cirebon, Majalengka, Bogor (West Java), Central Jakarta (D.K.I. Jakarta), South Tangerang City, Cilegon (Banten). Kepuh trees were most numerous in Cepu, Blora, and Central Java, where they were widely scattered rather than clustered. Mature kepuh trees are easy to harvest and are commonly found in cemeteries. However, the overall number remains relatively small, with only a few seedlings detected. Kepuh seeds have a thick skin cover and require dormancy-breaking treatments to germinate. Wildlife and other animals may interfere with breeding by consuming seeds or damaging young trees.

Kebumen Regency was found to have the largest population of malapari plants, which were scattered along the coastline. Fewer malapari trees were found in Purworejo and Triangulation Beach within Alas Purwo

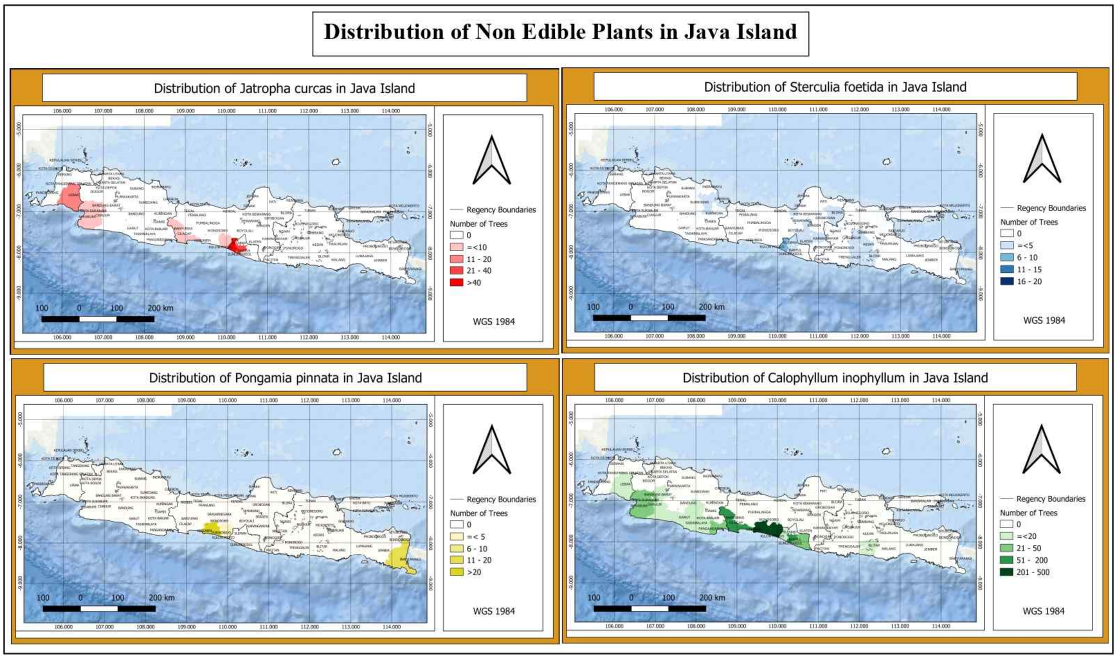

Fig. 1. Map for distribution of non-edible plants in Java Island.

National Park, Banyuwangi, East Java. In both areas, malapari plants were located along the coast. The trees in the Purworejo and Kebumen Regencies were observed to bear young, green fruits, whereas those in Alas Purwo National Park did not produce fruit at all. Malapari plants are typically found in coastal areas. Because of the simplicity of harvesting and abundance of seeds, this plant is frequently regenerated and improved as a research subject for producing carbon credits and fuel feedstock.

Distribution and population of nyamplung trees across various regions. Nyamplung trees are evenly distributed across several districts and cities, including Bantul, Gunung Kidul, Sukabumi, Lebak, Pangandaran, Tasikmalaya, Garut, Cianjur, Kebumen, Cilacap, and Purworejo. These plants typically grow in clusters, with the Kebumen Regency hosting the largest population, with a total of 400 trees. The remaining individuals were spread across Yogyakarta, Central Java, West Java, East Java, and Banten provinces. Nyamplung trees are commonly found in various coastal areas of Java and are likely to be present in other regions as well.

These plants can grow effectively in environments ranging from coastal areas to highlands up to 500 m above sea level. They thrive in sandy soils—with low to high sand content—as well as in humus-rich soils. Nyamplung flourishes in a wide variety of environments, including deserts. This plant produces fruit throughout the year and is relatively easy to regenerate because it can grow in both monoculture and mixed forests. Consequently, because of its high oil content, nyamplung has enormous potential as a source of biofuels, including biodiesel.

3.2. Types of non-edible plants and their habitat characteristics

The characteristics of the four types of non-edible plants on Java are presented in Table 1. These four plant species have morphological characteristics that allow them to grow in different geographical areas. Jarak grows at altitudes of 2 to 9 m above sea level, close to coastal areas. Jarak plants are mostly intentionally planted in garden fences. Jatropha plants range in height from 1.3 to 7 m, and range in diameter from 3.31 to 14.33 cm. The diameter obtained can be used to predict the age of jarak plants, which ranges from 3 to 14 years. Jarak plants are found growing in areas with temperatures of 22.03℃ to 28.05℃, humidity between 76.51% and 86.54%, and rainfall between 116.97 to 194.92 mm. Some areas in Yogyakarta Province, such as Gunung Kidul and jarak trees, bear young fruits. In some areas, such as Kulon Progo, Bantul, and Banten, jarak trees bore mature fruits ready for harvesting. Conditions vary by region, with some trees still flowering or bearing young fruits. Jarak has the potential to produce 2.5 to 3.5 tons/ha/year.

In this study, kepuh plants were mostly found in cemetery areas and were mostly wild plants. The estimated age of the kepuh plants can reach 298 years. Age estimation was performed by dividing the stem diameter by the Average Annual Growth Rate of kepuh plants, which was 1.41 cm/year. Young kepuh plants are typically seedlings that have sprouted from mature kepuh plants in the area or have been deliberately planted by several parties. Some kepuh plants are found in coastal areas, while other are located in highland areas, as the species can grow at various altitudes ranging from 3.6 to 343 m above sea level. The stem diameter of the kepuh plant varies from 9 to 420 cm, depending on the age of the plant. The height of the kepuh plants ranges from 7 to 46 m. Kepuh plants can grow in areas with temperatures of 22.03 to 29.19℃, humidity levels of 69.22% to 86.54%, and rainfall between 116.97 to 229.5 mm. Kepuh plants in Yogyakarta, Central Java, and East Java are mostly mature and ready for harvest, whereas those in West Java are still in earlier growth stages. The productivity of kepuh plants is 10 to 17 seeds per fruit,

Table 1. Characteristics of various non-edible plants on Java

No	Type	Habitat	Altitude (mdpl)	Height (m)	Stem diameter (cm)	Estimated age (years)	Temperature (℃)	Humidity	Rainfall	Seed productivity
1	Jarak Pagar (*Jatropa curcas*)	Coastal area	2–9	1.3–7	3.31–14,33	3–14	22.03–28.05	76.51–86.54	116.97–194.92	2.5–3.5 tons/ha/years (Henning, 1996)
2	Kepuh (*Sterculia foetida*)	Lowland, coastal area	3.6–343	7–46	12.74–420	9–298	22.03–29.19	69.22–86.54	116.97–229.5	300 kg /individual tree/year (Musawaa *et al*., 2022)
3	Malapari (*Pongamia pinnata*)	Coastal area	3–10	3–28	4.46–76.43	3–59	26.76–27.83	77.16–78.62	174.03–216.67	90 kg/individual tree/year (Alimah, 2011)
4	Nyamplung (*Calophyllum inophyllum*)	Coastal area	0–289	1.75–16.5	2.13–79.55	3–111	21.72–28.05	70.46–86.54	116.67–216.67	20 ton/ha/year (Bustomi *et al*., 2008)

or 300 kg seeds/ha/year (Yoga *et al.*, 2025).

The study identified malapari plants in coastal areas. Malapari plants can grow at an altitude of 3 to 10 m above sea level. Malapari plants grow wild at an estimated age of 3 to 59 years. Age assessment performed as described for kepuh plants yielded a value of 1.3 cm/year. The diameters ranges from 4.46 to 76.43 cm and tree heights ranged from 3 to 28 m. Malapari plants are still young or have no fruits at all. Climatic conditions in the area where malapari plants grow range from temperatures of 26.76℃ to 27.83℃, humidity between 77.16% to 78.62% and rainfall ranging from 174.03 to 216.67 mm. The productivity of malapari plants was 90 kg seeds/tree per year.

Nyamplung plants were found in as many as 921 trees and were spread along the coastal areas. Nyamplung plants are mostly planted as coastal abrasion barriers, with an estimated age of 3–111 years. Age estimated as previously described yielded a value of 0.715 cm/year. Nyamplung plants were found at altitudes from 0 to 289 m above sea level with temperatures from 21.72℃ to 28.05℃, humidity from 70.46% to 86.54% and rainfall from 116.67 to 216.67 mm. Morphological characteristics of the nyamplung plants varied, ranging from 2.13 to 79.55 cm in diameter with a height of 1.75 to 16.5 m. The productivity of nyamplung plants can reach 20 tons/ha per year.

3.3. Yield and quality of biodiesel from non-edible plants

Determination of oil quality is oriented towards the final product in the form of clean vegetable oil, which is tested using several parameters to describe the oil quality. The oil parameters refer to the utilization of vegetable oil in diesel fuel or biodiesel. The parameters used were oil yield, acid number, iodine number, saponification number, FFA content, moisture content, density, and kinematic viscosity. The results of vegetable oil testing are shown in Table 2. To compare the quality of vegetable oils that can be used as a reference, the parameters of yield, iodine number, saponification number, and density must have high values. Good quality must have low values for the acid number, FFA content, moisture content, and oil viscosity.

The highest yields were obtained from the extraction of nyamplung oil at 55.36%, kepuh oil at 24.32%, and jatropha oil at 23.38%, whereas the lowest yield was obtained from the extraction of malapari oil at 13.94%. Oil yield is an important parameter in the utilization of vegetable oil in diesel fuel because it affects the level of plant productivity and the calculation of production costs used to produce 1 liter of oil. Among the vegetable oils extracted, the nyamplung oil had the highest yield. Nyamplung oil has an advantage in oil yield compared with castor, kepuh, and malapari oils. A high

Table 2. Oil quality of various non-edible plants

Type	Yield (%)	Acid number (mg KOH/g)	Iodine numbers (g-I_2/100 g)	Saponification numbers (mg KOH/g)	FFA (%)	Water content (%)	Density (kg/m^3)	Viscosity (mm^2/s)
Jatropha	23.38	4.88	8.73	228.24	4.86	0.20	867.00	23.59
Kepuh	24.32	1.78	31.59	240.11	1.62	0.06	877.38	29.88
Malapari	13.94	4.15	31.73	222.60	5.17	0.07	866.00	31.73
Nyamplung	55.36	23.34	18.51	209.00	19.68	0.04	937.64	34.25

FFA: free fatty acid.

oil yield is beneficial for economics and productivity.

The acid number is a number that states the content of FFAs in fat or fatty oil (Uçar *et al*., 2024). The acid number of the extraction results in this study ranged from 1.78–23.34 mgKOH/gr. The highest was found from nyamplung oil and the smallest was found from kepuh oil. The number of acids in the oil is influenced by the FFA content. Fatty acids in seeds generally bind to glycerol compounds and form triglyceride compounds. However, fatty acids can also be found as FFA and do not bind to triglyceride compounds, which causes the acid number in the oil to be high (Tan *et al*., 2023). Each plant species has a different FFA value, which is influenced by the fatty acid composition of the oil. The acid number of vegetable oil is an important parameter for its utilization in biofuels. Good quality oil has a low number of acids. Of all the vegetable oils, kepuh oil had the lowest acid number.

The iodine number indicates the level of fat unsaturation. In this study, the iodine number of the extracted oils ranged from 8.73 to 31.73 g-I_2/100 g, with the highest value observed in malapari oil (31.73 g-I_2/100 g) and the smallest was found from jatropha oil (8.73 g-I_2/100 gs). The iodine number is a metric used to determine the degree of unsaturated fatty acids, primarily corresponding to the presence of double bonds capable of reacting with iodine (Helwani *et al*., 2021). Unsaturated fatty acids are characterized by the presence of double bonds in their carbon chains (Maulina *et al*., 2020). A higher iodine number indicates a greater number of C = C double bonds in fat (Atabani *et al.,* 2013). The iodine number of the oil is an important parameter for the utilization of vegetable oil in biodiesel. Good quality oil has a high iodine number value (Huang *et al*., 2022). Among all vegetable oils, malapari oil has the highest iodine number.

The saponification number is a number that states the amount (mg) of KOH required to saponify one g of fat or oil (Ivanova *et al*., 2022). The saponification number of the extraction results in this study ranged from 209 to 240.11 mgKOH/g, with the highest value observed in kepuh oil and the smallest in nyamplung oil. The oil saponification number is an important parameter for the utilization of vegetable oils in biofuels. Good quality oils have high saponification numbers. Of all vegetable oils, kepuh oil had the highest saponification number.

FFA content is a parameter that determines the amount of fatty acids not bound to glycerides due to hydrolysis in the oil. The FFA content of the extraction results in this study ranged from 1.62% to 19.68%, where the highest was found from nyamplung oil and the smallest was found from kepuh oil. The level of fatty acids in vegetable oil can be one of the parameters that determines the quality of the oil. A high FFA content indicates that the FFAs present in vegetable oil are also high; thus, the quality of the oil is even lower (Vicentini-Polette *et al*., 2021). The FFA content of oils is an important parameter for the utilization of vegetable oils in biofuels. Good quality oil has a low FFA content value (Pratika *et al*., 2024). Of all vegetable oils, kepuh oil had the lowest FFA content.

Moisture content is the amount of water contained in the oil, and it affects the fuel value. The moisture content of the extraction results in this study ranged from 0.04% to 0.20%; the highest found in the jatropha oil and the smallest in nyamplung oil. The moisture content of vegetable oil is a key parameter for assessing its quality. The high water content of vegetable oils causes hydrolysis, which increases its FFA content in vegetable oil (Emebu *et al*., 2022). Water can trigger the growth of microbes that produce enzymes that hydrolyze fats and cause rancidity. The moisture content of oil is influenced by the circumstances or conditions at the time of seed collection and the process carried out during oil extraction (Baena *et al*., 2022).

Density is defined as the mass per unit volume of an object. The density of the extraction results in this study ranged from 866 to 937.44 kg/m^3, with the highest density found in nyamplung oil and the smallest in malapari oil. Oil density is an important parameter in the utilization of vegetable oils in biofuels. Good quality oil has a high density value (Alomair *et al*., 2016). Of all vegetable oils, nyamplung oil had the highest density.

Viscosity is a quantity or measure that expresses the viscosity of a fluid and shows the amount of friction in the fluid itself. The viscosity of the extracted oil in this study ranged from 23.59 to 34.25 mm^2/s; the highest was found from nyamplung oil and the smallest was found from jatropha oil. The greater the viscosity of a fluid, the more difficult it is for the fluid to flow and the more difficult it is for an object to move in the fluid. The viscosity of an oil is influenced by the content of unsaturated fatty acids and the composition of its constituents contained in the oil. Unsaturated fatty acids have double bonds in their carbon chains that affect the liquid point (Alomair *et al*., 2016).

The chemical components of oil from various types of energy-producing plants were identified to determine the main constituent fatty acids in the oil. The main chemical components of each type of oil consisted of the five fatty acids with the highest concentrations. The main chemical components of the oils from various types of energy-producing plants are listed in Table 3.

The fatty acid composition was determined using GC-MS. The GC-MS method combines gas chromatography for sample separation with MS. The fatty acid compositions of the vegetable oils extracted in this study are shown in Table 3. The fatty acid composition was analyzed using GC-MS, and the five main components with the largest percentages were obtained. Based on the results shown in Table 3, the overall oil was shown to be dominated by unsaturated fatty acids, whereas jarak oil was dominated by linoleic acid at 31.83%, kepuh oil by sterkulat acid at 57.5%, and malapari and nyamplung oil by oleic acid at 59.62% and 43.70%. The fatty acid content can be used to distinguish the characteristics and quality of each oil.

Biodiesel can be made from non-edible oils, such as castor, kepuh, malapari, and nyamplung oil. Pratika *et al.* (2021) converted castor oil into biodiesel using a TiO_2/CaO catalyst, producing a yield of 79.68%, whereas Utami *et al*. (2022) obtained a yield of 94.83% using an NaOH catalyst. The NaOH catalyst exhibited better conversion because it is a homogeneous catalyst with

Table 3. Chemical components of oils from different types of energy-producing plants

No.	Fatty acids	Chemical formula/bonding	Molecular weight	Concentration (%)			
				Jarak	Kepuh	Malapari	Nyamplung
1	Vaxenic acid	$C_{18}H_{34}O_2$	282.5	0.71	-	-	0.51
2	Palmitic acid	$C_{16}H_{32}O_2$	256.43	16.09	18.81	14.47	16.09
3	Linoleic acid	$C_{18}H_{32}O_2$	280.45	31.81	9.52	10.46	31.41
4	Oleic acid	$C_{18}H_{34}O_2$	282.46	41.53	7.12	59.62	43.70
5	Stearic acid	$C_{18}H_{36}O_2$	284.48	-	-	4.36	-
6	10-Octadecynoic acid	$C_{18}H_{32}O_2$	280.4	-	5.81	-	-
7	Sterculic acid	$C_{19}H_{34}O_2$	294.5	-	57.5	-	-
8	Behenic acid	$C_{22}H_{44}O_2$	340.58	-	-	8.04	-
9	Myristic acid	$C_{14}H_{28}O_2$	228.37	8.29	-	-	7.97

higher catalytic activity than a heterogeneous catalyst (TiO_2/CaO). Biodiesel from kepuh oil feedstock with a NaOH catalyst also achieved a high conversion (93.55%). Other homogeneous catalysts, such as KOH, were utilized to convert malapari and nyamplung oils, resulting in respective yields of 92% and 96%. These findings indicate that non-edible oils have great potential for producing biodiesel fuels with high conversion rates (Table 4).

4. CONCLUSIONS

The kepuh trees grow across various regions in Java Island, mostly in cemeteries and forests. Jarak, malapari, and nyamplung mostly grow along the southern coast of Java Island. Kepuh is located in various regions of Java. This study highlights that oils derived from nyamplung, kepuh, jatropha, and malapari possess distinct characteristics that make them valuable potential bioenergy sources for Pertamina's Green Refinery. Nyamplung oil exhibited the highest yield (54.61%), density (937.44 kg/m³), and viscosity (34.25 m²/s), indicating its superior quality. Kepuh oil had the lowest acid number (1.78 mgKOH/g) and FFA content (1.62%), making it chemically stable. Jatropha oil showed the iodine number (8.73 g-I_2/100 g), reflecting its unsaturation level. Malapari oil has a high oleic fatty acid concentration (59.62%), emphasizing its energy potential. Each oil type has unique physical and chemical properties that ensure its adaptability for specific bioenergy applications, thereby supporting sustainable energy development. The application of jatropha, kepuh, malapari, and nyamplung as biodiesel feedstocks resulted in high conversion rates (79%–96%). These findings allow these non-edible plants to be employed for various purposes. For example, kepuh (low FFA) may be suitable for long-term storage fuels, whereas nyamplung (high viscosity and yield) might be appropriate for industrial blends or lubricant bases.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article was reported.

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Table 4. Summary of biodiesel production from non-edible oil

Feedstock	Method	Reaction condition	Biodiesel yield (%)	Reference
Jarak	Reflux transesterification	C: TiO_2/CaO T: 65℃, R: 90 min	79.68	Pratika *et al.* (2021)
Jarak	Distillation transesterification	C: NaOH T: 65℃, R: 90 min	94.83	Budiman *et al.* (2019)
Kepuh	Stirring transesterification	C: NaOH, V: 3.96 mm^2/s, T: 60℃, R: 2.5 h	93.55	Silitonga *et al.* (2013)
Malapari	Distillation transesterification	C: KOH, FP: 150℃, V: 4.8 Cst	92.00	Karmee *et al.* (2005)
Nyamplung	Microwave transesterification	C: KOH, D: 0.86 g/cm^3, V: 3.7 Cst	96.00	Qadariyah *et al.* (2018)

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