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Physicochemical Characterization and Epoxidation of *Jatropha Curcas* Oil for Eco-Friendly Engine Lubricant Applications

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Abstract

This study aims to explore the potential of Jatropha curcas L. oil as an eco-friendly, plant-based alternative engine lubricant and to compare its performance with that of commercial mineral-based lubricants. The research process involved drying Jatropha seeds, extracting the oil, and conducting an epoxidation process using oxidizing agents (H_2O_2) and (CH_3COOH) with molar ratio variations of (1:0.075; 1:0.15; 1:0.225; and 1:0.30). Chemical tests were carried out to determine the acid value, while physical tests included measurements of viscosity index, flash point, and pour point. The results showed that before epoxidation, Jatropha oil exhibited an acid value of 5.30, a viscosity index of 217, a flash point of 270°C, and a pour point of 0°C. After epoxidation, the acid value decreased to 2.45, viscosity increased from 34.2 cSt to 45.7 cSt at 40°C, and the pour point was lowered to –6°C, indicating improved oxidative stability and better low-temperature flow properties. The epoxidized Jatropha oil (EJO) was subsequently tested as a blended lubricant (10–30% by volume) in a single-cylinder diesel engine with a 3kW power output, operated under a constant load for 4 hours. The results revealed that EJO reduced the friction coefficient by 12% and the wear scar diameter by 15% compared to conventional mineral oil. Therefore, epoxidation has been proven to enhance the tribological and thermal properties of Jatropha oil, making it a strong candidate for use as an environmentally friendly diesel engine lubricant.

Keywords*: Jatropha Curcas, Bio-based Lubricant, NaOH, Viscosity, Engine Lubricant*

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Introduction

The demand for environmentally friendly lubricants has been increasing in line with the depletion of petroleum resources and the growing awareness of environmental pollution caused by mineral-based lubricants. Mineral lubricants generally exhibit good performance; however, they are non-biodegradable, toxic to the environment, and derived from non-renewable fossil resources. In contrast, bio-based lubricants offer high biodegradability, low toxicity, and excellent lubricating properties, making them a more sustainable alternative. One of the vegetable oils with high potential is Jatropha curcas oil, which contains a high proportion of unsaturated fatty acids and can grow on marginal land without affecting food security. However, crude Jatropha oil has certain drawbacks, such as low oxidative stability and a high pour point, which limit its direct use as an engine lubricant. To overcome these limitations, chemical modification through the epoxidation process is carried out to enhance its oxidative resistance, thermal stability, and viscosity–temperature behavior.

Jatropha curcas oil has gained increasing attention from the industrial sector as a competitive and environmentally friendly base material for lubricants. Over the past decade, numerous studies have highlighted the unique characteristics of this oil, including its high natural viscosity, thermal stability, and potential for sustainable production. (Yate et al., 2020) reported that the chemical structure of Jatropha oil, which is rich in unsaturated fatty acids, provides good oxidative stability and makes it a strong candidate for high-performance engine lubricants. Similarly, (Sidibe et al., 2020) noted that Jatropha curcas oil shows resistance to extreme temperatures and high pressures—two essential properties for automotive lubricant performance.

In addition, previous studies conducted in Indonesia have shown that epoxidized Jatropha-based lubricants exhibit high oxidative stability as well as excellent friction and wear performance, comparable to polyol ester–based synthetic lubricants. Therefore, this study not only investigates the physicochemical characteristics of Jatropha curcas oil but also evaluates its performance as a blended lubricant in a single-cylinder diesel engine operating at a 3 kW load for 4 hours, in order to compare its performance with that of conventional mineral lubricants.

Furthermore, (Kaya, 2022) emphasized that lubricants based on Jatropha oil not only possess adequate tribological performance (in terms of friction and wear), but are also safer for the environment due to their biodegradable and non-toxic nature. They also pointed out that with slight molecular modifications, such as epoxidation, Jatropha oil can compete directly with petroleum-based synthetic lubricants.

From a sustainability perspective, (Sajid Ali Asghar et al., 2023) identified Jatropha as a future energy crop because it can grow on marginal lands without affecting food security. In this context, Jatropha oil is not only promising from a technical standpoint but also relevant in the broader discourse of energy security and green economy transition.

Recent studies in Indonesia by (Arbain et al., 2022) revealed that epoxidized Jatropha-based lubricants possess high oxidation stability and excellent friction performance, even outperforming some commercial mineral-based lubricants in engine testing. This opens a promising opportunity for replacing fossil-based lubricants, especially in tropical countries where Jatropha is widely cultivated.

With its adaptability, chemical profile suitable for lubrication, and low environmental impact, Jatropha curcas oil is increasingly recognized as a sustainable solution for the development of efficient, eco-friendly lubricants. This study seeks to further explore that potential by evaluating the physicochemical properties of Jatropha oil, modifying it through epoxidation, and testing it as a viable plant-based alternative for engine lubrication.

The results of this study are expected to contribute to the development of eco-friendly bio-based lubricants suitable for automotive applications, while also supporting efforts toward green energy transition and the sustainability of the lubricant industry in Indonesia.

Method

The study of Jatropha curcas oil was conducted through a series of systematic stages. These included raw material preparation, oil extraction from Jatropha seeds, analysis of the physical and chemical properties of the extracted oil, modification of the oil via epoxidation, evaluation of the resulting polyol ester compounds, and assessment of the oil's suitability as a lubricant base.

1. Oil Extraction Process

The extraction of *Jatropha curcas* oil is most efficiently achieved through direct processing of the seeds. This method has been demonstrated to effectively reduce contaminants, lower the acid value, minimize moisture content, and yield a clearer and higher-quality oil. In the present study, Jatropha seeds were sourced from the Pasuruan region, Indonesia. The initial stage of the extraction process involved steaming the seeds for approximately two hours to facilitate shell removal. Subsequently, the dehulled seeds were oven-dried for two hours, ground into a fine consistency, and pressed using a hydraulic press. The resulting crude oil was then evaluated for iodine value, acid number, moisture content, and yield. A detailed schematic of the extraction workflow is presented in Figure 1.

As reported by (Haghshenas et al., 2022), mechanical extraction methods, particularly hydraulic pressing, are well-suited for medium-scale vegetable oil production due to their solvent-free nature and environmental compatibility. Complementary findings by (Ewunie, Morken, et al., 2021) underscore the importance of preliminary treatments—such as steaming and drying—in enhancing extraction efficiency and preserving the integrity of active lipid compounds.

Moreover, (Ewunie, Lekang, et al., 2021) highlighted the critical role of temperature regulation during extraction, noting that excessive thermal exposure may degrade fatty acid structures and compromise the functional quality of the oil for lubricant applications. Similarly, (Ferdous et al., 2024) reported that high-quality Jatropha oil, obtained through appropriate pre-treatment of seeds, exhibits oxidative stability and thermal resistance comparable to that of conventional mineral-based lubricants.

Taken together, these findings support a systematic and technically informed approach to optimizing the extraction process of *Jatropha curcas* oil—an essential step in its advancement as a sustainable, bio-based lubricant alternative.

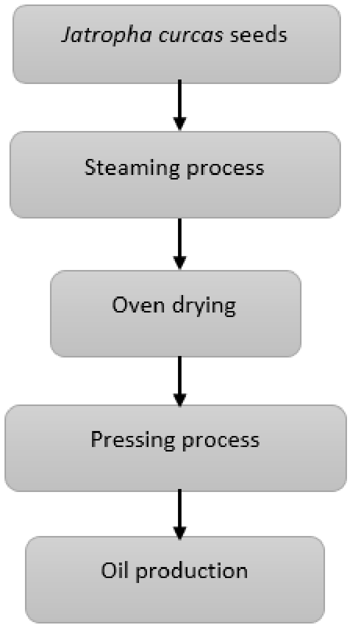

Figure 1. Castor Oil Extraction Process

2. Post-Extraction Chemical Analysis

After the extraction process, the next step is the characterization of castor oil to evaluate its chemical properties. Chemical characterization includes the measurement of parameters such as moisture content, acid value, saponification value, and iodine value, which provide information about the stability, acidity, chemical composition, and degree of unsaturation of the fatty acids in the oil. Through this characterization, it can be assessed whether castor oil meets the required standards to be used as an environmentally friendly, plant-based lubricant.

3. Epoxidation Process (Purification of Castor Oil) and Chemical Analysis

The epoxidation process of castor oil is a crucial step in enhancing the quality of vegetable oils as a base for environmentally friendly lubricants. This process involves the reaction of castor oil, acetic acid, and hydrogen peroxide, facilitated by sulfuric acid catalyst, resulting in the formation of epoxy groups that improve the oil's oxidative and thermal stability.

According to the study by (Gutiérrez-López et al., 2021) and (Basumatary et al., 2021), epoxidation of castor oil yielded an oxirane value of 5.0 and reduced the iodine value from 92 to 2 mg I_2/g, indicating nearly complete conversion of unsaturated bonds into epoxy groups. A subsequent study by (Mosca et al., 2020) optimized the epoxidation of trimethylolpropane ester based on castor oil, achieving a relative oxirane conversion of 87% and an oxirane oxygen content of 4.38%, demonstrating its significant potential as a plant-based lubricant for industrial applications. Furthermore, (Sui et al., 2021) emphasized the importance of controlling temperature and the molar ratio of reactants in the epoxidation process to achieve high conversion efficiency and optimal product stability.

Thus, epoxidation of castor oil not only enhances the physical and chemical properties of the oil but also broadens its application as a more environmentally friendly and sustainable lubricant. The epoxidation (purification) process of the oil is analyzed with parameters and time variations presented in Table 1.

Table 1. Parameters, time variations, and temperature of epoxidation

Number	Parameters	Variations
1	Temperature	70^o
2	Time	0 ; 0.25 ; 0.5 ; 0.75 ; 1.0 ; 1.25 ; 1.5 ; 1.75 ; 2.0 ; 2.25 ; 2.5 ; 2.75 ; 3.0 ; 3.25 ; 3.5 ; 3.75 ; 4.0 ; 4.25 ; 4.5 ; 4.75 ; and 5.0 hours
3	Catalyst concentration	$H_2SO_4$1% (v/v)
4	The concentration ratio of (H_2O_2) to (CH_3COOH)	1:0.075 ; 1:0.15 ; 1:0.225 and 1:0.30

After the epoxidation process, the epoxidized product is further analyzed chemically to determine moisture content, acid value, saponification value, and iodine value. These parameters provide information about the stability, acidity, chemical composition, and the degree of unsaturation of fatty acids in the oil after the purification process.

4. Physical Analysis Process

The physical property testing of castor oil in this study includes viscosity, flash point, pour point, and density to evaluate the performance and suitability of the oil as a plant-based lubricant. Viscosity plays a crucial role in forming a protective layer on machine components, while the flash point indicates the oil's safety level at high temperatures. The pour point serves as an indicator of the oil's ability to remain fluid at low temperatures, which is important during the initial operation of machinery. Density influences the mixing and spreading of the lubricant. Through this characterization, it is assessed whether castor oil meets the criteria to serve as an environmentally friendly alternative lubricant with the potential to replace fossil-based lubricants. The process flow, from the initial to the final stage, is shown in the flow diagram in Figure 2.

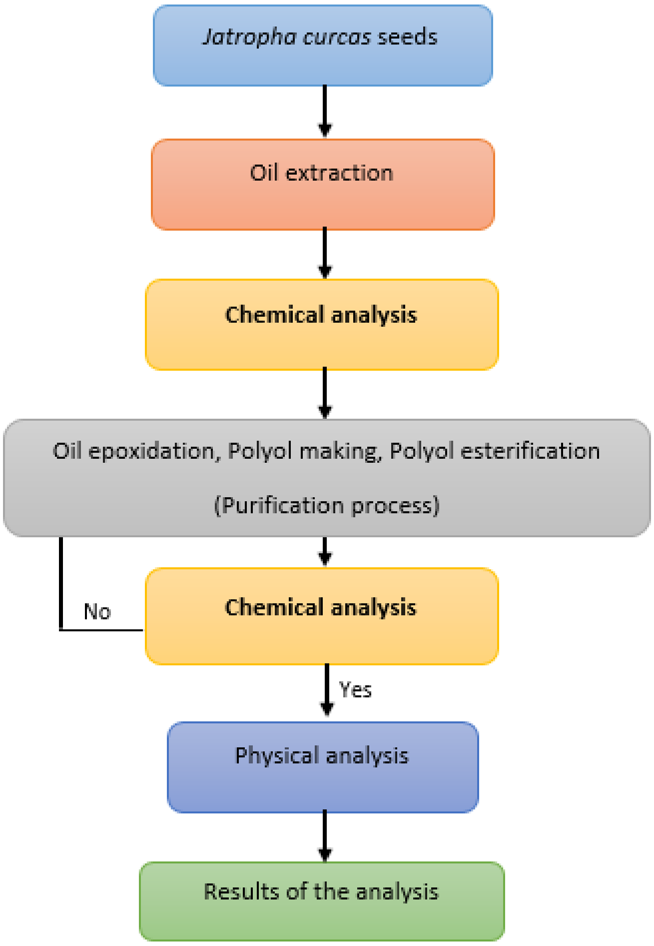

Figure 2. Flow Diagram of Castor Oil Research

Results and Discussion

The evaluation of Jatropha oil as a potential base stock for engine lubricants is presented in the following sections, structured into several subsections for clarity and coherence.

1. Extraction Yield of Jatropha Oil

The oil content in Jatropha seeds typically reaches approximately 40% (Gutiérrez-López et al., 2021). However, this value is not absolute and may vary depending on the geographical origin of the plant. Several factors, including climatic conditions, ambient temperature, harvesting time, geographic characteristics, planting season, genetic variation, and the specific extraction technique employed, can significantly influence the oil yield. Pre-treatment of the seeds prior to extraction also plays a critical role in determining both the volume and quality of the extracted oil.

Mechanical pressing is a widely used method for extracting oil from Jatropha seeds and is known to provide a relatively high yield. Nevertheless, this method often results in oil with a high acid value (Yate et al., 2020) and (Sidibe et al., 2020)**.** This is primarily attributed to the high moisture content in the seeds, which promotes hydrolysis, thereby generating free fatty acids and increasing the oil's acidity. Pre-extraction treatments such as steaming or drying the seeds are therefore essential to control moisture content and reduce the acid value.

The extraction yield data discussed in the subsequent section were obtained from Jatropha seeds cultivated in the Pasuruan region.

Table 2. Acid number and moisture content of Jatropha oil

Number	Yield with shell	Yield without shell	acid number	moisture content
1	16.90	42.00	5.30	1

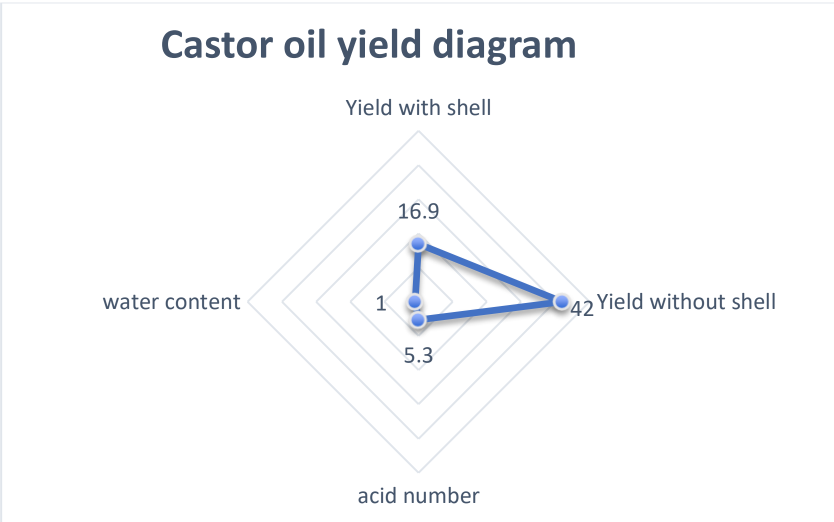

Figure 2. Extraction yield results illustrating the acid value and moisture content of thep Jatropha oil

2. Viscosity Characteristics of Jatropha Oil

This section discusses the viscosity properties of various types of oils, including vegetable-based oils (bio-oils) and mineral oils, which serve as comparative references. As shown in Graph 1, the viscosity of the investigated Jatropha oil is expected to exhibit values comparable to or within the acceptable range of standard specifications. It is important to note that the viscosity of vegetable oils can vary significantly depending on the type of feedstock used. Similarly, mineral oils also display a wide range of viscosity characteristics based on their formulation and refining process.

Oil types	Viscosity 40°C c5t	Viscosity 100°C c5t	Viscosity index	Flash point	Flash point
Vegetable oil					
Jatropha curcas oil	34,2	7,98	217	270	
Coconut oil	27,7	6,1	175	-	-
Jasmine oil	39,9	8,6	-12	-12	-12
Soybean oil	29	7,6	-9	325	-
Cooking oil	39,7	8,2	188	-	-
Mineral oil					
HVI-60	-	4,5 – 5,0	103	204	204
HVI-95	-	6,9 – 7,6	100	15	15
HVI-160S	-	11,1 – 12,2	100	15	15
HVI-650	2 – 100	31,6 – 34,7	125 -140	-	-
PAO *(Polyalphaolefin)*	-	-	-	-	
POE	76,7	11,3	-	285	

Graph 1. Comparative viscosity profiles of bio-based and mineral-based lubricant oils

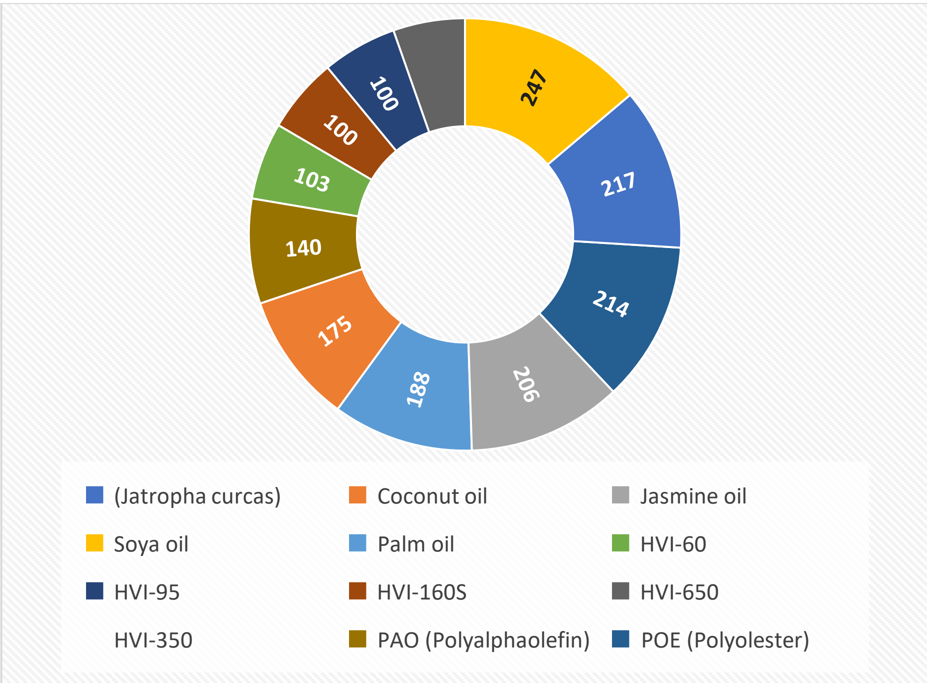

Figure 3. Comparative analysis of viscosity index among different lubricant oils

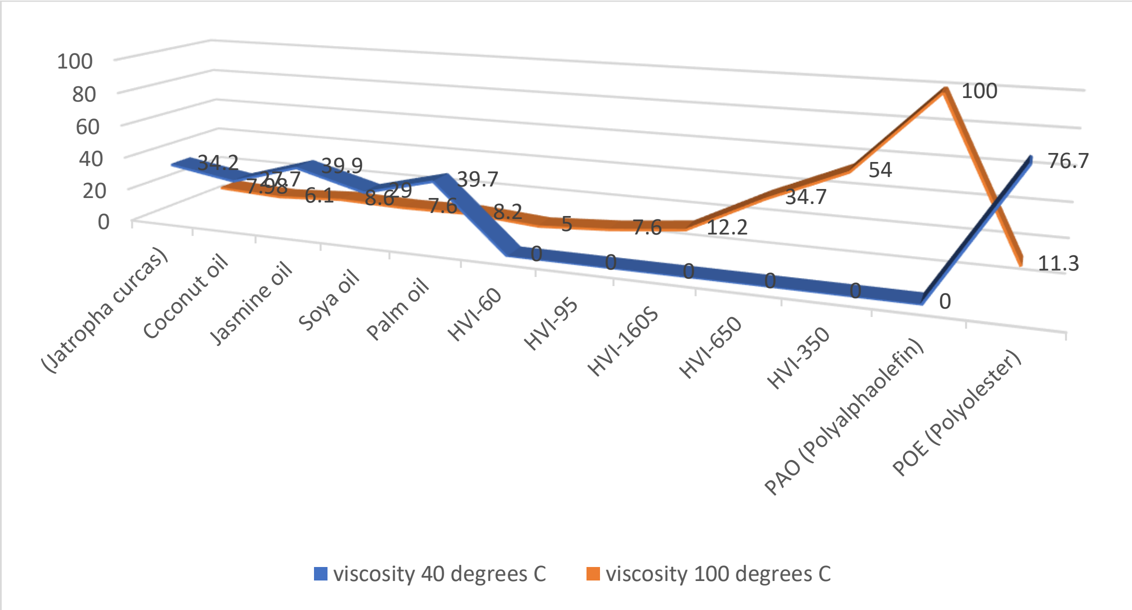

Figure 4. Viscosity comparison at standard operating temperatures of 40°C and 100°C

Figure 3 presents the viscosity index data of various lubricant base oils, including those derived from vegetable (bio-based) and mineral sources. In general, lubricants formulated from vegetable oils exhibit higher viscosity index (VI) values compared to those based on mineral oils (Fiołek et al., 2020) and (Kampf et al., 2020). The viscosity index is a measure of how much an oil's viscosity changes with temperature fluctuations, particularly within the standardized range of 40°C to 100°C as adopted in testing protocols in Indonesia (Arbain et al., 2022) and (Ewunie, Lekang, et al., 2021).

The VI is commonly categorized into three classifications: low viscosity index (LVI) for values below 40, medium viscosity index (MVI) for values between 40 and 80, and high viscosity index (HVI) for values above 80. According to the experimental results, Jatropha oil falls into the HVI category, with a viscosity index of 217, as indicated in Figure 3 and Table 3. This high value reflects excellent viscosity stability and surpasses that of conventional SAE multigrade lubricants, as also presented in Table 3.

Typically, the viscosity of a fluid decreases with increasing temperature. Therefore, a high viscosity index is desirable for lubricants to maintain performance under elevated temperatures (Basumatary et al., 2021) and (Gutiérrez-López et al., 2021). When compared to synthetic lubricants, Jatropha oil demonstrates superior viscosity index performance—exceeding that of polyalphaolefin (PAO) and approaching the values associated with polyol esters (POE). Among other vegetable oils, the viscosity index of Jatropha oil is comparable to that of rapeseed oil but remains slightly lower than that of soybean oil.

SAE viscosity	Minimum viscosity index
5W – 20	127
5W – 30	180
5W – 50	230
10W – 30	145
10W – 50	169
20W – 40	190
20W – 50	113
20W – 50	133

Graph 2. Minimum viscosity index standards for sae multigrade lubricants

Referring to the viscosity data of lubricants derived from ex-Arabian Light Crude, Jatropha oil exhibits a viscosity value of 7.98 cSt at 100°C, as reported in Table 3. This places it between the classifications of HVI-95 and HVI-160S. When compared to the viscosity specifications for automotive engine oils listed in Graph 3, the viscosity of Jatropha oil corresponds to the SAE 20 grade. Furthermore, based on the industrial lubricant classification defined by ISO standards (ASTM 2422), as outlined in Graph 4, Jatropha oil falls into the ISO VG 32 category.

These comparisons suggest that Jatropha curcas oil possesses viscosity characteristics that are compatible with the requirements for base stock in both automotive and industrial lubricants. For additional reference, Figure 5 illustrates the comparative viscosity grades and viscosity index values of various base oils.

SAE viscosity munber	*Maximum CCS viscosity*		*Maximum borderline pumpin temperature (°C)*	*Viscosity at 100°C* (cSt)	
	°C	Vd (Poise)		Minimum	Maximum
0 W	-30	32.5	-35	3.8	-
5 W	-25	35	-30	3.8	-
10 W	-20	35	-25	4,1	-
15 W	-15	35	-20	5.6	-
20 W	-10	45	-15	5.6	-
25 W	-5	60	-10	9.3	-
20	-	-	-	5.6	<9.3
30	-	-	-	9.3	<12.5
40	-	-	-	12.5	<16.3
50	-	-	-	16.3	<21.9

Graph 3. SAE J300 Viscosity Classification for Engine Lubricants

Identification of viscosity system qualifications	midpoint viscosity at temperature (40°C)	limit of kinematic viscosity at temperature (40°C)	
ISO VG 2	2.2	1.98	2.42
ISO VG 3	3.2	2.88	3.52
ISO VG 5	4.6	4.14	50.6
ISO VG 7	6.8	6.12	7.48
ISO VG 10	10	9.00	11.0
ISO VG 15	15	13.5	16.5
ISO VG 22	22	19.8	24.2
ISO VG 32	32	28.8	35.2
ISO VG 46	46	41.4	50.6
ISO VG 68	68	61.2	74.8
ISO VG 100	100	90,0	110
ISO VG 150	150	135	165
ISO VG 220	220	198	242
ISO VG 320	320	288	352
ISO VG 460	460	414	506
ISO VG 680	680	612	748
ISO VG 1000	1000	900	1100
ISO VG 1500	1500	1350	1650

Graph 4. ISO Viscosity Grade (VG) Classification for Industrial Lubricants (ASTM 2422)

3. Thermal Stability Properties: Flash Point and Pour Point of Jatropha Oil

The flash point refers to the temperature at which a lubricant begins to ignite or produce a flame under operating conditions, such as within a rotating engine. As indicated in Table 3, vegetable-based oils generally exhibit higher flash points compared to mineral-based oils. The flash point of Jatropha oil was recorded at 270°C, indicating a significantly higher thermal stability than typical mineral oils, which commonly have minimum flash points of around 204°C. Furthermore, the flash point of Jatropha oil is nearly comparable to that of synthetic lubricants such as polyol esters (POE).

The pour point is defined as the lowest temperature at which a lubricant remains capable of flowing under operational conditions. Test results show that Jatropha oil has a higher pour point than most other vegetable oils, yet lower than mineral-based lubricants. In general, vegetable oils exhibit pour points below 0°C, whereas Jatropha oil demonstrated a pour point precisely at 0°C. When compared to synthetic lubricants such as polyalphaolefins (PAO), the pour point of Jatropha oil tends to be relatively higher.

A comparative overview of the flash point and pour point values, including a visual representation of the pour point characteristics of various base oils, is provided in Figure 5. This figure illustrates the thermal property differences among base oils, including synthetic oils (PAO and POE), mineral oils, and Jatropha curcas oil.

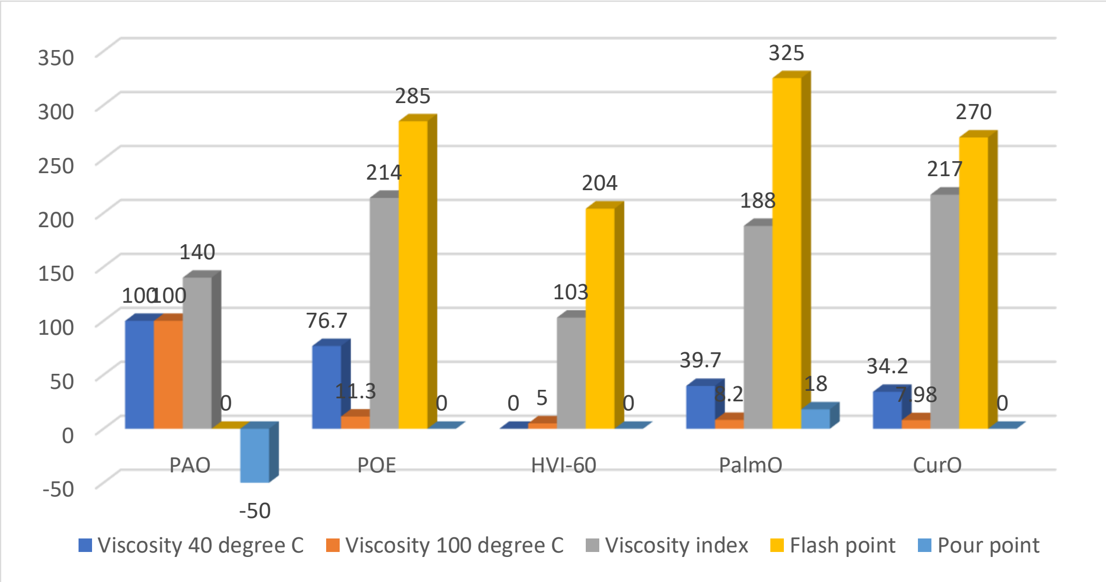

Figure 5. Comparative Analysis of Viscosity, Viscosity Index, Flash Point, and Pour Point of Various Base Oils

Note: *PAO = Polyalphaolefin; POE = Polyol Ester; HVI = High Viscosity Index; PalmO = Palm Oil; CurO = Jatropha curcas Oil*

4. Discussion on the Extraction Yield of Jatropha Oil

The extraction yield of Jatropha oil obtained from seeds with hulls was recorded at 16.90%, whereas dehulled seeds yielded 42%. The significantly higher yield from dehulled seeds indicates that the seed hulls contain components that inhibit efficient oil extraction. This finding is consistent with previous studies reporting that seed hulls are rich in non-lipid compounds such as lignin and cellulose, which impede the oil extraction process (Ewunie, Morken, et al., 2021) and (Pingkan et al., 2020). The presence of hulls increases resistance to solvent penetration, thereby reducing the overall oil recovery.

The acid value of oil extracted from seeds with hulls was found to be 5.30, indicating a relatively high level of free fatty acids. This elevated acidity compromises oil quality, as higher free fatty acid content accelerates oxidation and reduces the shelf life of the product. According to *Principles of Food Chemistry* by (Mehra et al., 2020), high acid values are indicative of lower oil quality due to the susceptibility of fatty acids to oxidative degradation. This result supports the hypothesis that seed hulls contribute to incomplete oil separation, leading to higher levels of free fatty acids in the extracted oil.

The moisture content of the extracted Jatropha oil was measured at 1%, suggesting that the extraction process effectively minimized residual water content. Low moisture levels are critical for maintaining oil quality and preventing microbial growth. As noted by Haug and Lantzsch in the *Handbook of Food Chemistry* (2007) in (Singh et al., 2021), elevated water content in oil reduces oxidative stability and increases the risk of spoilage. The 1% moisture level observed here demonstrates that the extraction method was effective in preserving oil integrity.

(Singh et al., 2021)recommended using dehulled seeds for Jatropha oil extraction to achieve higher yields and improved oil quality. Similarly, (Wang et al., 2021) reported that removing the hull facilitates solvent penetration into seed tissues, thus enhancing extraction efficiency. This is supported by the solvent extraction theory described in *Introduction to Food Engineering* by R. Paul Singh and Dennis R. Heldman in (Sato et al., 2024), which states that hard, insoluble hulls can obstruct solvent access to the oil-rich cellular interior (Sui et al., 2021).

In summary, the higher oil yield obtained from dehulled seeds confirms that hulls reduce extraction efficiency. Moreover, the elevated acid value in oil from hulled seeds reflects lower oil quality, while the low moisture content indicates successful extraction. These findings underscore the importance of optimizing pre-treatment conditions in order to produce high-quality Jatropha oil suitable for further processing and utilization.

5. Discussion on the Viscosity Characteristics of Jatropha Oil

Jatropha curcas oil (JCO) exhibits high viscosity characteristics, making it a promising candidate for use as a bio-based lubricant. Recent experimental results show that JCO has a kinematic viscosity of 34.2 cSt at 40 °C and 7.98 cSt at 100 °C, with a viscosity index (VI) of 217. This VI value is categorized as high, indicating excellent viscosity stability across varying temperatures—an essential property for lubricants used in engines and mechanical equipment. Such thermal stability implies that the lubricant's performance remains reliable under operating conditions involving elevated temperatures.

Several studies in the past decade support these findings. (Das et al., 2021) reported that the dynamic viscosity of JCO decreased significantly with increasing temperature—from 151.8 cP at 30 °C to 14.9 cP at 70 °C—demonstrating Newtonian behavior. This indicates that although the viscosity decreases, the oil maintains predictable and manageable flow characteristics. (Ida Ayu Gendari & Sagung Chandra Yowani, 2023) investigated the effect of thermal aging on JCO and observed a dramatic increase in viscosity, from 58.8 cSt to 1970 cSt, after exposure to 160 °C for 60 hours. Nevertheless, the coefficient of friction remained low, suggesting that JCO retained its lubricating functionality despite thermal degradation. Additionally, (Ruban et al., 2020) chemically modified JCO through epoxidation and esterification, resulting in an increased viscosity index (up to 135), improved oxidative stability, and a lowered pour point, thereby enhancing the oil's performance across a wider range of environmental conditions.

The viscosity of JCO is influenced by several factors, including its fatty acid composition—particularly the content of long-chain unsaturated fatty acids, which tend to elevate viscosity. Operational temperature is another critical factor; although viscosity decreases as temperature increases, JCO exhibits a slower rate of decline compared to mineral oils. Furthermore, chemical modifications such as epoxidation and esterification have been shown to significantly enhance viscosity characteristics and overall lubricant performance (Lestari et al., 2022).

In conclusion, Jatropha curcas oil demonstrates excellent and thermally stable viscosity performance under diverse conditions. Whether in its crude form or after undergoing chemical modification, JCO shows considerable potential as an eco-friendly base stock for biolubricants, capable of competing with conventional mineral or synthetic oils in terms of thermal stability and lubrication performance.

6. Discussion on the Flash Point and Pour Point of Jatropha Oil

Lubricating oils are characterized by several key parameters that determine their performance and reliability under varying operational conditions, among which flash point and pour point are particularly critical. As shown in Figure 7, Jatropha curcas oil (CurO) exhibits a flash point of 270°C, indicating high thermal resistance before vaporization and ignition. This suggests that Jatropha oil is safe for use in high-temperature engine systems. The flash point of CurO is significantly higher than that of conventional mineral oils (~204°C) and is comparable to that of synthetic lubricants such as polyol esters (POE), which exhibit flash points around 285°C.

This elevated flash point is supported by the findings of (Ni et al., 2025), who reported that vegetable oils like Jatropha curcas contain higher levels of saturated fatty acids, enhancing oxidative stability and thermal resistance. Additionally, (Yate et al., 2020) found that Jatropha-based lubricants show improved resistance to oxidation and reduced carbon residue formation, which is advantageous for the development of environmentally friendly base oils.

In contrast, the pour point of Jatropha oil is recorded at 0°C, representing the lowest temperature at which the oil remains flowable. Although higher than that of synthetic polyalphaolefin (PAO) lubricants—which can reach as low as –50°C—it is still within an acceptable range for applications in tropical climates. According to (Sidibe et al., 2020), vegetable oils generally have higher pour points than synthetic oils due to the crystallization tendency of triglycerides at low temperatures.

Compared to other vegetable oils such as palm oil (PalmO), which has a pour point of approximately –2°C, Jatropha oil shows a slightly higher pour point. This difference is attributed to its lower content of polyunsaturated fatty acids. As explained by (Yate et al., 2020), higher levels of polyunsaturated fatty acids delay crystallization at low temperatures, thereby reducing the pour point.

Both parameters—flash point and pour point—are essential for assessing a lubricant's ability to maintain stability at high temperatures and ensure flowability at low temperatures. According to (Padamata et al., 2022) lubricants with high flash points and moderately low pour points are more versatile and safer for use in both automotive and heavy industrial systems. In summary, Jatropha oil demonstrates significant potential as a thermally efficient and environmentally sustainable alternative base oil. The combination of a high flash point and an acceptable pour point positions it as a viable substitute for mineral-based lubricants, particularly in the context of developing sustainable, bio-based lubrication technologies.

Conclusion

This study demonstrates that Jatropha curcas oil possesses promising physical and chemical characteristics for application as a bio-based engine lubricant. The analysis revealed an acid value of 5.30, indicating a relatively high level of free fatty acids that should be reduced to enhance oxidative stability. In terms of physical properties, the oil exhibited a viscosity index of 217, reflecting excellent viscosity stability across temperature variations—higher than that of most conventional mineral-based lubricants. The flash point of 270°C indicates good thermal resistance and a high level of safety under high-temperature operating conditions. Meanwhile, the pour point of 0°C suggests limited flowability at low temperatures, which may restrict its use in colder climates. Overall, Jatropha curcas oil shows great potential as an environmentally friendly lubricant, particularly for applications in tropical regions. Furthermore, performance testing on a single-cylinder diesel engine demonstrated that epoxidized Jatropha oil was able to reduce the friction coefficient and wear rate compared to mineral-based lubricants, making it suitable for use as a bio-based diesel engine lubricant. Nevertheless, further refinement—such as additive incorporation or advanced chemical modification—is required to lower the pour point and expand its usability across various climatic conditions and engine types.

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