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Characterization of Malaysian Jatropha Seed Oil and Discovering the Process of Powdered Jatropha Leaves

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Abstract: Wax deposition is the main flow assurance problem that affects the oil and gas industry at various points of oil transport, hence a solution is being sought. The aim of this paper is to establish a solution using Jatropha curcas seed oil (JSO) from Malaysia and its sustainability as a wax inhibitor component. Extraction of JSO was carried out using a Soxhlet extractor and n-Hexane solvent. Characterization of JSO by gas chromatography–mass spectrometry (GC–MS) and Fourier transform infrared spectroscopy (FTIR) was performed to identify the components of JSO and their functional groups. GC–MS analysis showed that oleic acid was the major component of JSO with 44.91%. FTIR analysis showed the presence of ester fatty acid groups at a peak of 1746.48 cm^{-1}. The analysis revealed that the high content of oleic acid in JSO has great potential as a wax inhibitor to mitigate paraffin wax deposition and improve the flowability of crude oil. This research was extended by the discovery of the process of powdered Jatropha leaves, which have the potential as a wax inhibitor.

Keywords: Jatropha seed oil; fatty acid; oleic acid; wax inhibitor; Jatropha leaves

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1. Introduction

The need for smooth hydrocarbon flow increases as the need for deepwater exploration and production increases. Flow assurance is the flow of production fluids from the point of origin to sales in a reliable, safe, and profitable manner [1]. The temperature drop in deepwater exploration contributes to flow assurance issues, such as wax precipitation, which is common in surface facilities and pipelines [2,3]. The cold seabed environment triggers wax precipitation [4]. Wax precipitation is the result of a temperature drop below the wax appearance temperature (WAT), which affects the overall crude oil production and its flowability [5,6]. The impact on flowability can be observed as viscosity is affected by wax precipitation [7]. Wax precipitation reduces the inner diameter of the pipeline and restricts the flow; hence a promising solution needs to be found.

Up to date, injecting chemical wax inhibitors to mitigate wax deposition gained attention among researchers. Alpandi et al. [8] stated the evolution of chemical wax inhibitor generation started with polymer-based inhibitors in the early 1980s, followed by biosurfactant-based types in the late 1990s and finally plant-based ones in recent years. Several studies were conducted to solve the wax deposition issue using plant-based wax inhibitors such as crude palm oil, crude palm kernel oil and canola oil [9,10]. However, the use of this edible oil leads to the ethical challenge of food and fuel. Therefore, current researchers are focusing more on non-edible oil to mitigate wax deposition such as using Jatropha seed oil [5,11,12].

The use of Jatropha seed oil as a wax inhibitor is a promising alternative due to its properties, which are capable of creating a barrier between wax crystals [12]. Jatropha seed oil has the property that it is environmentally friendly and can be grown in rural areas [13,14]. Several studies were conducted in the past to reduce the wax deposition of Nigerian waxy crude oil using Jatropha seed oil from the Nigeria region. The oleic acid content in Nigerian Jatropha seed oil is only 43.11%, which contributes to the reduction of wax deposition [5,12]. However, the composition of Jatropha seed oil from the Malaysian region is still unknown, and there is limited work comparing gas chromatography–mass spectrometry (GC–MS) and Fourier transform infrared spectroscopy (FTIR) results for Malaysian Jatropha seed oil as a sustainable wax inhibitor.

This paper focuses on identifying the components of Malaysian Jatropha seed oil and their functional groups to understand if it is able to counter wax precipitation through wax inhibitor application. Oleic acid contains a polar end (OH) that creates a compact pyramidal form, the oxygen inhibits the wax's growth and creates an adsorptive surface poisoning mechanism. The main purpose is to extract and characterize the Malaysian Jatropha seed oil in order to identify the presence of oleic acid as a type of fatty acid that has a high potential as a wax inhibitor. The extraction is conducted by using the Soxhlet extraction method for better accuracy. The presence of the oleic acid in Malaysian Jatropha seed oil was determined using the retention time of the GC–MS and its functional groups were determined using band length from the FTIR. Moreover, the vibration energy of the carboxylic group can be identified using FTIR equipment [15]. The oleic acid component can act as a flow improver and wax inhibitor [5,12]. Previously, the oleic acid-based additive was evaluated as a great rheology modifier and pour point depressant [16]. The Jatropha seed oil has a significant amount of oleic acid [17]. Improving the flow of crude oil is a significant step indicating the reduction of wax precipitation and viscosity using Jatropha seed oil as an additive. This research was extended by discovering the process of powdered Jatropha leaves, which also have the potential as a wax inhibitor.

2. Materials and Methods

2.1. Extraction of Malaysian Jatropha Seed Oil

The Jatropha seeds used in this experiment go through various stages before being processed for extraction. The Jatropha seeds, which originated from the Malaysia region, were dried under the sun to ensure that excess moisture was removed. Then, the Jatropha seeds were crushed using a pestle and mortar to obtain the kernel, as shown in Figure 1. The obtained kernel was dried at 80 °C for one hour. The dried kernels were powdered using a mechanical blender. The powdered Jatropha seeds were sieved to ensure that the powdered particles were between 600 µm and 700 µm, as shown in Figure 2, to obtain a high extraction tendency.

The next step was extraction using a Soxhlet extractor to obtain the Jatropha seed oil, as shown in Figure 3. At the beginning of the process, 10 g of the powdered Jatropha seed was weighed and placed in the thimble and then placed in the extraction chamber. The extraction solvent n-Hexane was added to the boiling flask along with the anti-bumping agent at 150 mL. The solvent was heated at 70 °C for 4 h and 20 min as this time period is the criterion for complete extraction of the oil with high yield rate. The obtained samples were transferred to the rotary evaporator for separation of the mixture of Jatropha seed oil and n-Hexane, as shown in Figure 4. Evaporation was carried out at 71 °C for 1 h at atmospheric pressure. The yield rate can be calculated using Equation (1) [18].

$$Yeild\ of\ Jatropha\ seed\ oil\ (\%) = \frac{grams\ of\ Jatropha\ seed\ oil\ produced}{grams\ of\ Jatropha\ powder\ used} \times 100 \quad (1)$$

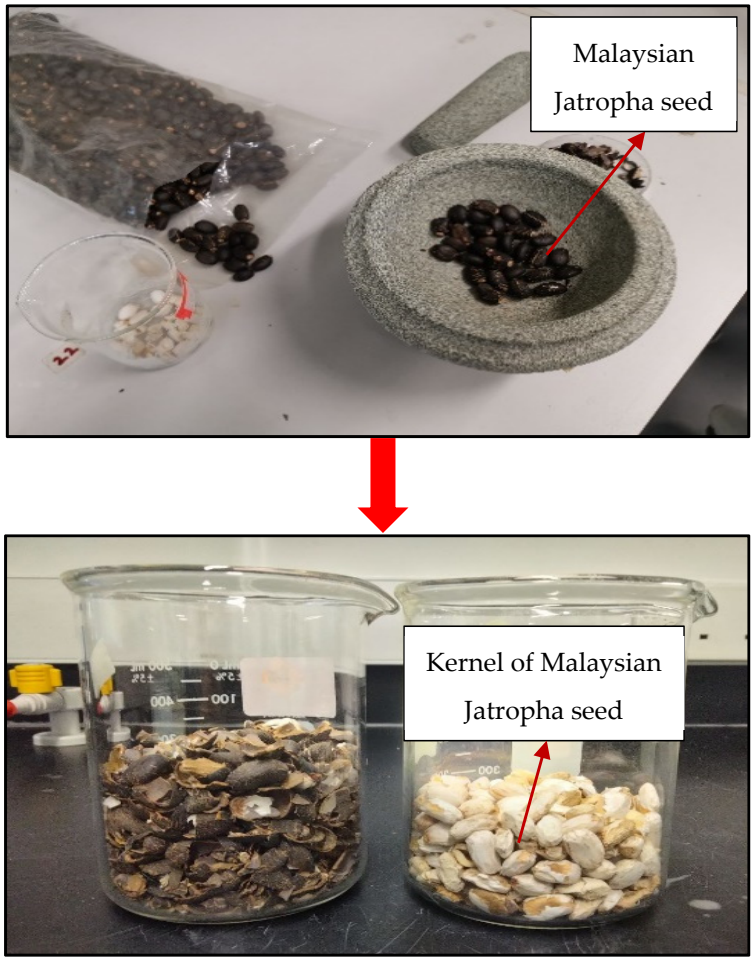

Figure 1. Kernel of Malaysian Jatropha seed.

Figure 2. Powdered Jatropha seed.

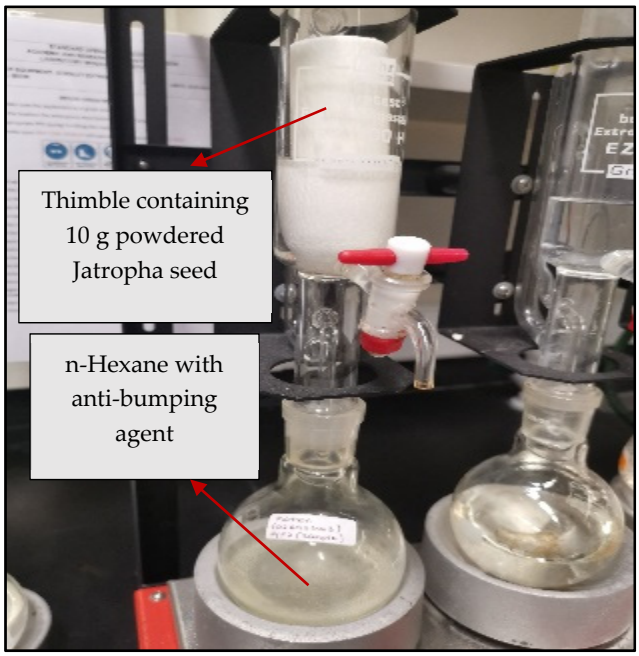

Figure 3. Soxhlet extractor design.

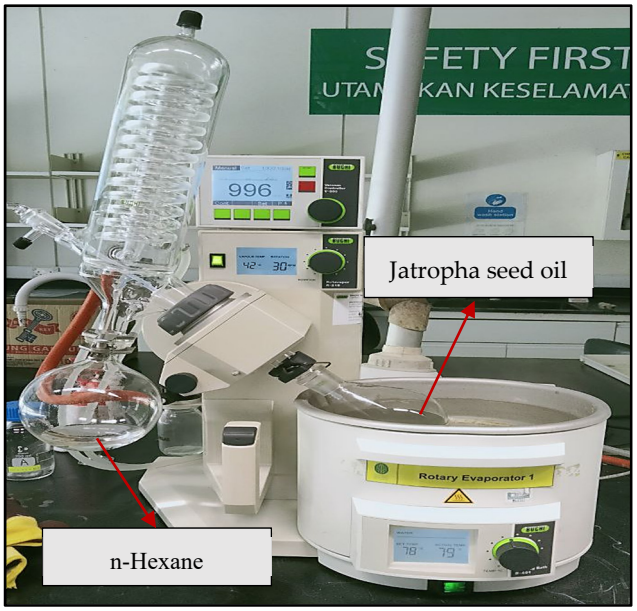

Figure 4. Rotary evaporator.

2.2. Characterization of Jatropha Seed Oil

The obtained Jatropha seed oil was then measured to 1 µm and placed in a vial for characterization by GC–MS (Agilent Technologies, DE, USA). GC–MS was performed using Agilent Technologies model 7820A and the capillary column of DB-5MS (30 m × 0.25 mm; 0.25 µm), as shown in Figure 5. The temperature of the column was first fixed at 60 °C for 5 min and then increased to 160 °C at 4 °C/min. The temperature was then increased to 320 °C at 15 °C/min for a holding time of 10 min. The split ratio applied was 50:1 with a maximum temperature setting of 325 °C. This analysis is used to determine the components of Jatropha seed oil and its percentage in a gas chromatogram.

Figure 5. GCMS equipment.

The percentage composition of this seed oil is calculated based on the area of each peak in the chromatogram. The area of each peak (treated as a triangle) can be determined using Equation (2).

$$Area = height \times width\ at \frac{1}{2}\ height \times attenuation \quad (2)$$

When using a thermal conductivity detector, a correction factor must be considered when determining the areas. The thermal conductivity of different substances and the response of the thermal conductivity detector tend to vary slightly. Therefore, a correction factor was used for each component of the mixture to account for this difference in conductivity and to minimize the error in the results. After the corrected areas are determined, the percent composition for each peak is calculated by adding the peak areas and then dividing each area by the total area and multiplying by 100.

For characterization of Malaysian Jatropha seed oil using FTIR equipment, a volume of 0.5 mL of Jatropha seed oil was required for functional group analysis. FTIR was performed using a Perkins Elmer model Frontier with the Attenuated Total Reflection (ATR) sampling mode, as shown in Figure 6. The transmission resolution of 4 cm^{-1} was applied with a measurement range of 4000 to 400 cm^{-1}. The generated FTIR spectrum helps to identify the functional group in Jatropha seed oil.

Figure 6. FTIR equipment.

2.3. Powdered Jatropha Leaves

In addition to Jatropha seeds, this study also examines powdered Jatropha leaves, which have the potential to act as wax inhibitors and reduce the viscosity of crude oil. This research discovered the process for producing powdered Jatropha leaves, as shown in Figure 7, and began by picking some leaves from the Jatropha tree and placing them on a tray. The Jatropha leaves were dried in an oven at 60 °C for about 30 min to ensure that excess moisture was removed. Then, the dried Jatropha leaves were placed in a mixer and blended at 600 rpm with a constant-speed mixer. The obtained powdered Jatropha leaves were weighed using a mass balance and the mass of 1.0 g was added to the Jatropha seed oil as a wax inhibitor. The mass ratio of powdered Jatropha leaves to Malaysian Jatropha seed oil used in this study is 1:7.5.

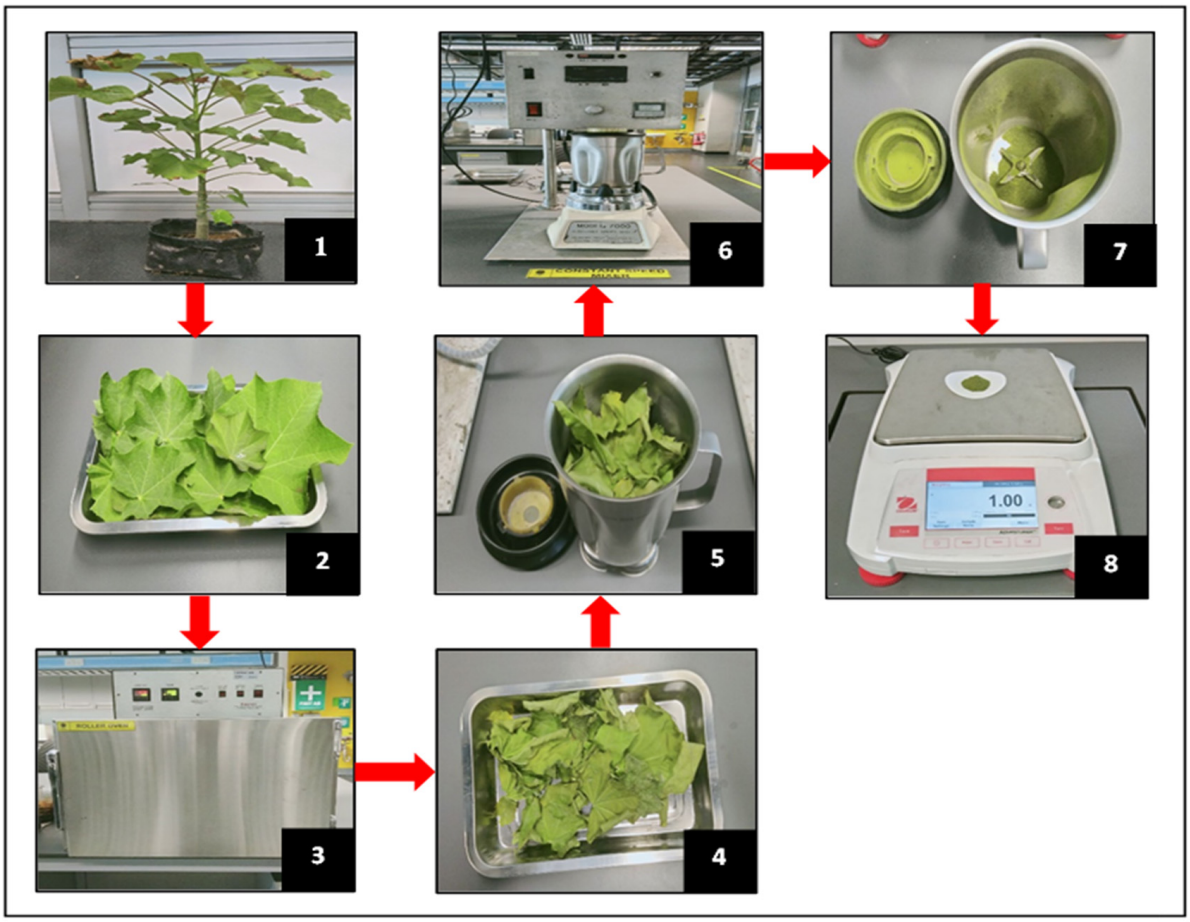

Figure 7. Process of powdered Jatropha leaves.

Further studies are required to verify the effectiveness of Malaysian Jatropha seed oil and the mixture of Malaysian Jatropha seed oil with Malaysian Jatropha leaves in mitigating wax deposition by rheological test. Therefore, a Fann viscometer (model 35) from Fann Instrument Company, Houston, TX, USA, was used to verify this potential wax inhibitor in waxy Penara crude oil. This type of crude oil used in this study has high wax appearance temperature, high pour point temperature and high wax content, which is 72.24 °C, 59.25 °C and 18.00 wt%, respectively [11].

First, the crude oil sample of about 175 mL was preheated in the oven at 60 °C and the sample was stirred with a magnetic stirrer until it was homogeneous. Then, the sample was put into the thermal cup and the upper case of the viscometer was tilted backward. The cup was placed under the sleeve and the pins at the bottom of the cup were inserted into the holes in the base plate. The upper housing was then lowered to its normal position

and the knurled knob between the rear support posts was turned to raise or lower the rotor sleeve until it was immersed in the sample to the marked line. The sample was stirred at 600 rpm for approximately 10 s. The dial reading was paused until stabilization (the time depends on the properties of the sample). Finally, the dial reading and shear rate were then recorded.

The experiment was repeated by adding potential wax inhibitors to the crude oil samples at different concentrations (1%, 3% and 5%) and temperatures (60 °C, 70 °C and 80 °C). Based on the obtained measured values, the apparent viscosity can be calculated using the standard formula in Equation (3). The measurements were repeated twice and the obtained results were averaged to ensure the accuracy and reliability of the results [11].

$$Apparent\ viscosity\ (cPs) = \frac{Reading\ at\ 600\ rpm}{2} \quad (3)$$

3. Results and Discussion

3.1. Malaysian Jatropha Seed Oil

The extracted Malaysian Jatropha seed oil yielded a significant amount of 6.5 mL to 10 mL on average for each extraction. The extracted Malaysian Jatropha seed oil exhibits a yellowish color and oily texture, as shown in Figure 8. The best storage condition for the samples would be 4 °C to maintain the quality of the Jatropha seed oil. The percentage yield of oil averaged from 62.9% to 72.1%.

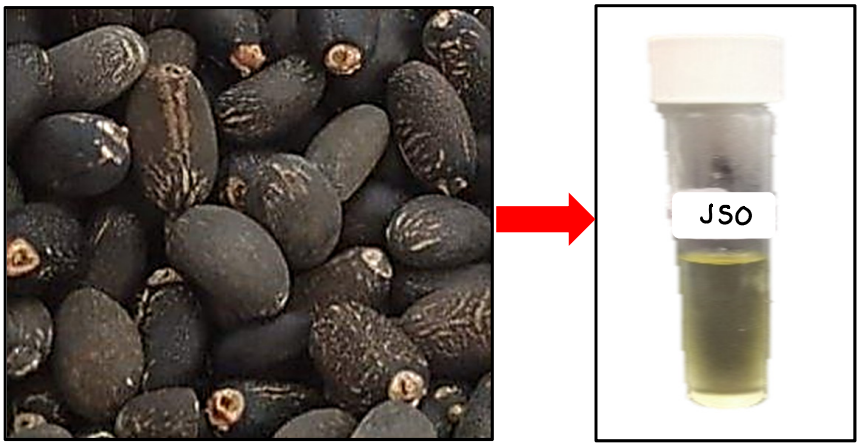

Figure 8. Malaysian Jatropha seed oil.

According to Tapanes et al. [19], the great properties of Jatropha seed oil such as less viscosity as compared to castor seed oil, better oxidation stability as compared with soybean oil, low acidity, less processing as compared to corn ethanol and good cold properties as compared to palm oil makes this non-edible oil has more potentially valuable. In addition, Jatropha seed oil is a slow-drying oil, that turns yellow on standing, and is colorless and odorless when fresh [20]. These findings make this study on Malaysian Jatropha seed oil as a wax inhibitor worth to be conducted to solve the wax deposition issue.

3.2. Gas Chromatography–Mass Spectrometry

The GC–MS equipment was used to determine the components of Malaysian Jatropha seed oil. This step is required for identifying the most effective and suitable fatty acid in the mitigation process of wax. Figure 9 shows the fatty acid composition spectrum of the Malaysian Jatropha seed oil from GC–MS.

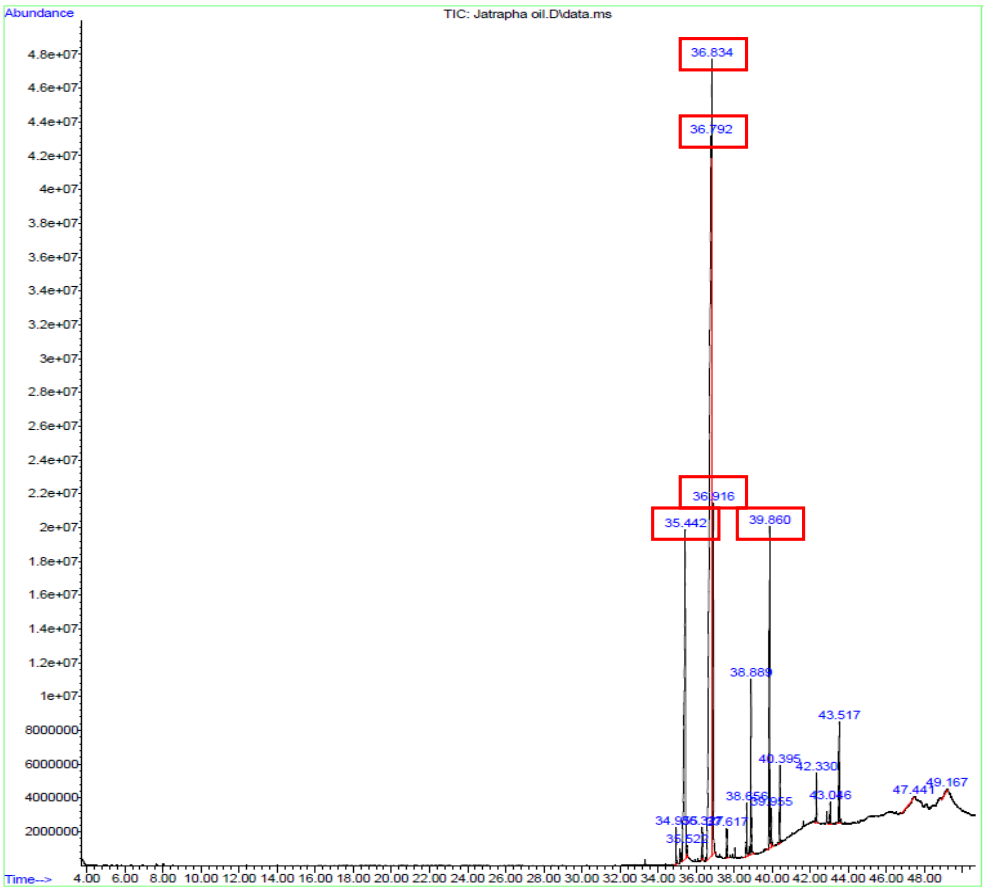

Figure 9. Fatty acid composition spectrum of Malaysian Jatropha seed oil from GC–MS.

Figure 9 shows that a total of 18 peaks were found in the GC–MS spectrum and five components of the fatty acid composition were identified (in the red frames). The main component of fatty acid found was oleic acid with 44.91%, followed by 9-octadecenoic acid, (E)- (17.24%), n-hexadecanoic acid (15.40%), oleic acid, 3-hyrdoxypropyl ester (6.74%) and octadecenoic acid (5.65%).

Based on the analysis, n-hexadecanoic acid, also known as palmitic acid, was identified in peak 2 with a retention time of 35.442 min. The molecular formula of n-hexadecanoic acid is $C_{16}H_{32}O$ with a molecular weight of 256.42. This compound contains a sixteen-carbon backbone, which is a straight-chain and saturated long-chain fatty acid. Moreover, it is observed that oleic acid is present in peak 5 with a retention time of 36.792 min. The data obtained show that the percentage of oleic acid in Malaysian Jatropha seed oil is the highest at 44.91% compared to the other fatty acid contents. Oleic acid contains polar hydroxyl groups that tend to reduce viscosity and improve the flowability of waxy crude oil. It also has the ability to prevent wax deposition by forming a barrier between interlocking wax crystals. $C_{18}H_{34}O_2$ is the molecular formula of oleic acid with a molecular weight of 282.5. Oleic acid is known as octadic-9-enoic acid, which contains a double bond at C-9 and has Z (cis) stereochemistry. Oleic acid plays a role as a carboxylesterase inhibitor and is derived from a hydride of a cis-octadec-9-ene and is known as a conjugate acid of an oleate.

Moreover, the highest peak in spectrometry was at a retention time of 36.834 min, indicating the presence of 9-octadecenoic acid, (E)- at 17.24%. It is a fatty acid commonly found in nature, known as unsaturated fatty acid and most commonly used for commercial purposes. The molecular weight of 9-octadecenoic acid, (E)- is 282.5 with $C_{18}H_{34}O_2$ as its molecular formula. In addition, octadecenoic acid was found in peak 7 at a retention time of 36.916 min with a total percentage of 5.65%. The molecular formula of octadecenoic acid is $C_{18}H_{34}O_2$ with a molecular weight of 282.5. It is an alpha, beta-unsaturated monocarboxylic

acid. It was found that octadecenoic acid and 9-octadecenoic acid, (E)- are also part of oleic acid. This is because these three compounds have a similar molecular formula and molecular weight. Octadecenoic acid is also known as octadec-2-enoic acid and contains a double bond at position 2. It is obtained from a hydride of an octadec-2-ene.

At peak 11 and at a retention time of 39.860 min, oleic acid, 3-hyrdoxypropyl ester, was found to be 6.74%. Its molecular weight is 340.5 and the molecular formula is $C_{21}H_{40}O_3$. The chemical structure of the major fatty acid components in Malaysian Jatropha seed oil found in this study is summarized in Figure 10.

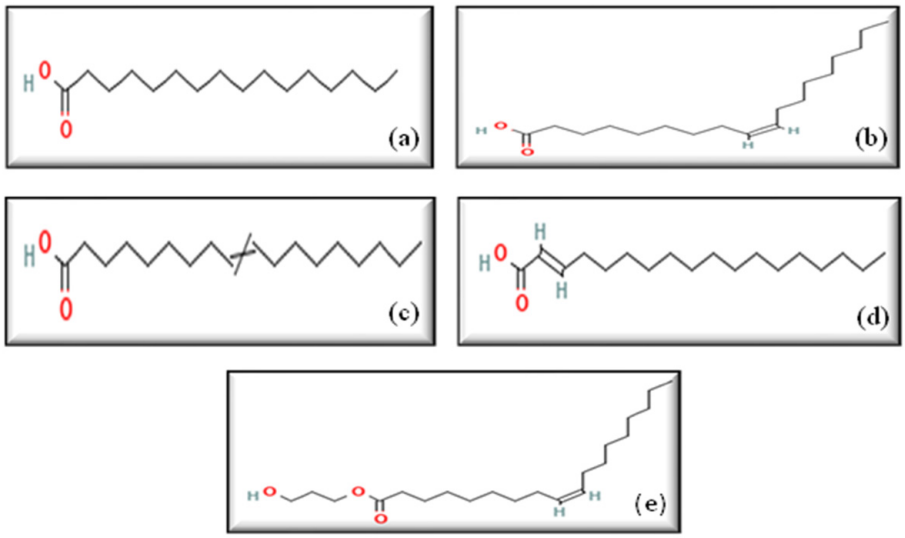

Figure 10. Chemical structure of main fatty acid components in Malaysian Jatropha seed oil. (**a**) n-Hexadecanoic acid (**b**) Oleic acid (**c**) 9-Octadecenoic acid, (E)- (**d**) Octadecenoic acid (**e**) Oleic acid, 3-hydroxypropyl ester.

Based on the analysis, monounsaturated oleic acid is the most abundant fatty acid found in Malaysian Jatropha seed oil. The content of oleic acid in the Jatropha oil extracted from the seeds of Malaysia in this study was higher (44.91%) compared to those from Nigeria (43.11%) and Indonesia (42.40%), for which the research was conducted by Akinyemi et al. [12] and Emil et al. [21], respectively. This indicates that Malaysian Jatropha seed oil is highly capable as a wax inhibitor in decreasing wax deposition. Malaysian Jatropha seed oil is effective in mitigating one of the serious flow assurance issues, especially in an aging reservoir such as the Malay basin. Further research needs to be conducted to monitor its performance as a natural wax inhibitor on various types of waxy crude oil. The difference in values of oleic acid content in Jatropha seed oil from different origins might be attributed to the difference in fatty acid composition, climate and soil conditions. Table 1 shows the summary of oleic acid content in Jatropha seed oil obtained from seeds of different origins.

Table 1. Oleic acid composition of Jatropha seed oil extracted from the seeds of Malaysia, Nigeria and Indonesia.

Reference	Seeds Origin	Oleic Acid Composition (%)	Factor Difference of Oleic Acid Content
This study	Malaysia	44.91	• Fatty acid composition
Akinyemi et al. [12]	Nigeria	43.11	• Climate condition
Emil et al. [21]	Indonesia	42.40	• Soil condition

However, despite all these factors, it is still proved that oleic acid is the main active component in Jatropha seed oil which is involved in the interaction with crude oil containing higher hydrocarbons. These interactions between molecules lead to wax deposition

inhibition. The molecules of the monosaturate present in the seed oil of Jatropha are capable of attaching to the larger molecules of paraffin in solution and this behavior is able to separate them from generating wax aggregation and building up the wax deposition. This finding supported that the use of Malaysian Jatropha seed oil is capable of delaying the wax crystallization process and contributing to a solution for flow assurance problems with an environmentally friendly option at a lower cost [11].

3.3. Fourier Transformed Infrared Spectroscopy

The FTIR equipment was used to analyze Jatropha seed oil in order to identify the presence of ester fatty acid. The FTIR analysis provided the wavenumber which points out the functional group present in Jatropha seed oil. The FTIR spectrum in this study gave its result in transmittance versus wavenumber data. According to Nandiyanto et al. [18], there are three wavenumber regions divided in the infrared radiation (IR) which are near-IR spectrum (4000–13,000 cm^{-1}), mid-IR spectrum (400–4000 cm^{-1}) and far-IR spectrum (<400 cm^{-1}). Figure 11 shows the wavenumber of Malaysian Jatropha seed oil from the FTIR band.

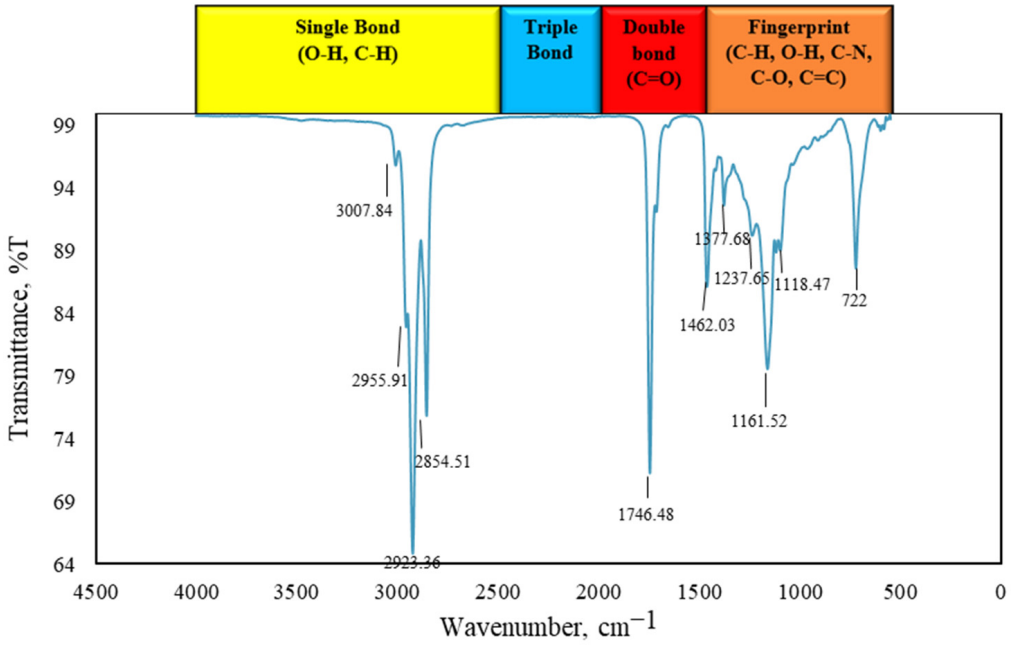

Figure 11. Wavenumber of Malaysian Jatropha seed oil from FTIR band.

Figure 11 illustrates the analysis of Malaysian Jatropha seed oil. The appearance peaks in the FTIR band represent the specific functional group and a compound class of components available in the Jatropha seed oil based on the wavenumber obtained. Firstly, there are more than five numbers of peaks in this FTIR band. This condition indicates that the analyzed chemical is not a simple chemical. Secondly, there are nine peaks that contained a single-bond area involving O-H, C-H, C-N and C-O bonds. However, there is no C≡C bond due to this triple-bond region not being detected in the non-edible oil of Jatropha seed oil. Meanwhile, a two double-bond region was found with C=O and C=C bonding in the material.

The IR spectrum in Figure 11 shows that the 3007.84 cm^{-1} wavenumber signifies a weak and broad intensity with the O-H stretching functional group. It is from the alcohol compound class and contains intramolecular bonds. In addition, C-H stretching functional groups were found at the wavenumbers 2955.91 cm^{-1}, 2923.36 cm^{-1} and 2854.51 cm^{-1}. The compound class for this functional group is an alkane and medium intensity was found at these three peaks.

The wavenumber at the peak 1746.48 cm^{-1} indicates the presence of the C=O stretching carboxyl functional group with strong intensity. This functional group represents the ester fatty acid compound class. Jatropha seed oil tends to have a high amount of oleic acid from the fatty acid group, which helps in improving the waxy crude oil flowability and contributes to viscosity reduction. It also contains a six-membered lactone in this compound. It was observed that there was no OH stretch, confirming the purity of the Jatropha seed oil without any water or emulsion contaminants.

Moreover, medium intensity was observed at the wavenumber 1462.03 cm^{-1} with the C-H bending functional group. This is placed in the alkane compound class and becomes a part of the methylene group. The phenol compound class was discovered at the wavenumber 1377.68 cm^{-1}. At this peak, O-H bending was detected with medium intensity. Other than that, at wavenumber 1237.65 cm^{-1}, medium intensity with the C-N stretching functional group was observed. This group represents the amine compound class.

Based on the FTIR spectrum, the functional group of C-O stretching with strong intensity was found at wavenumbers 1161.52 cm^{-1} and 1118.47 cm^{-1}. However, the compound class observed was different at these two peaks where 1161.52 cm^{-1} indicates tertiary alcohol, meanwhile, 1118.47 cm^{-1} represents secondary alcohol. Lastly, a strong intensity was discovered at wavenumber 722 cm^{-1} with the C=C bending of the functional group. This is located in the alkene compound class and contains disubstituted (cis). The FTIR band wavenumber of Jatropha seed oil varies according to the peak intensity. Table 2 shows the summary of the functional groups and compound classes of Malaysian Jatropha seed oil obtained from the wavenumbers in the FTIR band.

Table 2. Functional group of Malaysian Jatropha seed oil.

Wavenumber (cm^{-1})	Appearance/Intensity	Functional Group	Compound Class	Comments
3007.84	Weak, broad	O-H stretching	Alcohol	Intramolecular bonded
2955.91	Medium	C-H stretching	Alkane	-
2923.36	Medium	C-H stretching	Alkane	-
2854.51	Medium	C-H stretching	Alkane	-
1746.48	Strong	C=O stretching	Esters	6-membered lactone
1462.03	Medium	C-H bending	Alkane	Methylene group
1377.68	Medium	O-H bending	Phenol	-
1237.65	Medium	C-N stretching	Amine	-
1161.52	Strong	C-O stretching	Tertiary alcohol	-
1118.47	Strong	C-O stretching	Secondary alcohol	-
722	Strong	C=C bending	Alkene	Disubstituted (cis)

Based on the FTIR analysis as shown in Figure 11 and Table 2, this study of Malaysian Jatropha seed oil focused on the mid-IR spectrum. There are four divided regions representing the mid-IR spectrum, which are the single-bond region (2500–4000 cm^{-1}), the triple-bond region (2000–2500 cm^{-1}), the double-bond region (1500–2000 cm^{-1}) and the fingerprint region (600–1500 cm^{-1}).

Throughout this characterization analysis, it was proved that ester fatty acid was found in Malaysian Jatropha seed oil in the double-bond region of wavenumber 1746.48 cm^{-1} indicated with strong intensity and indicating C=O fatty acid ester stretching. The ester functional group was observed as a carbonyl compound because the wavenumber obtained falls between 1750 cm^{-1} and 1725 cm^{-1}, and this discovery was supported by Coates [22] and Nandiyanto et al. [18]. This finding validates the results obtained from GC–MS, which indicate the presence of fatty acids such as oleic acid as the main component in Malaysian Jatropha seed oil. The delocalized unpaired electron over the $\prod$-orbital at the double-bond and hydroxyl function of unsaturated fatty acid components of Jatropha seed oil could interact with the paraffin wax component resulting in viscosity reduction of waxy crude oil.

The infrared radiation was subjected to contact with the Jatropha seed oil sample. Specific transmission or absorption of energy was obtained when the atomic vibrations of a

molecule in the sample gained impacts from IR radiations. Therefore, specific molecular vibrations contained in the Jatropha seed oil sample were determined using FTIR. Kiefer [23] stated that characterization analysis using FTIR is relatively sensitive, good in accuracy and quite rapid. Therefore, FTIR is quite popular and is suggested compared to other types of characterization analysis.

3.4. Effectiveness of Malaysian Jatropha Seed Oil and Powdered Jatropha Leaves

A rheological test was conducted using Fann viscometer equipment to perform the viscosity measurement for crude oil and to verify the effectiveness of Malaysian Jatropha seed oil as a wax inhibitor. Figure 12 shows the outcomes of the rheological test conducted using Panera waxy crude oil blend with Malaysian Jatropha seed oil at temperatures 60 °C to 80 °C.

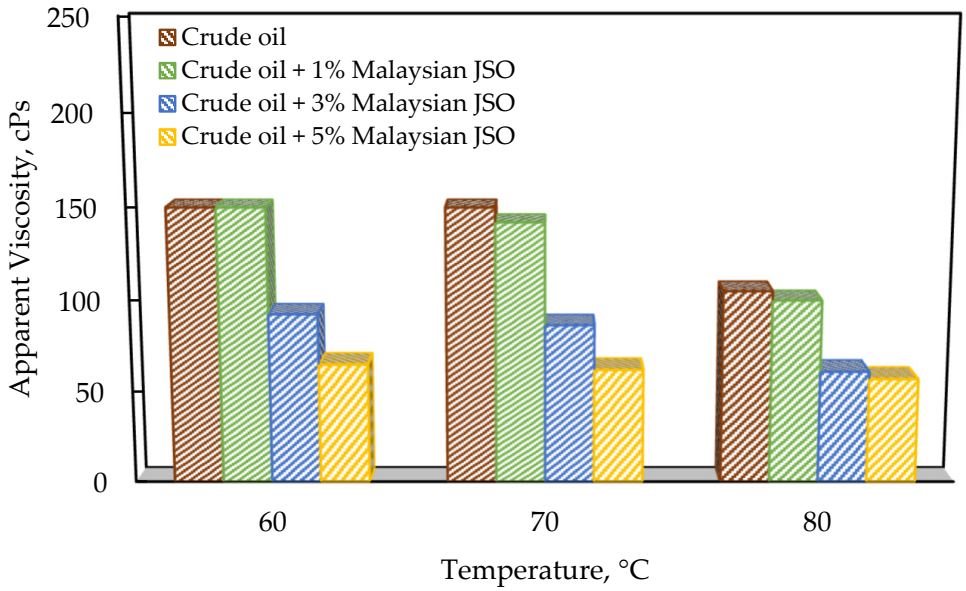

Figure 12. Rheological test of Panera waxy crude oil with and without addition of Malaysian Jatropha seed oil.

Based on the bar chart in Figure 12, it was found that the addition of Malaysian Jatropha seed oil with 1%, 3% and 5% concentrations successfully reduced the apparent viscosity of the Panera waxy crude oil at temperatures of 60 °C to 80 °C. The concentration of 5% Malaysian Jatropha seed oil showed the highest efficiency when it reduced the apparent viscosity of crude oil from 150 cPs to 65 cPs, 62 cPs and 57 cPs at temperatures 60 °C, 70 °C and 80 °C, respectively. The oleic acid component in this seed oil with 44.91% interacts with the paraffin wax molecule in Panera crude oil and delays the crystallization process of the wax. This condition causes the viscosity reduction of crude oil.

Due to the great performance of 5% Malaysian Jatropha seed oil as a sustainable wax inhibitor, further investigation on the rheological test was performed by utilizing powdered Jatropha leaves blend with 5% Malaysian Jatropha seed oil. Figure 13 shows the results of the experiment conducted on the rheological test.

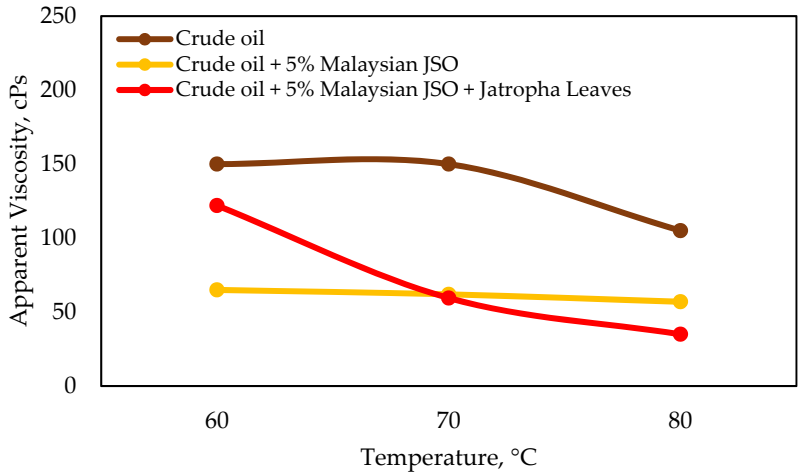

Figure 13. Rheological test of Panera waxy crude oil blend with the mixture of powdered Jatropha leaves and 5% Malaysian Jatropha seed oil.

Based on Figure 13, the results show that the mixture of powdered Jatropha leaves and 5% Malaysian Jatropha seed oil effectively reduced the apparent viscosity of Panera waxy crude oil from 60 °C to 80 °C. It is found that this mixture is more efficient compared to 5% Malaysian Jatropha seed oil at temperatures of 70 °C and 80 °C. These findings proved the effectiveness of this mixture containing powdered Jatropha leaves, which can be considered a natural wax inhibitor in mitigating wax deposition and increasing the flowability of waxy crude oil.

4. Conclusions

This work investigated the composition of Malaysian Jatropha seed oil, which is known to be non-edible and has great potential as a wax inhibitor. The Soxhlet extraction process provided high yields averaging 62.9% to 72.1%, justifying the viable oil content of Jatropha seeds. Characterization performed by GC–MS and FTIR showed the presence of oleic acid and the ester fatty acid functional group, which is the most important component for reducing viscosity and improving flowability. The overall result confirmed that Malaysian Jatropha seed oil has the ability to store oleic acid by up to 44.91% as its main component. This research was extended by the discovery of the process of powdered Jatropha leaves, which are suitable as a wax inhibitor. Further studies were conducted to verify the effectiveness of the blend of 5% Malaysian Jatropha seed oil and powdered Jatropha leaves in reducing wax deposition through rheological tests. The results showed that this blend effectively reduced the viscosity of waxy Penara crude oil from 60 °C to 80 °C.

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