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Physical and Chemical Properties Analysis of *Jatropha curcas* Seed Oil for Industrial Applications

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***Abstract*—**A study on the physicochemical properties of *Jatropha curcas* seed oil for industrial applications were carried out. Physicochemical properties of *J. curcas* seed oil (59.32% lipids) showed high content of LA (36.70%), iodine value (104.90 mg/g) and saponification value (203.36 mg/g). The present study shows that, *J. curcas* seed oil is rich in oleic and linoleic acids. The *J. curcas* seed oil with the highest amount of polyunsaturated fatty acids (linoleic acid) can find an application in surface coating industries and biolubricant base oil applications, whereas the high amount of monounsaturated fatty acid can find an application as a biodiesel feed stock. *J. curcas* seed oil contains major TAG of monounsaturated OLL, POL, SLL, PLL, OOL, OOO and POP followed by LLL. *J. curcas* seed oil can be classified as unsaturated oil with an unsaturated fat level of 80.42%. Hence the *J. curcas* seed oil has great potential for industrial applications such as in paint and surface coatings, production of biodiesel and biolubricant. Therefore, it is crucial to have more research on *J. curcas* seed oil in the future to explore its potential as a future industrial oilseed crop.

***Keywords*—**Physical, chemical, *Jatropha curcas* seed oil, industrial applications.

I. Introduction

J. curcas seed oil is non-edible due to the presence of anti-nutritional factors such as phorbol esters [1]. The utilization of non-edible and renewable crops such as *J. curcas* seed oil is expected to minimize this problem. In addition, the increased environmental concern and the anticipated diminution of petroleum reserves are the main reasons for the exploration of alternative non-edible crops for biodiesel production [2].

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J. curcas seed oil used in a direct injection diesel engine showed lower emissions of hydrocarbons and oxides of nitrogen compared to those from mineral diesel [3]. About 40-50% of *J. curcas* seed oil can substitute for diesel without any engine modification or preheating of the blends [4] and can be used as a fuel in diesel engines by blending it with methanol [5].

Malaysia is one of the countries looking into *J. curcas* because it replicates the poverty alleviating power of palm oil, while at the same time avoiding the problems associated with palm biodiesel and its important role in different industries. The *J. curcas* seed oil has a strong purgative action and is also widely used for treating skin disease, eczema and to soothe rheumatic pain [6].

There has been considerable research on the physicochemical properties of *J. curcas* seed oil. The composition of *J. curcas* seed oil from Nigeria consists of mainly fatty acids such as palmitic acid (13%), stearic acid (2.53%), oleic acid (48.8%) and linoleic acid (34.6%) [7]. *J. curcas* seed oil contains a high percentage of unsaturated fatty acid, which is about 78-84%. This makes the oils suitable for biodiesel production. However, the chemical compositions of the oil vary according to the climate and locality [8].

The origin of *J. curcas* was Mexico and Central America. It was introduced into Africa, Asia and is now cultivated world-wide, especially in tropical and subtropical countries [9]. Nowadays, the *J. curcas* plantation is receiving considerable attention in many parts of the world due to the advantages, including higher yield than other plant oils, such as soya, rapeseed, etc., easy to cultivate and reclamation of waste land [10]. The objective of this study is to evaluate the physicochemical characteristics of the seed oil extracted from the *J. curcas* seeds collected from Malaysia.

II. Experimental and Methodology

A. Oil Extraction

J. curcas seed oil extraction was determined in accordance with [11]. About 500g milled *J. curcas* seeds were weighed and placed in a thimble. The thimble was then placed in the soxhlet chamber, which was suspended above a boiling flask containing 2500mL hexane. The hexane was heated to 60°C for 11 hours. The chamber containing the milled *J. curcas* seeds was slowly filled with warm hexane, until the warm hexane exceeded a certain temperature level when it overflowed and spilled over into the boiling flask. This cycle

was repeated many times. After extraction for 6 hours, the hexane was evaporated by a rotary evaporator in water bath at 50°C for 60min.

B. Colour

Colorimetric measurements, according to [12], were carried out using a manual colorimeter Orbeco-Hellige, equipped with glass colour standards and a glass cuvette of 3.3-cm optical path.

C. Lipid Content

The weight of the oil extracted from 500g of seed powder was determined to calculate the lipid content. The result was expressed as the percentage of lipids in the composition of the dry seed powder.

D. Acidity

Free fatty acid (FFA %) and acid value (as oleic) were determined according to [11]. Approximately 50mL of isopropanol was placed into the flask, and about 0.5mL phenolphthalein was added and was neutralized by addition of sodium hydroxide (NaOH, 0.02 N) until a permanent pink colour was obtained. The neutralized isopropanol was added to the 5g of *J. curcas* seed oil, which was placed into an Erlenmeyer flask, and about 0.5mL of phenolphthalein was added. After shaking the mixture gently, the mixture was neutralized by the addition of (NaOH, 0.02 N) until the first permanent pink colour was obtained.

E. Iodine Value

The iodine value was determined according to [11]. About 0.3g of *J. curcas* seed oil was placed in a 500mL flask. Then 15mL of carbon tetrachloride (CCl_4) was added to dissolve the oil, and 25mL of the wijs solution was added into the flask and the stopper was inserted.

After shaking the mixture gently, the flask was placed in the dark for 1 hour. After standing for 1 hour, 20mL of potassium iodide (KI, 10% v/v) solution and 150mL of water were added, the mixture was titrated with the sodium thiosulphate ($Na_2S_2O_3$, 0.1 N) solution until the yellow colour due to the iodine had almost disappeared, 1mL of the (starch, 1% v/v) indicator solution was added, and the titration was continued until the blue colour just disappeared after very vigorous shaking. The blank test was carried out under the same conditions.

F. Saponification Value

The saponification value (SV) was determined according to [11]. About 2g of *J. curcas* seed oil was placed into conical flask, and 25mL ethanolic potassium hydroxide (KOH, 0.5 N) was added with some boiling stones. The boiling flask was connected to the condenser and the mixture was boiled gently for 1 hour.

After the boiling, the mixture was cooled and 1ml of phenolphthalein, (1% v/v) was added, the mixture was titrated with hydrochloride acid (HCl, 0.5N) until the pink colour of the indicator just disappeared. The blank test was carried out under the same conditions.

G. Unsaponifiable Matter

Unsaponifiable matter was determined according to [11]. About 10g of *J. curcas* seed oil was placed into a round-bottomed flask and 30mL ethanol and 5mL of aqueous KOH solution were added with some boiling stones into the round-bottomed flask.

The round-bottomed flask was connected to a condenser, and the mixture was boiled gently for 1 hour. After the boiling, the heating was stopped and the reaction mixture was transferred into the separating funnel. The flask was rinsed with 10mL ethanol followed by 20mL warm distilled water and then 20mL cold distilled water, and all the washings were transferred into the separating funnel.

The contents of the separating funnel were left to cool at room temperature, after that 50mL of hexane was added into the separating funnel. After shaking the mixture vigorously for 1min, the mixture was left a few minutes to get two phases. The soap solution phase was converted completely into the second separation funnel, and 50mL of hexane was added into the separating funnel.

After shaking the mixture vigorously for 1 minute, the mixture was left a few minutes to get two phases. The extractions using 50mL of hexane were repeated five times. The combined extracts in the separating funnel were washed three times with 25mL of 10% (v/v) ethanol, after shaking the separating funnel vigorously; the ethanol layer was drawn off after each wash.

The hexane was evaporated to dryness under the vacuum using a rotary evaporator, the drying was completed in a vacuum oven at 75-80°C, and was cooled in a desiccator and was weighed (W_r). The residue was dissolved in 50mL 95% ethanol, and was titrated with 0.02 N NaOH solution using phenolphthalein indicators to a faint pink colour.

H. Viscosity

The viscosity of the *J. curcas* seed oil was measured using chemistry Labs. Inc. Viscometer [12]. The spindle size S05 was used at 100rpm for 1min in room temperature.

I. Gas Chromatography Method

Gas chromatography method (GC) analysis was performed using Shimadzu Gas chromatography (GC) equipped with a flame ionisation detector and capillary column (30m × 0.25mm × 0.25mm film). The parameters of GC have been carried out according to [11].

The fatty acids were determined using their fatty acid methyl esters and were injected into gas-chromatography for analysis. The identification of the peaks was carried out by retention times by means of comparing them with genuine standards analyzed under the same conditions.

J. High Performance Liquid Chromatography Method

High performance liquid chromatography (HPLC) analysis was performed using a Waters model 1515 equipped with refractive index detector and spherisorb C18 column (250mm × 4.8mm × 3mm), which was used for analysis of the TAG. The parameters of HPLC were carried out according to [11]. Triacylglycerol of *J. curcas* seed oil and FFA were determined

by using HPLC. *J. curcas* seed oil and the FFA were dissolved in 10mL of the mixture acetone: acetonitrile before 20mL of the sample being into HPLC.

III. Results and Discussion

In determining the colour of the *J. curcas* seed oil, Cielab coordinates were used. In this coordinate system the R* value is a measure of redness. The Y* value is a measure of yellowness. *J. curcas* seed oil colour comes from the presence of highly coloured material and carotene extracted from the seed, however, most of the colour is due to a low residual level of gossypol, which is a yellow pigment, and its derivatives [13]. Some of the pigments can be removed by adsorption bleaching; gossypol can only be removed by alkali-refining. The higher Y* is a measure of 5, which makes *J. curcas* seed oil darker in colour. At room temperature, the colour of the Malaysian *J. curcas* seed oil appeared as golden-yellow oil (Table I).

Table I shows the physicochemical properties of the *J. curcas* seed oil compared to the Malaysian and Nigerian *J. curcas* seed oil. The *J. curcas* seed oil in this study contained a relatively high percentage of total lipids content 59.32±0.09 compared to the Nigerian *J. curcas* seed oil, which was 47.25% and similar to the Malaysian *J. curcas* seed oil at 60.45%.

The lipid content of *J. curcas* seed has been found to be higher than rubber seed oil 40±0.11% [11]. The relatively high lipid content of *J. curcas* seed indicates that *J. curcas* seeds are suitable as non-edible plant oil feedstock in oleochemical industries (biolubricants, biodiesel, fatty acids, soap, fatty nitrogenous derivatives, surfactants and detergents) [14].

The FFA% and acid value of *J. curcas* seed oil are 1.89±0.10; 3.76±0.07, respectively, which are lower than the rubber seed oil 7.55±0.02; 15.03±0.04, respectively, [11] due to the increase of the FFA of the oil with the length of storage. Otherwise, a high free fatty acid content would be nutritionally desirable by its enhancement of the availability of fatty acids (especially the unsaturated ones), which normally esterifies to the glycerol moiety of the triacylglycerol [15].

The iodine value is a measure of the unsaturation of fats and oils. A higher iodine value indicates higher unsaturation of fats and oils [15]. The iodine value of *J. curcas* seed oil in this study is 104.90±0.25 (mg/g), which is lower than Malaysian *J. curcas* seed oil 135.85 (mg/g) and Nigerian *J. curcas* seed oil 105.20±0.70 (mg/g). The present saponification value of the *J. curcas* seed oil 203.36±0.36 mg/g is lower than the Malaysian *J. curcas* seed oil 208.50 mg/g. The average molecular weights of TAG of *J. curcas* seed oil is 827.59 g/mol.

The unsaponifiable matter is important in determining the total quantity of substances present in oil or fat, and, after saponification with an alkaline hydroxide, it is insoluble in water but soluble in the solvent used. The *J. curcas* seed oil was saponified by an ethanolic alkaline hydroxide solution, followed by dilution. The unsaponifiable matter was extracted with hexane. The total quantity of unsaponifiable matter of *J. curcas* seed oil is 1.76±0.03% as shown in Table I.

TABLE I
Physicochemical Properties of *J. curcas* Seed Oil

Parameter	Value
Color	Golden-yellow
R	0
Y	5
Total lipid content (%)	59.32±0.09
Free fatty acid as oleic acid (%)	1.89±0.10
Acid value (mg KOH/g)	3.76±0.07
Iodine value (wijs)	104.90±0.25
Saponification value (mg/g)	203.36±0.36
Unsaponifiable matter (%)	1.76±0.03
Viscosity at room temperature (cp)	32

The unsaponifiable matter is important in determining the amount of substances present in the *J. curcas* seed oil. At room temperature, kinematic viscosity of the *J. curcas* seed oil was detected at 32 cp. This is a comparable value with that reported elsewhere [16]. The viscosities of J. *curcas* seed oil must be reduced for biodiesel application since the kinematic viscosity of biodiesel is very low compared to plant oils.

The determination of fatty acid composition of the *J. curcas* seed oil reveals important characteristics, as shown in Table II. Three major long chain fatty acids were detected in the *J. curcas* seed oil, which are oleic 43.32%, linoleic 36.70%, and palmitic 13.19% acids. Other fatty acid compositions were less than 10% and comprised stearic 6.36% and palmitoleic 0.40% acids.

TABLE II
Fatty Acids Composition of *J. curcas* Seed Oil

Fatty acid composition	Value
Palmitic	13.19
Palmitoleic	0.40
Stearic	6.36
Oleic	43.32
Linoleic	36.70
∑ Saturated Fatty acid	19.55
∑ Unsaturated Fatty Acid	80.42

In general, the *J. curcas* seed oil in this study contained more unsaturated fatty acids 80.42% than Malaysian *J. curcas* seed oil 78.95% [17] and Nigerian *J. curcas* seed oil 72.70% [16]. Medium fatty acids such as capric, lauric and myristic were not detected. As a comparison, the *J. curcas* seed oil in this study and Malaysian *J. curcas* seed oil contain less palmitic. Plant oils that are rich in polyunsaturated fatty acids such as linoleic acid, include soybean 53.2% and sunflower 66.2%, which tend to give methyl ester fuels with oxidation stability. Plant oils with high degree unsaturation tend to have a high freezing point.

Due to its industrial potential, it is crucial to determine the triacylglycerol (TAG) profile for the *J. curcas* seed oil. The results from the reversed phase HPLC show that the oil is composed of at less thirteen important TAGs (Fig. 1) in which the mechanism of separating the TAGs involves the chain length and degree of unsaturation of the fatty acids [18].

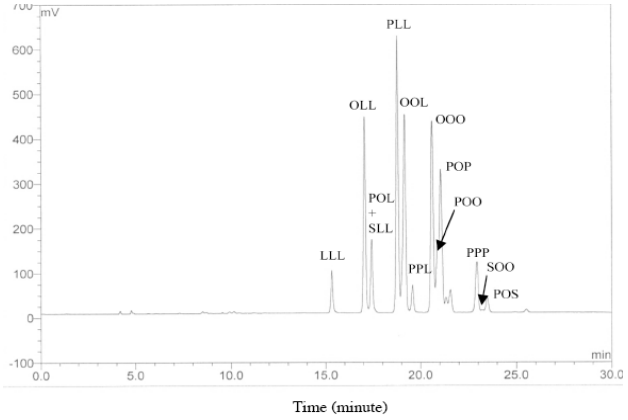

Fig. 1 HPLC chromatogram of TAGs composition of *J. curcas* seed oil

The TAGs composition in *J. curcas* seed oil was identified according to the equivalent carbon number (ECN) compared with standard (Table III).

TABLE III
TAG COMPOSITION OF *J. CURCAS* SEED OIL

TAGs	ECNs	Composition
LLL	42	5.51
OLL	44	15.01
POL + SLL	44	7.97
PLL	44	15.88
OOL	46	17.72
PPL	46	2.04
OOO	48	11.45
POO	48	16.94
POP	48	0.60
Unknown	48	0.28
Unknown	48	0.49
PPP	48	3.59
SOO	50	0.19
POS	50	1.13

The *J. curcas* seed oil is rich in triacylglycerol, containing (98.8%), depending on the FFA% [19]. The TAG exists in the solid or liquid form depending on the nature of the constituent fatty acids. Most plant triacylglycerols have low melting points and are liquid at room temperature. They contain a large proportion of unsaturated fatty acids, such as oleic, linoleic, and linolenic.

IV. CONCLUSION

The present study shows that, *J. curcas* seed oil is rich in oleic and linoleic acids. The *J. curcas* seed oil with the highest amount of polyunsaturated fatty acids (linoleic acid) can find an application in surface coating industries and biolubricant base oil applications, whereas the high amount of monounsaturated fatty acid can find an application as a biodiesel feed stock.

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