European Journal of Scientific Research
ISSN 1450-216X Vol.29 No.3 (2009), pp.396-403

http://www.eurojournals.com/ejsr.htm

Characteristic and Composition of *Jatropha Curcas* Oil Seed from Malaysia and its Potential as Biodiesel Feedstock Feedstock

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Abstract

Due the environmental concern and limited resources of petroleum oil has increase the demand of biodiesel. One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils The fact that *Jatropha* oil can not be used for nutritional purposes without detoxification makes its use as energy/fuel source very attractive. The lipid fraction of *Jatropha oil* seed were extracted and analyzed for their chemical and physical properties such as acid value, percentage free fatty acids (% FFA), iodine value, peroxide value and saponification value as well as viscosity, and density. The fatty acid and triacylglycerol (TAGs) composition of the extracted lipid was revealed using the gas chromatography (GC) and high pressure liquid chromatography (HPLC) method. Both oleic acid (44.7%) and linoleic acid (32.8%) were detected as the dominant fatty acids while palmitic acid and stearic acid were the saturated fatty acids found in the *Jatropha* oil.

OLL (22.94%) and OOL (17.9%) was detected as major triacylglycerol composition in the *jatropha* oil. The oil extracts exhibited good physicochemical properties and could be useful as biodiesel feedstock and industrial application.

Keywords: *Jatropha* curcas, biodiesel, fatty acid, triacylglycerol

1. Introduction

Currently due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need o develop alternative energy resources, such as biodiesel fuel. Vegetable oil is a promising alternative because it has several advantage, it is renewable, environ-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. Therefore, in recent years several research been have studied to use vegetable oils as fuel in engines as biodiesel. (Pramanik, 2003; Bozbas, 2005). Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, sunflower oil, rapeseed oil, and canola oil have been used to produce biodiesel fuel and lubricants (Demirbas, 2003)

Biodiesel is monoalkyl esters of fatty acids derived from vegetable oils or animal fats, is known as a clean and renewable fuel. Biodiesel is usually produced by the transesterification of vegetable oils or animal fats with methanol or ethanol (Knothe et al., 2006). Biodiesel has many advantages include the following: its renewable, safe for use in all conventional diesel engines, offers the same performance and engine durability as petroleum diesel fuel, non-flammable and nontoxic, reduces tailpipe emissions, visible smoke and noxious fumes and odors. The use of biodiesel has grown dramatically during the last few years. Feedstock costs account for a large percent of the direct biodiesel production costs, including capital cost and return (Bozbas, 2005).

One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils (Veljkovic´ et al., 2006). The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the commercials filling stations. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative. With no competing food uses, this characteristic turns attention to *Jatropha curcas*, which grows in tropical and subtropical climates across the developing world (Openshaw, 2000).

The fact that Jatropha oil can not be used for nutritional purposes without detoxification makes its use as energy or fuel source very attractive as biodiesel. In Madagascar, Cape Verde and Benin, *Jatropha* oil was used as mineral diesel substitute during the Second World War (Agarwal, 2007). *Jatropha curcas* (Linnaeus) is a multipurpose bush/small tree belonging to the family of Euphorbiaceae. It is a plant with many attributes, multiple uses and considerable potential. The plant can be used to prevent and/or control erosion, to reclaim land, grown as a live fence, especially to contain or exclude farm animals and be planted as a commercial crop. It is a native of tropical America, but now thrives in many parts of the tropics and sub-tropics in Africa/Asia (Gubitz et a., 1999; Kumar and Sharma, 2008; Openshaw, 2000; Martınez-Herrera et al., 2006).

The wood and fruit of *Jatropha* can be used for numerous purposes including fuel. The seeds of *Jatropha* contain viscous oil, which can be used for manufacture of candles and soap, in cosmetics industry, as a diesel/paraffin substitute or extender. This latter use has important implications for meeting the demand for rural energy services and also exploring practical substitutes for fossil fuels to counter greenhouse gas accumulation in the atmosphere. These characteristics along with its versatility make it of vital importance to developing countries (Kumar and Sharma, 2008). In view of these, the present research was designed to study the psycho-chemical properties including the fatty acids and TAGs composition of *Jatropha* oil seed from Malaysia.

2. Material and Methods

2.1. Seed material

Local *Jatropha Curcas* seeds were purchased from Bionas Sdn. Bhd. The seeds were selected according to their condition where damaged seeds were discarded before seeds in good condition were cleaned, de-shelled and dried at high temperature of 100–105 ◦C for 35 min. Seeds were grounded using grinder prior to extraction.

2.2. Oil extraction

The seed kernels were ground, using a mechanical grinder, and defatted in a soxhlet apparatus, using hexane (boiling point of 40–60 ◦C). The extracted lipid was obtained by filtrating the solvent lipid contained to get rid of the solid from solvent before the hexane was removed using rotary evaporator apparatus at 40 ◦C. Extracted seed oil was stored in freezer at−2 ◦C for subsequent physicochemical analysis.

2.3. Chemical and Physical analysis of seed oil

2.3.1. Oil Content.

The weight of oil extracted from 10 g of seeds powders was measured to determine the lipid content. Result was expressed as the percentage of oil in the dry matter of seed powders.

2.3.2. Acid value, % FFA.

Acid value of seed oil was determined according to AOAC Official Method Cd 3a- 63. Percentage free fatty acids (FFAs) were calculated using oleic acid as a factor.

2.3.3. Iodine value

Iodine value of seed oil was determined according to AOAC Official Method 993.20.

2.3.4. Saponification value

The saponification value was determined according to MPOB Official Test Method 2004.

2.3.5. Peroxide value

The peroxide value was determined according to AOAC Official Method 965.33

2.3.6. Viscosity

Viscosity of seed oil was carried out using Brookfield RV-I. Spindle of S03 was used at 10 rpm in room temperature.

2.3.7. Density

The density of the samples was determined at 25 °C by using density meter Anton paar DMA 4500.

2.4. Fatty Acid Compositions.

Fatty acid composition of seed oil was determined using agilent 6890 series gas chromatography (GC) equipped with flame ionization detector and capillary column (30m×0.25mm×0.25mm). About 0.1 ml oil was converted to methyl ester using 1ml NaOMe (1 M) in 1ml hexane before being injected into the GC. The detector temperature was programmed at 240ºC with flow rate of 0.8 ml/min. The injector temperature was set at 240ºC. Hydrogen was used as the carrier gas. The identification of the peaks was achieved by retention times by means of comparing them with authentic standards analyzed under the same conditions.

2.3.9. TAGs Composition

TAGs profile of jatropha oil was determined by using high-performance liquid chromatography (HPLC) equipped with ELSD 800 detector (altech). The TAGs of the oil was separated using commercially column, inertsil ODS 3 (250mm x 4.6mm) The mobile phase was a mixture of acetonitrile: diclhrohometane (60:40) set at a flow rate of 0.8 ml/min, with pressure 2.3 bar. TAG peaks were identified based on the retention time of available commercial TAGs standard

3. Discussion

3.1. Chemical and Physical Properties

The data collected from the study of the physical and chemical properties of the test samples (Table 1) shown oil content of *jatropha* kernel was determined at 63.16%. Oil content of *jatropha* kernel was found higher than linseed, soybean, and palm kernel which is 33.33%, 18.35% and 44.6%, respectively (Gunstone, 1994). High oil content of *Jatropha Curcas* indicated that *Jatropha Curcas* are suitable as non-edible vegetable oil feedstock in oleochemical industries (biodiesel, fatty acids, soap, fatty nitrogenous derivatives, surfactants and detergents, etc). Currently, *Jatropha Curcas* can produce 2000 liter/ha oil per annual (Azam et al., 2005).

Table 1: Chemical and Physical Properties

Parameter	Value
% FFA as oleic acid	2.23±0.02
Iodine value	103.62±0.07
Saponification value	193.55±0.61
Peroxide value	1.93±0.012
Percentage oil content (kernel)	63.16±0.35
Density at 20° C (g/ml)	0.90317
Viscosity at room temperature (cp)	42.88
Physical state at room temperature	Liquid

a Values are mean±standard deviation of triplicate determinations

The iodine value is a measured of the unsaturation of fats and oils. Higher iodine value indicated that higher unsturation of fats and oils (Knothe, 2002; Kyriakidis and Katsiloulis, 2000). The iodine value of jatropha oil was determined at 103.62g I_2/100g, standard iodine value for biodiesel was 120 for Europe's EN 14214 specification. The limitation of unsaturated fatty acids is necessary due to the fact that heating higher unsaturated fatty acids results in polymerization of glycerides. This can lead to the formation of deposits or to deterioration of the lubricating (Mittelbach, 1996). Fuels with this characteristic (e.g Sunflower oil, soybean oil and safflower oil) also likely to produce thick sludges in the sump of the engine, when fuel seeps down the sides of the cylinder into crankcase (Gunstone, 2004). The iodine values of *jatropha curcas* place them in the semi-drying oil group. High iodine value of jatropha are caused by high content of unsaturation fatty acid such as oleic acid and linoleic acid. *Jatropha* oil seed oil consists of 78.5% unsaturated fatty acid (table 2). The iodine values of *jatropha* oil seed of suggest their use in production of alkyd resin, shoe polish, varnishes etc. (Akintayo, 2004).

The usual method of assessment hydroperoxides (primary oxidation products) is by determination of peroxide value (Gunstone, 2004). Peroxide value of *jatopha* oil seed showed a low value (as crude seed oil) of 1.93meq/kg, proving the oxidative stabilities of the seed oil relatively. The high iodine value and oxidative stability shows that the seed oil upholds the good qualities of semidrying oil purposes (Eromosele et al., 1997). Saponification value of the studied oil were 193.55.

High saponification value indicated that oils are normal triglycerides and very useful in production of liquid soap and shampoo industries. Experimental result showed that Jatropha oil seeds has FFA content 2.23%. The FFA and moisture contents have significant effects on the transesterification of glycerides with alcohol using catalyst (Goodrum, 2002). The high FFA content (>1% w/w) will happen soap formation and the separation of products will be exceedingly difficult, and as a result, it has low yield of biodiesel product. The acid-catalyzed esterification of the oil is an alternative (Crabbe et al., 2001), but it is much slower than the base-catalyzed transesterification reaction. Therefore, an alternative process such as a two-step process was investigated for feedstock having the high FFA content (Veljkovic´ et al., 2006).

Viscosity defined as resistance liquid to flow. Viscosity increased with molecular weight but decreased with increasing unsaturated level and temperature (Nouredini et al 1992). At room temperature kinematic viscosity of the sample were detected at 42.88 cp. The viscosity of Jatropha oil seed must be reduced for biodiesel application since the kinematic viscosity of biodiesel were very low compared to vegetable oils. High viscosity of the jatropha oil seed are not suitable if its use directly as engine fuel, often results in operational problems such as carbon deposits, oil ring sticking, and thickening and gelling of lubricating oil as a result of contamination by the vegetable oils. Different methods such as preheating, blending, ultrasonically assisted methanol transesterification and supercritical methanol transesterification are being used to reduce the viscosity and make them suitable for engine applications (Pramanik, 2003; Banapurmath, 2008). The density of a material is a defined as the measured of its mass per unit volume (e.g. in g/ml). The density vegetable oil lower than of water and the differences between vegetables oil are quite small, particularly amongst the common vegetable oils. Generally, the density of oil decreases with molecular weight, yet increase with unsaturation level (Gunstone, 2004). From the experiment was conducted, the density of *jatropha* seed oil were 0.90317 g/ml.

3.2. Fatty Acid Composition

Fatty acid composition determination was another important characteristic carried out on this study (Table 2). The properties of the triglyceride and the biodiesel fuel are determined by the amounts of each fatty acid that are present in the molecules. Chain length and number of double bonds determine the physical characteristics of both fatty acids and triglycerides (Mittelbach and Remschmidt, 2004). Transesterification does not alter the fatty acid composition of the feedstocks and this composition plays an important role in some critical parameters of the biodiesel, as cetane number and cold flow properties (Ramos et al., 2008). Fatty acid composition of studied oil shown in table 2 compared with other vegetable oils such as palm oil, sunflower oil, palm oil and soybean oil.

There are three main types of fatty acids that can be present in a triglyceride which is saturated (Cn:0), monounsaturated (Cn:1) and polyunsaturated with two or three double bonds (Cn:2,3). Various vegetable oil is a potential feedstock for the production of a fatty acid methyl ester or biodiesel but the quality of the fuel will be effected by the oil composition. Ideally the vegetable oil should have low saturation and low polyunsaturation i.e be high in monounsaturated fatty acid (Gunstone, 2004). Vegetable oils that rich in polyunsaturated such as linoleic and linolenic acids, such as soybean, sunflower (table 2), tend to give methyl ester fuels with poor oxidation stability. Vegetable with high degree unsaturation tend to have high freezing point. This oil have poor flow characteristic and may become solid (e.g palm oil) at low temperatures though they may perform satisfactorily in hot climates. (Gunstone, 2004). The predominant fatty acid in studied oil consist of monounsaturated (45.4%), followed by polyunsaturated fatty acid (33%) and saturated fatty acid (21.6%). Monounsaturation of *jatropha* seed oil more higher than other vegetable oil as palm kernel, sunflower and palm oil (table 2).

The major fatty acids in *Jatropha* seed oil were the oleic, linoleic, palmitic and the stearic fatty acid. Oleic acid showed the highest percentage of composition of 42.8% followed by linoleic acid with 32.8%. Thus, *Jatropha* seed oil can be classified as oleic–linoleic oil. Compared to others vegetable oil (table 2), jatrhopa oil seed has highest oleic contain than palm oil, palm kernel, sunflower, coconut and soybean oil. According to the European standard the concentration of linolenic acid and acid containing four double bonds in FAMEs should not exceed the limit of 12% and 1%, respectively. *Jatropha* oil seed only consist of 0.2% linolenic acid,which is lower compared to the sunflower oil and palm oil (table 2).

Table 2: Fatty acid compositon (%)

Fatty Acid	Jatropha curcas oil seed	Palm kernel oil[a]	Sunflower oil[a]	Soybean oil[a]	Palm oil[a]
Oleic 18:1	44.7	15.4	21.1	23.4	39.2
Linoleic 18:2	32.8	2.4	66.2	53.2	10.1
Palmitic 16:0	14.2	8.4	-	11.0	44.0
Stearic 18:0	7.0	2.4	4.5	4.0	4.5
Palmitoliec 16:1	0.7	-	-	-	-
Linolenic 18:3	0.2	-	-	7.8	0.4
Arachidic 20:0	0.2	0.1	0.3	-	-
Margaric 17:0	0.1	-	-	-	-
Myristic 14:0	0.1	16.3	-	0.1	1.1
Caproic 6:0	-	0.2	-	-	-
Caprylic 8:0	-	3.3	-	-	-
Lauric 12:0	-	47.8	-	-	0.2
Capric 10:0	-	3.5	-	-	-
Saturated	21.6	82.1	11.3	15.1	49.9
Monounsaturated	45.4	15.4	21.1	23.4	39.2
Polyunsaturated	33	2.4	66.2	61.0	10.5

[a]From Edem, D.O. (2002)

3.3. TAGs Composition

The TAGs profile of *Jatropha* seed oil,was characterized by reversed phase HPLC where the mechanism in separating the TAGs involves the chain length and degree of unsaturation of the fatty acids (Gutierrez and Barron,1995). The identified TAGs of Jatropha seed oil were concluded by comparing the retention time of standard TAGs peak chromatographs obtained under same analytical condition. Triacyglycerol content of jatropha oil seed is showed at table 3 below. From the chromatograph obtained, showed that the most prominent polyunsaturated TAG was OOL (22.94%), followed by OLL (17.9%), , POL (14.95%), PLL +MOL 7.08, SOO (2.48%). Monounsaturated that has been detected were MPP+OOO (16.65%) POO (9.72%), PLP+MOP (1.85%) and POP (0.91%).

Table 3: TAGs composition (%)

Triacylglycerol	Relative Composition (%)	Triacylglycerol	Relative Composition (%)
OOL	22.94	SOO	2.48
OLL	17.90	PLP+MOP	1.85
MPP+OOO	16.65	POP	0.91
POL	14.95	POS	0.59
POO	9.72	MM	0.48
PLL + MOL	7.08	CC	0.44
Nd	3.60	PP	0.38

4. Conclusion

The major fatty acids in *Jatropha seed* oil were the oleic acid, linoleic acid , palmitic acid and the stearic acid. The most prominent TAGs of jatropha seed oil were OLL and OOL. The oil extracts exhibited good physicochemical properties and could be useful as biodiesel feedstock and industrial application. Feedstock costs account for a large percent of the direct biodiesel production costs, including capital cost and return. The way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils. With no competing food uses, this characteristic turns attention to *Jatropha curcas*, which grows in tropical and subtropical climates across the developing world.

Acknowledgement

The authors acknowledge the UKM, the grant number UKM-OUP-BTT-25/2007 for the financial support, the staff of Malaysian Palm Oil Board (MPOB) and Nuclear Malaysia (MINT) for their help.

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