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ORIGINAL PAPER

Comparative Evaluation of Physicochemical Properties of Jatropha Seed Oil from Malaysia, Indonesia and Thailand

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Abstract The jatropha oil was extracted from the jatropha seeds collected from different origins viz., Malaysia, Indonesia and Thailand. The physicochemical properties such as density, viscosity, percentage free fatty acid (FFA), iodine value, saponification value and peroxide value of the extracted jatropha seed oil were evaluated. The evaluation of fatty acid composition using gas chromatography (GC) revealed that, oleic (42.4–48.8%) and linoleic acid (28.8–34.6%) are the dominant fatty acids present in the jatropha seed oil. The saturated fatty acids such as palmitic and stearic acid lie in the range 13.25–14.5 and 7–7.7%, respectively. The observed major triacylglycerol (TAG) composition was OOL (22.94–25.75%) and OLL (15.52–20.77%).

Keywords Jatropha seeds · Non-edible oil · Biodiesel · Fatty acid · Iodine value

Introduction

Jatropha is a drought-resistant perennial crop able to grow in a wide range of soils [1]. It is a quick growing crop and can produce seeds for up to 50 years [2]. The jatropha nuts/seeds become capable of having their oil extracted after 2–5 years of plantation depending on the soil quality and rainfall. The annual yield of jatropha nuts/seeds is in the range from 0.5 to 12 tons. The cultivation of jatropha is successful in the tropics with annual rainfall of 250–3,000 mm [1]. Jatropha can also grow at low and high altitude areas that have an average annual temperature above 20 °C and can tolerate slight frost. The marginal soil qualities with a low nutrient content [3] are sufficient for growing jatropha plants. The cultivation of jatropha may be advantageous to farmers due to the fact of soil erosion prevention, its ability to act as living fence and reclamation of waste land. [3].

Jatropha is a multipurpose plant with many attributes and considerable potential. The various parts of jatropha plant have many useful applications [4]. The oil extracted from the seed can be utilised as a biodiesel feed stock and in soap production. During the World War II [5], the jatropha seed oil was used as a diesel substitute. The leaves are used in traditional medicine against coughs or as an antiseptic [6]. The tree itself can be used as fire wood and as a hedge plant for protection. The latex produced from the branches can act as a haemostatic agent. The oil cake, a by product remaining after the extraction of oil can be used as an organic fertilizer. Jatropha oil is non-edible due to the presence of anti-nutritional factors such as phorbol esters [7].

The utilisation of edible food crops (corn, soya, etc.) for the production of biofuels are expected to create a short supply of food for human consumption. The utilisation of non-edible and renewable crops such as jatropha is expected to minimize this problem. In addition to this, 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 [8].

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The centre of origin of jatropha was Mexico and Central America. It was introduced in to Africa, Asia and is now cultivated world-wide especially in tropical and subtropical countries [9]. Nowadays, the jatropha plantation is receiving considerable attention in many part of the world due to the advantages such as (1) higher yield than other vegetable oils such as palm, soya, rapeseed, etc. (2) easy to cultivate and (3) reclamation of waste land [3]. The objective of the present research is to evaluate the physico-chemical properties of seed oil extracted from the jatropha seeds collected from different origin viz., Malaysia, Indonesia and Thailand. The outcome of this study revealed that the jatropha oil may have a potential as a biodiesel feed stock.

Materials and Methods

Seed Material

Jatropha seeds from Malaysia and Thailand were purchased from Bionas Sdn. Bhd. Seeds from Indonesia were a gift from the joint marketing office of PT Perkebunan Nusantara, Indonesia. The seeds were selected in such a way that, the damaged seeds were discarded and the seeds in good condition were cleaned, de-shelled and dried at a temperature of 100–105 °C for 35 min. Seeds were ground using a grinder before oil extraction.

Oil Extraction

The extraction of jatropha oil was carried out using solvent extraction. The oil was extracted from the ground jatropha seed powder using hexane as the solvent for 6 h. The extracted oil was filtered and excess solvent was removed using a rotary evaporator at 40 °C. Finally, the seed oil was stored in a freezer at −2 °C for subsequent physicochemical analysis.

Chemical Analysis of Seed Oil

Acid Value, % FFA

The acid value of seed oil was determined according to AOAC (Association of Official Agricultural Chemists) Official Method Cd 3a-63. The percentage of free fatty acids (FFAs) was calculated using linoleic acid as the factor.

Iodine Value

The iodine value of the seed oil was determined according to AOAC Official Method 993.20.

Saponification Value

The saponification value was determined according to the Malaysian Palm Oil Board (MPOB) Official Test Method 2004.

Peroxide Value

The peroxide value was determined according to AOAC Official Method 965.33.

Fatty Acid Compositions

Fatty acid composition of the seed oil was determined using an Agilent 6890 series gas chromatograph (GC) equipped with a flame ionization detector and a capillary column (30 × 0.25 × 0.25 mm). About 0.1 ml of oil was converted to the methyl ester using 1 ml NaOMe (1 M) in 1 ml hexane before being injected into the GC. The detector temperature was programmed for 240 °C with a flow rate of 0.8 ml/min. The injector temperature was set at 240 °C. Hydrogen was used as the carrier gas. The peaks were identified by measuring the retention time of the samples and comparing the same with authentic standards analysed under the same conditions.

Physical Analyses of Seed Oil

Viscosity

The viscosity of the seed oil was determined using Brookfield RV-I. A spindle of S03 was used at 100 rpm at room temperature.

Density

The density of the samples was determined using an Anton-Paar DMA 4500 density meter.

TAGs Compositions

The TAGs profile of jatropha oil was determined using a Hewlett Packard (HP) reverse phase high-performance liquid chromatograph (RP-HPLC) equipped with an ELSD 800 detector (Altech). The TAGs of the oil were separated using a commercially packed column Inertsil ODS-3 (250 mm × 4.6 mm). The mobile phase was a mixture of acetonitrile:dichloromethane (60:40) set at a flow rate of 0.8 ml/min and a pressure of 2.3 PSI. Sample preparation involved the sample being diluted with a mixture of acetonitrile:dichloromethane (60:40) before being injected (20 μl) into the HPLC. TAG peaks were identified based on the retention time of commercial TAG standards analysed under same condition.

Results and Discussion

The physicochemical properties of jatropha oil extracted from the seeds of different origin viz., Malaysia, Indonesia and Thailand are given in Table 1. The oil content obtained from the seeds of different country lies in the range 61.36–64.23%. The highest oil content was observed in the Thailand seed variety as compared to the seeds of other two countries. The observed oil yield in the case of jatropha was found to be higher than the other vegetable oils such as linseed (33.33%), soybean (18.35%) and palm oil (44.6%) reported elsewhere [10]. The presence of such a high oil content in jatropha seeds has received considerable attention from research scientists eager to explore it as a biodiesel feedstock and also as a material in the oleochemical industries.

The iodine value is a measure of the unsaturation levels in fats and oils. A high iodine value is an indication of the presence of high unsaturation levels in the oils [11]. The determined iodine values of jatropha seed oil was 107.57, 103.62 and 92.57 for the samples from Indonesia, Malaysia and Thailand respectively. The high iodine value of jatropha oil is due to the presence of high amounts of unsaturated fatty acids such as oleic and linoleic acid (Table 2). The iodine value results of all the three samples of jatropha oil are well within the value of 120 (as specified in EN14214) which is an indication of its potential for use as a biodiesel feedstock [12, 13]. The obtained iodine value of jatropha seed oil has been found satisfactory for exploring its use in the production of alkyd resin, shoe polish, varnishes, etc. [14].

The peroxide value determines the formation of hydro peroxides (primary oxidation products) [15]. The peroxide values obtained for the samples from Thailand, Malaysia, and Indonesia were 1.08, 1.93 and 3.70 mq/kg, respectively. The highest peroxide value was observed for the oil from Indonesia. This can be attributed to the presence of higher amounts of polyunsaturated fatty acids such as linoleic acid (Table 2) as compared to the other two samples. The instability of any oil is directly related to the level of unsaturation. Large amounts of polyunsaturated fatty acids present are more reactive than the mono unsaturated fatty acids in the oil [16].

Table 1 The physicochemical characteristics of jatropha oil extracted from seeds from Malaysia, Indonesia and Thailand

Parameter	Malaysia	Indonesia	Thailand
% FFA	2.23 ± 0.02	9.20 ± 0.22	1.69 ± 0.01
Iodine value	103.62 ± 0.07	107.57 ± 0.97	92.53 ± 0.80
Saponification value	193.55 ± 0.61	200.66 ± 0.80	216.09 ± 1.07
Peroxide value	1.93 ± 0.01	3.70 ± 0.02	1.08 ± 0.01
Oil content	63.16 ± 0.35	61.36 ± 0.10	64.23 ± 0.24
Density (20 °C)	0.9027	0.9095	0.9024
Viscosity at room temperature (cSt)	47.50	53.94	39.20
Physical state at room temperature	Liquid	Liquid	Liquid

Table 2 Fatty acid composition of the jatropha oil extracted from the seeds of Malaysia, Indonesia and Thailand

Fatty acids (no of carbon atoms:degree of unsaturation)	Relative Composition (%)		
	Malaysia	Thailand	Indonesia
Unsaturated			
Oleic acid (18:1)	44.7	48.8	42.4
Linoleic acid (18:2)	32.8	28.8	34.6
Palmitoleic acid (16:1)	0.7	0.6	0.7
Linolenic acid (18:3)	0.2	0.1	0.2
Saturated			
Palmitic acid (16:0)	14.2	13.2	14.5
Stearic acid (18:0)	7.0	7.7	7.0
Arachidic acid (20:0)	0.2	0.3	0.2
Margaric acid (17:0)	0.1	0.1	0.1
Myristic acid (14:0)	0.1	0.1	0.1

The saponification values of jatropha seed oil for Malaysian, Indonesian and Thailand samples were 193.55, 200.66 and 216.09, respectively. A high saponification value indicated that, jatropha oil possesses normal triglycerides and may be useful in the production of liquid soap and shampoo [15]. The oil obtained from the Thailand jatropha seeds has showed the highest saponification value of 216.09 compared to the oils from the Malaysian and Indonesian seeds. The observed FFA content of jatropha oil found to be higher for the seeds from Indonesia (9.7%) followed by Malaysia (2.23%) and Thailand (1.69%). The FFA was found to have a correlation with the presence of polyunsaturated fatty acids (Table 2). The jatropha oil from the Indonesian seeds has a high content of polyunsaturated fatty acids (34.8%) followed by Malaysia (33%) and Thailand (28.9%).

The ability of any fluid to pump and flow within an engine is determined by its viscosity. The desired viscosity of diesel fuel ranges from 1.9 to 4.1 cSt. The viscosity obtained from the jatropha oil from Indonesia (53.94 cSt) seeds was higher compared to Malaysian (47.50 cSt) and Thailand (39.20 cSt) seeds. Transesterification is one of the known and efficient methods of reducing the viscosity of the vegetable oil to make it suitable as a biodiesel. The measured densities of the jatropha seed oil was 0.9095,

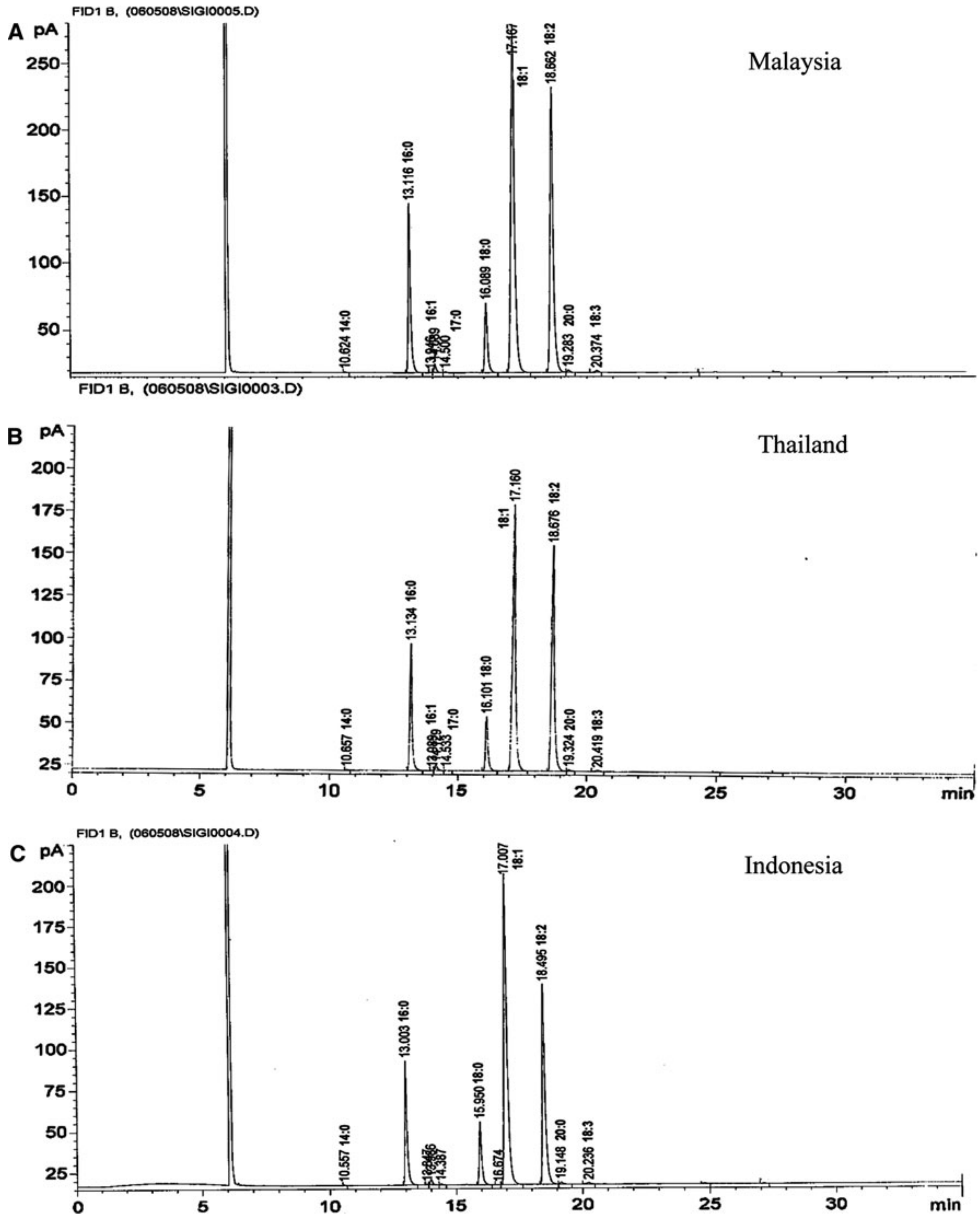

Fig. 1 Fatty acid profile of jatropha seed oil extracted from the seeds from Malaysia, Indonesia and Thailand

0.9027 and 0.9095 g/ml for the oils extracted from Indonesian, Malaysian and Thailand seeds, respectively.

Fatty Acid Composition

Table 2 and Fig. 1 show the fatty acid composition of jatropha oil extracted from the seeds of Malaysia, Thailand and Indonesia. The most abundant fatty acid is the mono unsaturated oleic acid and polyunsaturated linoleic acid in all the three oil samples. The oleic acid content of the oil extracted from the seeds of Thailand was higher (48.8%) compared to those from Malaysia and Indonesia. The oil extracted from the seeds from Indonesia had highest percentage of linoleic acid (34.6%) compared to those from

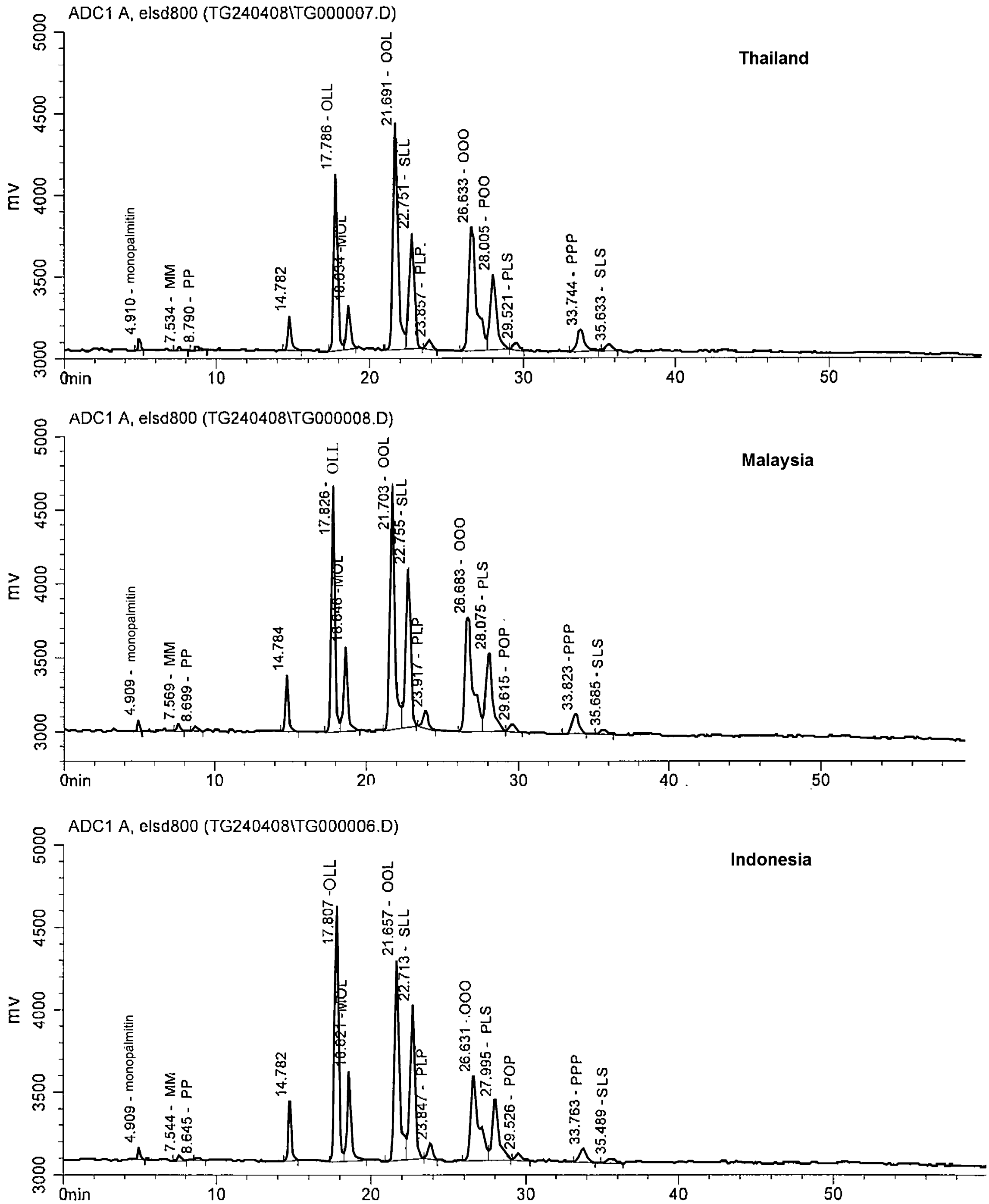

Fig. 2 TAGs profile of jatropha seed oil extracted from the seeds from Malaysia, Indonesia and Thailand

Malaysia and Thailand. The presence of oleic acid was found to be higher in all the three jatropha seed oils in the present investigation compared to other vegetable oils such as palm oil (39.2%), sunflower (21.1%) and soybean oil (23.4%) [17]. The ideal vegetable oil for biodiesel feedstock should consist of a larger amount of monounsaturated fatty acids than polyunsaturated fatty acids. Oil containing high amount of polyunsaturated fatty acids tend to exhibit a poor oxidation stability and may not be able to be used at low temperatures due to a high pour point [16]. In general, the oil from the Thailand jatropha seeds has shown a higher amount of unsaturation (78.3%) than Malaysian (78.1%) and Indonesian (77.8%) varieties. This may be attributed to the difference in (1) fatty acid composition and (2) soil/climate condition. However, the observed total percentage difference in the unsaturated and saturated fatty acid

Table 3 TAGs composition of the jatropha oil extracted from the seeds from Malaysia, Indonesia and Thailand

TAG	Relative composition (%)			ECN
	Malaysia	Thailand	Indonesia	
OOL	22.94	25.75	21.5	46
OLL	17.90	15.52	20.77	44
OOO	16.65	20.51	14.02	48
SLL	14.95	12.74	16.17	46
PLS	9.72	10.50	8.67	48
MOL	7.08	4.02	7.98	44
Nd	3.60	2.83	4.17	–
PPP	2.48	3.76	2.01	50
PLP	1.85	0.94	1.52	46
POP	0.91	0.98	1.03	48
SLS	0.59	0.89	0.83	50

L linolenic acid, *O* oleic acid, *P* palmitic acid, *S* stearic acid, *M* myristic, *C* caprylic, *Nd* these are TAGs peaks to be identified, *ECN* equivalent carbon number

composition of jatropha oil extracted from Malaysia, Thailand and Indonesia was negligible. The presence of polyunsaturated fatty acid such as linoleic acid in the jatropha oil is expected to impart semi-drying characteristics and can find an application in the surface coating industries [18].

TAG Profile

The TAGs profile of jatropha seed oil of the present investigation 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 [19]. The results of reversed phase HPLC showed that, the jatropha oil of the present investigation was composed of at least 13 important TAGs (Fig. 2). The TAG composition for the jatropha oil extracted from the seeds of Malaysia, Indonesia and Thailand did not show any significant difference (Table 3, Fig. 2). The major TAGs present were OOL (21.5–25.75%) followed by OLL (15.52–20.77%) and OOO (14.02–20.51%). The peaks observed before the first TAG peaks appeared at 8 min may be due to the presence of monoacylglycerols (MAG) and diacylglycerols (DAG). A similar behavior was noticed by Yong and Salimon [20] with respect to the presence of MAG and DAG in the characterization of *Elateriospermum tapos* seed oil. The percentage fatty acid composition obtained from the calculation of TAG data appears to have a slight difference as compared to the one obtained directly from GC. This may be due to the difficulty of (1) distinguishing the regioisomers arising from the different binding positions of the fatty acids and recognise the order of elution of different components intuitively as like GC and (2) the formation of "critical pairs" with close behaviour on reverse phase chromatography.

Conclusions

Based on the physicochemical evaluation of the jatropha oil obtained from the seeds of different origin viz., Malaysia, Thailand and Indonesia, the jatropha oil can be classified as an unsaturated oil due to the presence of sufficient amounts of oleic and linoleic acids. The highest amount of monounsaturated (mainly as oleic acid) fatty acid was noticed for the oil extracted from the seeds from Thailand (49.4%) followed by Malaysia (33%) and Indonesia (43.1%).The jatropha oil with the highest amount of polyunsaturated fatty acids (Indonesian seed) can find an application in surface coating industries whereas the jatropha oil containing a high amount of monounsaturated fatty acid (Thailand seed) can find an application as a biodiesel feed stock. The high yield of jatropha oil compared to those of other vegetable oils is an advantage for selecting this oil to produce cost competitive products.

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