2014 5th International Conference on Food Engineering and Biotechnology
IPCBEE vol.65 (2014) © (2014) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2014. V65. 12

Jatropha Curcas Oil Characterization and Its Significance for Feedstock Selection in Biodiesel Production

Nurudeen Ishola Mohammed[1], Nassereldeen Ahmed Kabbashi[1+], Md Zahangir Alam[1] and Mohammed Elwathig Mirghani[1]

[1] Bioenvironmental Engineering research Centre (BERC), Department of Biotechnology Engineering, Faculty of Engineering, International Islamic University Malaysia, Jalan Gombak, 50728 Kuala Lumpur, Malaysia.

Abstract. Over time, the quest for alternative fuel devoid of environmental degradation has intensified research on biodiesel synthesis from diverse feedstock. Biodiesel is an environmental friendly alternative liquid fuel that can be used in any diesel engine with little or no engine modification. There has been kindled interest in vegetable oils consideration for making biodiesel on account of its less polluting nature and benefits of its renewability compared to fossil diesel fuel. Once biodiesel is accorded the needed support and incentive, it stands to offer enormous benefits for the environment and the local population in terms of employment opportunity as well as provision of modern energy carriers for the use of rural communities. Moreover, non-edible oil such as *jatropha curcas* oil has experienced ongoing inquiry due to food-energy feud of some edible oils utilized as feedstock in biodiesel synthesis. In producing biodiesel which can be economically viable, it is imperative that the characteristic features of the feedstock are determined in order that all the available alternative approaches to produce the fuel are weighted before there can be any consideration for a particular method. In this paper, three *jatropha curcas* oil species were characterized and the implication of the various characteristic features in choosing the feedstocks for consideration in biodiesel synthesis are evaluated and discussed.

Keywords: Biodiesel, *Jatropha curcas*, Characterization, Properties.

1. Introduction

The world have witness continual increment in the production and consumption of vegetable oil due to growing population, technological advancement and industrialization. For instance, there was tremendous increase in the utilization of vegetable oil either for food or use as fuel to about 27% in just one decade [1]. The world dependency on petroleum and fossil fuel has caused a renewed interest in the quest for alternative energy sources and among the energy sources that have recorded enormous research is biodiesel.

Of concern is the energy security which deepen inquisition for alternative energy sourced basically from renewable biomass. In producing biodiesel, vegetable oils, animal fats and waste cooking oil are some of the many feedstocks that have been use in the process [2], adopting a myriad of production processes. The method to be used for a particular production process depends on the purity of the feedstock in order that unwanted product may be avoided.

Biodiesel according to the ASTM definition is a diesel engine fuel comprising monoalkyl esters and long-chain fatty acids which are derived from vegetable oils and fats. It is referred to as B100 and expected to meets the requirement of ASTM D 6751[3].

Fatty acids alkyl esters (Biodiesel) are characterized by their physical and fuel properties such as density, viscosity, iodine value, acid value, cloud point, pure point, gross heat of combustion, and volatility [3].

+ Corresponding author. Tel: + 60122593936; fax: +60361964442.
E-mail address: alkabbashi@yahoo.com.

Biodiesel fuels produce slightly lower power and torque and consume more fuel than conventional diesel fuel. Biodiesel is more advantageous to diesel fuel in terms of its sulfur content, flash point, aromatic content, biodegradability and environmental sustainability [4].

The cost of biodiesels is subject to the feedstock utilized in the production processes which is also dependent on the purity the oil. Of importance is the effect of geographical location, diversity in crop production in season, the cost of crude petroleum, and some other factors in biodiesel costing. Currently, biodiesel is much more expensive than petroleum diesel. The high cost of biodiesel is in large part due to the high price of the feedstock of high purity requirement. However, biodiesel can be synthesized using other feedstocks of solid state such as beef tallow, pork lard, and yellow grease [5], materials considered as low cost feedstocks.

Commercially, most of the biodiesel currently synthesized utilizes soybean oil in Brazil, rape seed oil in Europe and United States, palm oil in Malaysia and Indonesia, -depending on the relative abundance of the feedstock- methanol, and an alkaline catalyst. The value of soybean and palm oil as a food product makes production of a cost effective fuel very challenging. Nevertheless, there exist many low cost oils and fats such as restaurant waste, animal fats and non-edible vegetable oil such as *jatropha curcas* oil that could be transformed into biodiesel. The problem with processing these low-cost oils and fats is that they often contain large amounts of free fatty acids (FFAs) that cannot be converted into biodiesel using an alkaline catalyst [6], [7].

Jatropha curcas oil is a non-edible vegetable oil that has witness renewed interest due to some of its advantages like its propagation over other non-edible oils [8]. It is a perennial crop with high oil content of about 30-50% wt % [9] and capable of growth potential in tropical and semi tropical region of the world [10]. India is presently known to be the highest producer of biodiesel from *jatropha curcas* oil. This plant oil has some characteristics that determine the quality and quantity of the yield when used as feedstock for biodiesel production depending on the climatic condition of where it is grown and conditions in extracting the oil.

The crude *jatropha curcas* oil from different location of the world is known to possess diverse characteristics features, which consign it to only some specific production process that eschew formation of unwanted product such as soap and some other impurities that can impact greatly on the downstream processes and thereby reduce the product yield.

In this research, three variety of *jatropha curcas* oils were characterized for their various physicochemical properties such as density, viscosity, iodine value, saponification value, peroxide value and acid value were determined and the implication of the various properties were discussed in details.

2. Materials and Methods

2.1. Materials

Three *Jatropha curcas* oils species were used in the research, one was sourced from Sudan, the other two were sourced from two different industries in Malaysia namely Bionas Sdn Bhd and UKM plantation. Analytical reagents such as potassium hydroxide, phenolphthalein, potassium iodide, sulfuric acid etc with all reagents being of analytical grade were sourced from local suppliers in Malaysia such as Bumi Telus, Next Gene etc.

2.2. Sample preparation

The three oil samples were dried in oven at temperature of 105^0C and were identified as BD (oil sample from Bionas Sdn Bhd.), UK (oil sample from UKM) and SD (oil sample from Sudan).

2.3. Test procedure

2.3.1. Determination of saponification value

To determine the saponification values of the samples, ethanolic potassium hydroxide (0.5 N) was pipetted into conical flasks containing 1.0 g of sample. The content of each flask was reflux for 45 min with occasional shaking, then cooled to room temperature, after which it was titrated with sulfuric acid (0.5 N)

using phenolphthalein as indicator. A blank was subjected to the same process. Results were expressed as mg $KOHg^{-1}$. The saponification values of the oil samples were determined as follows [11].

$$\text{Saponification value} = \frac{(Vb-Vs)\ x\ 28.05}{W} \quad (1)$$

Where Vb = titre value for blank, Vs = titre value for sample and W = weight of sample in gram.

2.3.2. Determination of peroxide value

In determining the peroxide values, oil samples (0.5 g) were added into a boiling tubes containing 1 g of powdered potassium iodide. Glacial acetic acid/chloroform mixture (20 mL; 2:1) was added, the boiling tubes was placed in boiling water for 1 min after which the content were poured into conical flasks containing potassium iodide solution (20 mL; 5 %). The boiling tubes were rinsed twice with distilled water (25 mL) and content added into the conical flasks. The whole content was titrated with sodium thiosulphate (0.002 M) solution to colourless end points using starch as indicator. Results were expressed as mMol/kg [11]. Peroxide values of the oil samples were calculated as follows:

$$\text{Peroxide value} = \frac{(Vs-Vb)x\ molarity\ of\ titrant\ x\ 10^3 gkg^{-1}}{W} \quad (2)$$

Where Vb = Titre for blank; Vs = Titre for sample; W= weight of sample in grams.

2.3.3. Determination of acid value

The number of mg of potassium hydroxide required to neutralize the free acids in 1 g of the sample was determined by placing 0.5 g of samples in conical flasks containing mixture of ether and ethanol (50 mL; 95% v/v). The resulting solutions were titrated with 0.1 N potassium hydroxide solution using phenolphthalein as indicator [11]. The acid values were expressed as KOH g^{-1} and calculated as follows:

$$\text{Acid value} = \frac{(Vb-Vs)x\ 5.61}{W} \quad (3)$$

Where Vb = Titre for blank, Vs = Titre for sample and W = weight of sample in gram.

2.3.4. Determination of iodine value

The samples (2%) were prepared in chloroform, titrated with Wij's solution (5 mL), mixed thoroughly and allowed to stand in the dark for 3 min. Potassium iodide solution (5 mL; 7.5%) was then added and titrated to a light straw colour using 0.1 N sodium thiosulphate solution. Starch indicator (3 drops) was thereafter added and titration continued to a colourless (white or milky) end point. Results were expressed as I_2/100 [11]. Iodine values of the oil samples were calculated as follows:

$$\text{Iodine value} = \frac{(Vb-Vs)x\ 1.269}{W} \quad (4)$$

Where Vb = Titre value for blank, Vs = Titre value for sample and W = weight of sample in gram.

3. Results and Discussion

3.1. Results

Table 1: physical properties of the selected *jatropha curcas* oils

Jatropha oil samples	Units	BD	UK	SD
Moisture content	%	0.06	0.23	0.17
Density	g/cm^3	3.40	3.60	3.60
Viscosity	Pa.s	0.053	0.078	0.054
Phase at room temp (26 ^{0}C))		Liquid	Liquid	Liquid

Table 2: chemical properties of the selected *jatropha curcas* oils

Properties	Units	BD	UK	SD
Saponification value	$mgKOH^{-1}$	220.01	215.99	218.79
Peroxide value	mMol/kg	31.84	53.84	24.64
Acid value	KOH g^{-1}	14.60	8.42	17.20
Iodine value	I_2 100 g^{-1}	4.38	2.10	4.28

3.2. Discussion

3.2.1. Moisture content

The formation of soap, caused majorly by the water content in biodiesel feedstock can hinder the separation of biodiesel from glycerol fraction [12]. In catalyzed methods, the presence of water has negative effects on the yields of methyl esters because the feedstock is prone to soap formation rather than biodiesel. From the result presented, it is seen that sample BD has the lowest water content while sample UK has the highest, hence, UK has greater propensity for soap formation compared to other samples.

Nevertheless, when supercritical alcohol method route is employed, presence of moisture aids biodiesel formation [13] and thus sample UK will be the better feedstock. Besides, the amount of moisture present in the oil or fuel is needed for estimation of the actual fuel in transaction, taxation, exchanges and custody transfer [14]. Thus sample UK will cost more in transport and taxation when compared to other samples.

3.2.2. Acid value

Acid value indicates the amount of free fatty acids found in fat or oil. Acid value provides information about the age of oil sample; also it signifies the effect of oil exposure to atmospheric oxygen, hot moist air or action of microorganisms and records how much generation of free fatty acids has taken place. A high acid value implies a stale oil or fat which has been stored under inappropriate storage condition.

Technically, acid value is the mass of potassium hydroxide (KOH) in milligrams that is needed to neutralize one gram of chemical substance. More acid value implies more amount of free fatty acid (FFAs), the presence of which interferes with methanol in transesterification process. The yield of biodiesel is dependent on the acid value as lower acid value produce higher biodiesel throughput. It thus implies that sample UK with the least acid value will be better feedstock for transesterification process, while sample BD and SD with high acid values are better candidate for hydroesterification.

3.2.3. Peroxide value

The peroxide value (PV) of fat or oil is employed to measure the extent to which the oil or fat has become rancid during the storage process. Autoxidation in fat and oils is subject to the molecular structure of the fat or oil with the level of unsaturation a factor promoting the autoxidation. Estimation of peroxide value allows for determination of oxidative rancidity (autoxidation) of fat or oil samples as peroxides are intermediate in the autoxidation reaction. It shows from the result that sample UK is more rancid while sample SD is the least rancid. This is an indication of the extent to which the sample UK has been either exposed to the atmosphere or the age of it extraction is longer while that of sample SD is more recent.

Oxidative rancidity is a reaction involving oxygen which results in deterioration of fats and oils affecting the flavor and odour of the fat or oil sample. Peroxide value is employed for assessment of spoilage level in oil sample as it records the concentration of peroxides in an oil or fat. The peroxide value is the quantity of peroxide oxygen present in one kilogram of fat and oil at a particular period in time. Traditionally, it is measured in units of milliequivalents, which has been usually abbreviated as mequiv or meq.

Besides, different oil or fat samples have diverse peroxide value and correlation of rancid taste. The odour and flavors associated with typical oxidative rancidity are as a result of carbonyl-type compounds. It is pertinent to be aware that peroxide value changes with time and proper cognizance should be accorded in handling and testing oil samples. No model available relating peroxide value to rancidity is almost always accurate. Peroxide value of virgin oil is expected to be less than 10milliequivalents/kg but when the value is about 30-40 milliequivalents/kg a rancid taste is imminent, high peroxide value implies a high degree of rancidity but moderate values may be due to depletion of peroxides after attaining high concentration.

3.2.4. Saponification value

This is the hydrolysis of fats and oils in the presence of an alkaline such as potassium hydroxide or caustic soda to produce glycerol and corresponding salt of fatty acids. Saponification value indicates the nature of fatty acids available in triacylglycerol. The longer the carbon chain of the fat hydrolyzed, the reduced the quantity of acid liberated per gram of sample and hence the reduced the saponification value of such oil sample. This feature implies that the propensity of soap formation is higher in sample UK while lowest in sample BD.

3.2.5. Iodine value

Iodine value is the measure of the degree of unsaturation in fats acids available in triacylglycerol. The longer the carbon chain of the fat hydrolyzed, the reduced the quantity of acid liberated per gram of sample and hence the reduced the saponification value of such oil sample. This feature implies that the possibility of soap formation is higher in sample UK while lowest in sample BD. Unsaturation of fatty acid composition determines the yield in biodiesel therefore sample BD with the highest iodine value is expected to produce highest yield when used in biodiesel synthesis while sample UK is expected to produce least yield relative to the production route employed.

3.2.6. Viscosity

Vegetable oil viscosity is an indication of the internal fluid friction of the oil. It is in other words the resistance offered to the flow of the oil which as a result inhibits any dynamic change in the fluid motion [15]. Temperature effect on the viscosity of oil is an inverse relationship implying that when the temperature of the oil is raised there is corresponding decrease in the viscosity of the oil and hence the ease with which the oil flows. This property is a significant feature for flow of oil in the injector nozzles and orifices [16].

Viscosity remains the most significant among the fuel properties of biofuel due to its effect on the operation of fuel injection equipment especially at reduced temperature when the fluidity of the fuel is adversely dependent on the viscosity.Islam et al., 2004 reported that the combustion efficiency of fuel relative to formation of atomized and finer droplet which is produced by the ease with which the oil-flow is a measure of the fuel viscosity [16].

3.2.7. Density

Another important biofuel property is the density which is defined as the mass per unit volume of the oil at a particular temperature. Of importance is the density of oil as it determines the performance of the diesel engine [15] and this feature is used in the determination of fuel Cetane index [3]-[14].

4. Conclusion

This study reported the physico-chemical properties of three jatropha curcas oil sample sourced from different locations. Results show that the prospect of *jatropha curcas* oil in biodiesel production cannot be under estimated. Findings revealed that the detailed scientific knowledge relative to the physico-chemical properties of the seed oil is of immense significant for feedstock selection relative to the production technique adopted in biodiesel synthesis.

5. References

[1] Willerding, Andréa Luis, Carvalho Neto, Francisco Geraldo Mello da Rocha, Gama, Auricéa Matos da, Carioca, Cláudia Regina Ferreira, & Oliveira, Luiz Antonio de. (2012). Hydrolytic activity of bacterial lipases in amazonian vegetable oils. *Química Nova*, ***35***(9), 1782-1786.

[2] B. R. Moser, 2009. Biodiesel production, properties and feedstocks. *Invitro cell. Dev. Biol-Plant*. **45**:229-266.

[3] A. Demirbas, (2008). Biodiesel: 'A realistic Fuel Alternative for Diesel Engine. DOI 10. 1007/978-1-84628-995-8. *Springer*. ISBN-13: 9781846289941.

[4] B. K. Bala, (2005). Studies on biodiesels from transformation of vegetable oils for diesel engines. *Energy Edu Sci Technol* 5:1–45.

[5] A. Demirbas, (2005). Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods. *Progress Energy. Combust.* **31**:466-487.

[6] A. Demirbas, (2003). Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: A survey. *Energy Conver. Manage*. **44**: 2093-2109.

[7] M. Canakci, and J. Van Gerpen, (2001). Biodiesel production from oils and fats with high free fatty acids. *Trans: Am Soc Agric Eng* **44**: 1429-1436.

[8] H. C. Ong, T. M. I. Mahlia, H. H. Masjuki and R. S. Norhasyima, 2011. Comparison of palm oil, *jatropha curcas* and calophyllum inophyllum for biodiesel: A review. *Renewable and Sustainable Energy Reviews,* **15**:3501-3515.

[9] K. Pramanik (2003). Properties and use of *jatropha curcas* oil and diesel fuel blends in compression ignition engine. *Renewable Energy*. **28**:239–48.

[10] S. A. R aja, D. S. Robinson-Smart, and C. Lindon Robert Lee, (2011). Biodiesel production from *jatropha* oil and its characterization. *Research journal of chemical science.* **1**(1) 81-87.

[11] H. A. Ogbunugafor, F. U. Eneh, A. N. Ozumba, M. N. Igwo-Ezikpe, J. Okpuzor, I. O. Igwilo, S. O. Adenekan, and O. A. Onyekwelu (2011). Physico-chemical and Antioxidant Properties of *Moringa oleifera* Seed Oil. *Pakistan Journal of Nutrition*. **10** (5): 409-414.

[12] G. Madras, C. Kolluru, and R. Kumar, (2004). Synthesis of biodiesel in supercritical fluids. *Fuel* **83**:2029–2033.

[13] D. Kusdiana, and S. Saka, (2004). Effects of water on biodiesel fuel production by supercritical methanol treatment. *Bioresorce Technol.* **91**:289-295.

[16] M. N. Islam, M. N. Islam, M. R. A. Beg, 2004. The fuel properties of pyrolysis liquid derived from urban solid wastes in Bangladesh. *Bioresour Technol* **92**:181–186.

[14] A. Srivastava, and R. Prasad, (2000). Triglycerides-based diesel fuels. *Renew. Sust. Energ. Rev*.**4**:111-133.

[15] C. Song, (2000). Introduction to chemistry of diesel fuels. In: C. Song, C. S. Hsu, I. Moshida, (eds.) *Chemistry of Diesel Fuels*. Taylor and Francis, London, p.13.