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Physico-chemical characteristics of oil and biodiesel from Nigerian and Indian *Jatropha curcas* seeds

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ABSTRACT

The oil and biodiesel produced from Nigerian and Indian *Jatropha curcas* seeds were evaluated using a parametric Student's t-test model. The characteristics assessed include oil yield, specific gravity, density, acid value, free fatty acid, iodine value, saponification value, peroxide value, viscosity and flash point. The results revealed significant differences ($p < 0.05$) between the yield of the Nigerian and Indian Jatropha oils (80% vs 56%). The acid value, free fatty acid, iodine value, peroxide and viscosity values were significantly higher in the Nigerian Jatropha oil compared to the Indian Jatropha oil. There was no significant difference in the density and moisture content between the two Jatropha oils. A higher flash point was recorded for the Nigerian Jatropha diesel. The calorific value was 48.31 MJ/kg in the Nigerian Jatropha diesel as against 47.50 MJ/k Indian Jatropha diesel. Most of the properties of the Nigerian Jatropha diesel evaluated compared favourably with the ATM and EN (for biodiesel) standard values. It could be concluded from this study that, *Jatropha curcas plant* found in Nigeria has the potential of boosting the economy in term of biodiesel production.

Key words: *Jatropha curcas* plant, characteristics of oil and biodiesel

INTRODUCTION

The drought resistant *Jatropha* plant which is known as Physic plant is found growing on uncultivated land in most parts of Africa and could be used as hedge plant (http://www.unilorin.ed.ng). The plant is considered as the best source of biofuel production among the various plants based fuel resources the world over (Tint and Mya, 2009). *Jatropha curcas f*ruit is made up of a green epicarp, a fleshy mesocarp and hard endocarp. The plant is known as a diesel fuel plant as the seed could yield substantial quantity of oil which can be converted to biodiesel without refining (Becker and Makkar, 2009). The plant can yield about 1000 barrels of oil per year per sq mile *curcas* which grows on degraded agriculture lands incurs little or not carbon debts. Hence, it offers immediate and sustained greenhouse gas advantage. The various other uses of the plant (soap, organic fertilizer, pesticide and other more) make it to stand at the top as there is no competition between the plant and man. Due to its potential, scientists in developing countries have the responsibility of militating against climate change as well as creating new sources of income for the rural farmers.

This underutilized biofuel plant will help in meeting the challenges of global biofuel demand (37 billion gallon) by 2016 (http://www.jatrophaworld.org). Currently, Nigerian government has shown great interest in Jatropha plant and other biofuel plants. The aim of the government is to gradually reduce the nation's dependence on imported gasoline, reduce environmental pollution as well as create commercially viable industry that can precipitate domestic job (Federal Government of Nigeria Policy on Biofuel, 2008). Hence, the thrust of this study was to evaluate the oil and biodiesel properties of Nigerian and Indian *Jatropha curcas* seeds.

MATERIALS AND METHODS

Collection of *Jatropha curcas* seed

The seeds were collected around the University of Ilorin main campus and also within Ilorin metropolis, Nigeria. The collected seeds coats were dehulled by using a club (small stick) and later the hulls and the seeds were separated by winnowing. The seeds were milled to form the meal. The oil content of the meal was obtained by both mechanical and chemical methods using hydraulic pressing for three days and cold extraction was equally used for both the Nigerian and Indian seeds with n-hexane.

Conversion of the *jatropha curcas* crude oil to biodiesel

Various methods used in the conversion of Jatropha oil into biodiesel include base catalyst transesterification (Divani et al., 2009). Additionally, Tint and Mya (2009) also produced biodiesel from Jatropha oil using the transesterification method (ethanol as alcohol and sodium hydroxide pellets as alkali agents). In this study the crude oil from *Jatropha* seed was converted to biodiesel by the method of Benjamin et al. (2007) which was modified Figure 1.

Physical and chemical analyses

Moisture content

It was determined by oven drying a known quantity of the oil in the oven at 105 °C for 24 hours after which the percentage moisture was calculated as follows:

$$\% \text{ Moisture} = \frac{(\text{Initial weight of oil} - \text{Final weight of oil})}{\text{Initial weight of oil}} \times 100$$

Oil yield

The oil was extracted using mechanical method and chemical method using hydraulic pressing and soxhlet extraction method (*n*-hexane) as described by A.O.A.C. (1990) respectively.

Specific gravity and density

This was determined using specific gravity bottle while the density was also measured using pyconometer.

Values

The acid value, iodine value and saponification value were determined using the method of BPC (1988). The viscosity was determined using Brookfield Digital viscometer (Model DV-1-DVTD) Brookfield Engineering Laboratory USA. Free fatty acid and peroxide values were determined using titration method (A.O.A.C., 1990). The flash point was determined using Pensky-Martens apparatus.

Jatropha curcas seeds
↓Milled
Jatropha seed meal
↓Hydraulic pressing
Jatropha seed cake
↓Hydraulic pressing
Jatropha oil ←Ethanol (30%) † KOH 3% by weight
↓
Mixture of the solution in oil
↓
Transesterification Reactor at 65 °C (50-100ppm stirred)
↓
Settling tank → Glycerin
(2-3$^{1/2}$hours)
↓
Impure biodiesel →Alkaline water
(1:1 Water)
↓
Washing Tank
↓
Drying (110 °C for 15 minutes)
↓
Pure biodiesel

Figure 1: Flow chart of biodiesel produced from *Jatropha curcas* oil.

Statistical analysis

All data collected for the Nigerian and Indian Jatropha oils and biodiesels were subjected to a parametric Student's t-test.

RESULTS AND DISCUSSION

The results of the physical characteristics of oil obtained from Nigerian and Indian *Jatropha curcas* seeds using two methods of oil extraction are shown in Table 1. The chemical methods gave higher oil yield compared to the mechanical method and this could be due to the greater exposure of the surface area in which the chemical was able to penetrate better. This shows that the chemical method of oil extraction was better than the mechanical method. Additionally, the Nigerian *Jatropha curcas* seed was superior in terms of oil yield compared to the Indian type. The oil yield of the Nigerian Jatropha was higher than 30-40% reported by Lozano (2007) but fell within the value (60-80%) as reported by Reinhard (2007).

Moisture is a chemical contaminant which is mixed with lubricating oil like Jatropha oil, and it is the major causes of most engine failure; hence the moisture content reported herein (Nigerian and Indian *Jatropha curcas* oils) was lower than 0.2% as reported for Jatropha oil (Tint and Mya, 2009). The low moisture content shows that the oil is of good quality and could not be easily subjected to contamination/rancidity (Fellows, 1997). It is noteworthy that free fatty acids and moisture have significant effect on the transesterification of glyceride with alcohol using catalyst (Goodrum, 2002).

There was no significant difference between the density of oil obtained from Nigerian and Indian Jatropha seeds however, the value reported in this study was consistent with the report of Akbar et al. (2009).

Table 1: Comparison of the characterization of oil from Nigerian and Indian *Jatropha curcas oil**.

Parameters	Nigeria type (Chemical method of extraction) (T1)	Nigerian type (Mechanical method of extraction (T2)	Indian type (chemical method of extraction) (T3)	Significances ($p<0.05$)
Specific gravity	0.9010	0.8959	0.8985	T1vsT2; T1vsT3, T2vs T3 (NS)
Density (g/ml)	0.8863	0.8813	0.8838	T1vsT2; T1vsT3, T2vs T3 (NS)
Acid value	18.76b	23.87a	13.71c	T1vsT2*,T1vsT3*,T2vsT3*
Free fatty acid	9.39b	11.94a	6.85c	T1vsT2*,T1vsT3*,T2vsT3*
Iodine value	20.30	26.09	29.24	T1vsT2; T1vsT3, T2vs T3 (NS)
Saponification value	240.53a	230.71a	97.61b	T1vsT3*, T2vsT3*
Peroxide value	56.00a	44.00b	39.20b	T1vsT2*,T1vsT3*
Viscosity	20.49	76.18	17.95	T1vsT2; T1vsT3, T2vs T3 (NS)
Moisture (%)	0.101	0.102	0.100	T1vsT2; T1vsT3, T2vs T3 (NS)
Calorific value (MJ/kg)	37.2	36.5	36.7	T1vsT2; T1vsT3, T2vs T3 (NS)
Oil yield (%)	80.00a	61.00b	56.00c	T1vsT2*,T1vsT3*,T2vsT3*

*Means of four determinations

The value of the specific gravity of the oil reported in this study was consistent with the work of Tint and Mya (2009), Kalbande (2009), Reyadth (2009) and standard EN-biodiesel value. However, the value was higher than the value reported by Reinhard (2007) for the Mexico type of *Jatropha curcas* oil.

Peroxide value of the oil showed the oxidative stabilities of the seed oil. The higher the peroxide value of oil the greater the development of rancidity and this limits its value in the food industry. Hence, *Jatropha curcas* oil could not be used in the food industry (Olaniyan and Oje, 2007) due to the presence of phorbolester which is the major antinutrient (Belewu, 2008).

Viscosity increased with the molecular weight and decreased with increasing unsaturated level and high temperature (Nourrechni et al., 1992). The viscosity of the oil (Nigerian Jatropha seed) was found to be higher than the Indian Jatropha seed oil. However, the value reported by Nevase et al. (2008) fell within this range. The more viscous an oil is, the better its use as lubricant, hence *Jatropha curcas* oil will have high lubricating properties (Olaniyan and Oje, 2007). The high saponification value reported in this study shows that the oil is normal triglyceride and it is very useful in the production of soap and shampoo (Akbar et al., 2009).

The acid value gives an indication of the quality of fatty acids in the oil/diesel. The acid value was higher in the Nigerian Jatropha curcas oil. This reflects the high fatty acid content of the oil. The value of both Nigerian and Indian Jatropha oils are higher than ASTM value and the effect of esterification is to reduce the fatty acid level to the lowest value.

Iodine value is a measure of the unsaturated of fats and oil and high iodine value shows high unsaturation of the oil. The limitation of unsaturation of fatty acid is vital due to the fact that heating highly unsaturated fatty acids results in polymerization of glycerides which could lead to the formation of deposits (Mittlebach, 1996).

The fatty acid value reported in this study fell within the values reported by Akbar et al. (2009) and Tint and Mya (2009). However, the fatty acid content needs to be neutralized for biodiesel production. The calorific value is in the range of values reported for other plant oils (Becker and Makkar, 2008). The value reported in this study was consistent with the reports of Nevase et al. (2008) and Becker and Makkar (2008).

Table 2 shows the characteristics of biodiesel produced from Nigerian and Indian *Jatropha curcas* oils. The density noted for the two *Jatropha curcas* oils was similar to the standard value reported by EN14214 and Makkar and Becker (2008). Additionally, the specific gravity followed similar trend and it was similar to ASTM standard value.

The calorific value obtained in this study was consistent with the report of Nevase et al. (2008) and Divani et al. (2009). The viscosity of the biodiesel is vital when considering the spray characteristics of fuel in the engine due probably to the fact that a change could alter combustion characteristics. Hence, the viscosity reported herein was higher than ASTM standard due probably to the variation in temperature, the lower the temperature the higher the viscosity value.

The flash point is related to the safety requirement in handling and storage of fuel, however biodiesel falls under non hazardous category, therefore the higher value reported in this study shows that the biodiesel is safe for usage (Patil and Singh, 1991). It can be concluded from this study that production of biodiesel form Nigerian *Jatropha curcas* plant is feasible with higher quality and quantity product. Additionally, growing of *Jatropha curcas* will help in mopping up climate change due to its ability in fixing up carbondioxide (3 tons of carbondioxide/ acre/year).

Table 2: Comparison of the characterization of biodiesel production from Nigerian and Indian *Jatropha curcas*.

Parameters	Nigeria type (Chemical method of extraction)	Nigerian type (Mechanical method of extraction)	Indian type (chemical method of extraction)	Standard value (ASTM & EN Biodiesel values)
Viscosity at 40 °C	9.60 20.49 (oil)	19.6 76.18 (oil)	20.6 17.6 (oil)	
Flash point	200 °C	140 °C	195 °C	170 minimum
Density (g/cm^3)	0.8687 0.8813 (oil)	0.8685 0.8863 (oil)	0.8682 0.8838 (oil)	0.860-0.900
Specific gravity	0.8816 0.8959 (oil)	0.8803 0.9010 (oil)	0.8807 0.8985 (oil)	0.86-0.90
Calorific value (MJ/kg)	48.31	47.22	47.50	

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