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INFLUENCE OF SITE VARIATION ON *Jatropha curcas* SEED YIELD AND QUALITY OF BIODIESEL

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Abstract
Influence of site variation on Jatropha curcas seed yield and quality of biodiesel from three seed sources (Ibadan, New Bussa, and Kano) was investigated. Biodiesel was produced using oil extracted from the three seed sources using standard laboratory methods. Completely randomized design at three replicates per treatment was adopted for the experiment. The biodiesel produced was subjected to physicochemical analysis to elicit its quality. The seed yield (227.10 g) from Ibadan seed source was greater than New Bussa and Kano seed sources (175.20 and 51.30 g) respectively. Also New Bussa had higher seed yield (175.20 g) than Kano seed source (51.30 g). However, the oil yield (59 %) from Kano seed source was higher than New Bussa seed source (44.25 %) while it was lowest for Ibadan seed source (39.38 %). The biodiesel yield (76.94 %) from Kano seed source was higher than New Bussa seed source (64.45 %) and lowest for Ibadan seed source (49.44 %). In terms of the biodiesel quality, Kano seed source had the highest biodiesel quality judging from the physicochemical properties of biodiesel produced from the three seed sources. Since Jatropha curcas grown in the forest and savannah ecological zones of Nigeria has a potential for high oil yield and high quality of biodiesel, cultivation of the plant species should be encouraged on both small scale as well as large scale basis in these ecological zones.

Key Words: *Jatropha curcas, Site variation, Seed yield, Biodiesel, Seed sources*

Introduction
Fast depleting non – renewable natural resources and increasing energy demand have stimulated interest in developing alternative fuel sources. Petroleum sources are limited because they are non – renewable and can be depleted. Therefore, the interest on renewable energy sources has to increase. Consequently, there is the need to research into bio – energy sources

that are renewable and sustainable. An example of such renewable energy is biodiesel. The significant increase in the prominence of biodiesel as an alternative fuel for diesel engine arose from diminishing fossil fuel reserves. Another major issue of concern about fossil fuel is the environmental hazards associated with its use. They are increasingly associated with the emission of greenhouse gases particularly carbon dioxide (CO_2) which leads to global warming, emergence of drought, spread of diseases and depletion in population sizes of both plant and animal species (Lash and Ahuja, 1990).

It has been reported that within the last 20 years about 75 % of man – made CO_2 emissions were from burning of fossil fuels (Galadima *et al.,* 2011). Nigeria is the largest emitter of these undesirable gases in sub – Sahara Africa, and the world's second biggest culprit involved in gas flaring, contributing immensely to global atmospheric pollution New African Magazine (2011).

To curb the pollution of the environment, the Federal Government of Nigeria mandated the Nigerian National Petroleum Corporation (NNPC) to draft a policy in August 2005 so that the nation's over dependence on oil and gas economy and the environmental threats associated with fossil fuel exploitation could be reduced to considerable levels (Galadima *et al.,* 2011). The mandate required that the policy is designed to allow the future usage of biofuels in the country (Galadima *et al.*, 2011). Biofuels can also be used as desirable replacements for toxic octane and cetane enhancers in gasoline and diesel engines respectively. Moreover, biodiesel is an alternative fuel produced from different types of renewable vegetable oils, animal fats or different types of recycled cooking oil by transesterification reaction (Montes *et al.*, 2011). It is oxygenated, sulphur free, biodegradable and environmentally friendly alternative automotive fuel (Hanny and Shizuko, 2008). In conventional process, biodiesel is manufactured by alkaline-catalyzed trans-esterification of oil in methanol. The alkalis frequently used are KOH, NaOH or their corresponding alkoxides; some solid catalysts were also assayed (Montes *et al.,* 2011).

However, biodiesel production from edible oil seeds grown for traditional market may prove too expensive for use as fuel and may bring about rising cost of food. So, there is the need for an alternative biodiesel feedstock that is cheap, non - edible and meets all criteria for biodiesel feedstock. Likewise, it has been reported that approximately 70 – 95 % of the total cost of biodiesel production arises from the cost of the raw material i.e. vegetable oils or animals fats. One way of reducing biodiesel production cost is to use less expensive feedstock containing fatty acids such as non - edible oils, animal fats, waste food oil, and by - products of vegetable oil refining. Fortunately, non - edible vegetable oils, mostly produced by seed - bearing trees and shrubs can provide an alternative with no competition for food uses. This characteristic turns attention to *Jatropha curcas* to be used for production of biodiesel (Musa and Aberuagba, 2012).

Jatropha curcas is an easy – to - establish shrub that grows to a height of 5 to 8 meters and is mainly grown in Asia and Africa. The species is a succulent plant that sheds its leaves during the winter season (Karaj and Muller, 2010). It grows on well - drained soils with good aeration and is well adapted to marginal soils with low nutrient content (Sirisomboon *et al.*, 2007).

J. curcas grows almost everywhere from the rainforest to the Savanna vegetation. While the seed yields of the plant species across the various sites of occurrence have been reported to be high, it is not yet known whether the oil and biodiesel yield will be correspondingly high or may vary with site characteristics. In other words, information on the yield and quality of biodiesel of the plant species as influenced by site variation is critical as this will form the basis for recommending the best source(s) of *J. curcas* seeds for biodiesel production. The study is therefore aimed at determining the yield and quality (density, specific gravity, iodine value, free fatty acid, , peroxide value, viscosity, flash point, pour point as well as the smoke point) of *Jatropha curcas seeds* and biodiesel from three sites (Kano, New Bussa, Ibadan).

Materials and Methods

Study Area and Seed Sources

The seeds for the provenance for the study were obtained from three different ecological zones in Nigeria namely; Ibadan (Rainforest), New Bussa (Guinea Savanna) and Kano (Sudan Savanna). The seeds were planted in an experimental plot at Forestry Research Institute of Nigeria (FRIN), Jericho Hill, Ibadan. FRIN is situated in Ibadan Northwest Local Government Area of Oyo State.

Ibadan lies between latitude 7° 26′ N and longitude 3° 26′ E. The climate of Ibadan is tropical with two distinct seasons which are dry season commencing from November to March and the rainy season from April to October (FRIN Annual Report, 2010). The total rainfall is 1702 mm while the maximum temperature ranges between 29.2ºC to 35.3ºC with mean maximum temperature of 32.2ºC and relative humidity ranges between 63% to 87% with average relative humidity of 76.4%. Forestry Research Institute of Nigeria is bounded by residential, commercial and agricultural centres (Adeoye *et al.*, 2011). Open lands, water bodies, government acquisition, public and semi - public land – use are noticed in the area. The soil of Ibadan is categorised as alfisols. In comparison to Mollisols, Alfisols tend to have lower fertility because they are more leached. Alfisols have an argillic horizon (USDA, 1978).

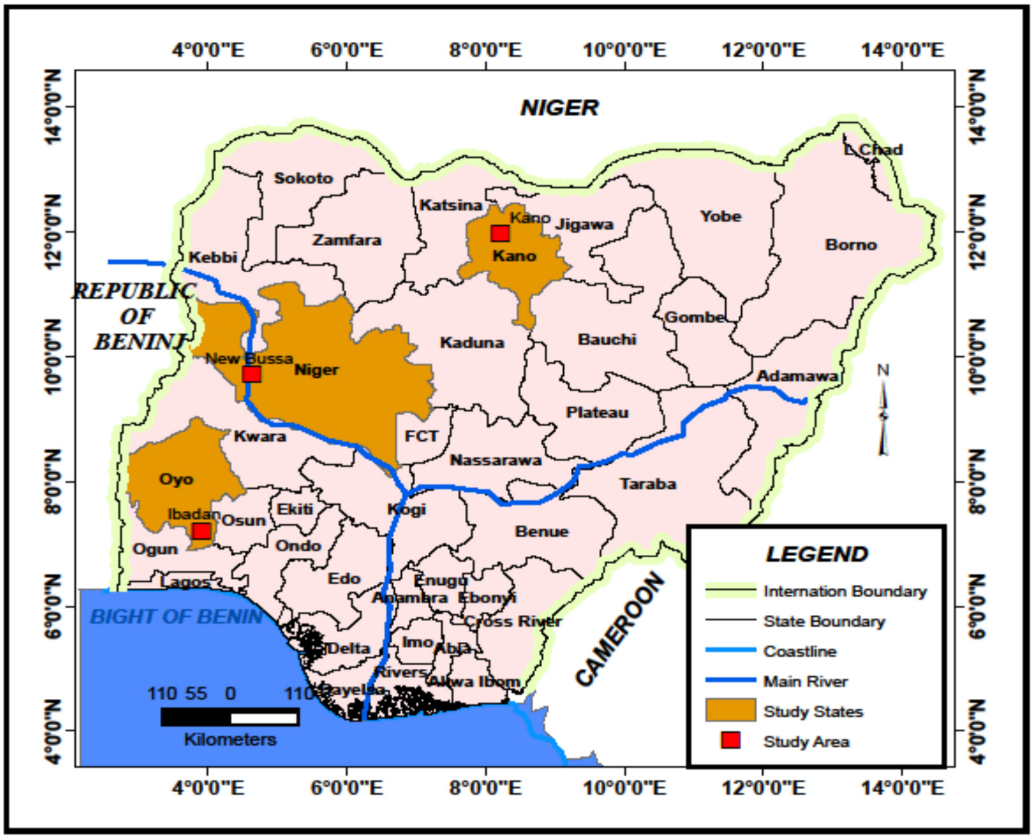

Fig 1: Map of Nigeria Showing the Study Area.
Source: Department of Geography, University of Ibadan

Sample Collection

In each site 25 trees were purposively selected and seeds collected from the trees were then dehulled and winnowed [to remove impurities. Thereafter the seeds were screened for purity and air-dried for 3 days in a well-ventilated room.

The design of experiments was a completely randomized design with three replicates per treatment. Each site where seeds were collected constituted a treatment.

Extraction of Jatropha curcas Oil from Seeds

Oil was extracted from the plant dried kernels using a cold extraction method with n-hexane (40-60°C). Solid impurities were removed from the oil by filtration while the oil was concentrated and the hexane removed before storage in sealed container prior to biodiesel production. The oil obtained was weighed and recorded whereas other physicochemical properties of the oil (free fatty acids, iodine value, saponification value, peroxide value, specific gravity and density) were determined in accordance with the international standard (AOAC, 2003).

Determination of Biodiesel Yield and Quality

Biodiesel was produced through a process of transesterification using the method adopted by Adebayo *et al* (2011) and determination of the flash point, viscosity, pour point and smoke point were done based on a standard method (Tint and Mya, 2009).

Data Analysis

The results of the oil yield and biodiesel quality of the *Jatropha curcas* seeds per site were subjected to analysis of variance to test for significant variations.

Results

The average yields of seeds and oil extracted from kernels of *Jatropha curcas* from Ibadan, New Bussa and Kano are presented in Table 1. The seed yield from Ibadan seed source was significantly higher (227.10 g) than New Bussa and Kano sources. Also New Bussa had a significantly higher (175.20 g) seed yield than Kano seed source (51.30 g). However, the oil yield from Kano seed source was higher ($P \leq 0.05$) (59%) than New Bussa seed source (44.25%) while it was lowest (39.38%) in Ibadan seed source.

Physicochemical Properties of Extracted Oils

The physicochemical properties of oils extracted from seeds from the three seed sources are presented in Table 2. As shown in the table, the iodine value of the *Jatropha* oils of the three sources was significantly different ($P \leq 0.05$). Ibadan seed source had the highest iodine value (140.34 g/100 g) followed by New Bussa seed source (138.32 g/100 g) and Kano seed source (125.6 g/100 g). However, the density of oils extracted from the seeds of *Jatropha curcas* from Ibadan, New Bussa and Kano sources was not significantly different ($P \geq 0.05$). For specific gravity, Ibadan seed source was significantly higher (0.89) than those of New Bussa (0.86) and Kano (0.85) which were almost not different from each other. Likewise, the saponification value of oil from Ibadan was significantly higher (279.0 mg NaOH/g) than those of New Bussa and Kano seed sources (214.83 mg NaOH/g and 194.99mg NaOH/g). The peroxide value of Ibadan seed source (0.51m g/kg) was significantly different from those of New Bussa (0.39 mg/kg) and Kano (0.34 mg/kg) seed sources, whereas in the case of free fatty acids Ibadan (34.83%) and New Bussa (35.63%) seed sources were not significantly different ($P \geq 0.05$) but were higher than that of Kano (26.23%) seed source which was the lowest.

Weight and Yield of Biodiesel and Glycerol

The weight and yield of biodiesel and glycerol extracted from seeds of *Jatropha curcas* from the three seed sources are presented in Table 3. The weight of biodiesel and that of glycerol in Ibadan were lower than those of New Bussa and Kano seed sources. There was no significant difference between New Bussa and Kano seed sources weight of biodiesel and glycerol. The weight of biodiesel and glycerol were not significantly different from New Bussa and Kano seed sources. However, the yield of biodiesel was highest (76.94%) in Kano seed source followed by New Bussa (64.45%) and Ibadan (49.44) seed source. The yields of glycerol were not significantly different for New Bussa and Kano seed Sources (Table 3).

Physicochemical Properties of Biodiesel

The physicochemical properties of biodiesel extracted from *Jatropha curcas* from the three seed sources are presented in Table 4. The flash point, viscosity, density, pour point and smoke point for Ibadan, New Bursa and Kano seed sources were significantly different ($P \leq 0.05$) (Table 4).

Table 1 Average yield of seed and oil from kernels of *Jatropha curcas* from three seed sources

Seed Sources	Seed Yield (g))	Oil yield (%)
Ibadan	227.10[a]	39.38[a]
New Bussa	175.20[b]	44.25[b]
Kano	51.30[c]	59.77[c]

Means with dissimilar superscript in a column are significantly different (P≤0.05)

Table 2: Physicochemical properties of *Jatropha curcas* oil from three seed sources

Seed Sources	Iodine g/100g	Density kg/m	Specific gravity	Saponification Value mgNaOH/g	Peroxide Value mgeq/kg	Free fatty acids %
Ibadan	140.34[a]	0.92[a]	0.89[a]	279.00[a]	0.51[a]	34.83[a]
New Bussa	138.32[ab]	0.92[a]	0.86[b]	214.83[b]	0.39[b]	35.63[a]
Kano	125.6[b]	0.90[a]	0.85[b]	194.99[c]	0.34[b]	26.23[b]

Means with dissimilar superscript in a column are significantly different (P≤0.05)

Table 3: Weight and yield of biodiesel and glycerol extracted from *Jatropha curcas* seed from three seed sources

Seed Sources	Weight of biodiesel (g)	Yield of biodiesel (%)	Weight of glycerol (g)	Yield of glycerol (%)
Ibadan	9.8[a]	49.44[a]	1.68[a]	8.38[a]
New Bussa	13.00[a]	64.45[b]	1.91[b]	9.57[b]
Kano	15.37[b]	76.94[c]	1.92[b]	9.59[b]

Means with dissimilar superscript in a column are significantly different (P≤0.05)

Table 4: Physicochemical properties of biodiesel extracted from *Jatropha curcas* from three seed sources

Seed Sources	Flash Point (O^C)	Viscosity $mm^{2/s}$	Density g/cm	Pour Point (O^C)	Smoke Point (O^C)
Ibadan	132.33[a]	4.44[a]	834.89[a]	9.93[ab]	105.67[ab]
New Bussa	131.22[ab]	4.40[a]	825.11[ab]	9.98[a]	107.17[a]
Kano	130.22[b]	4.09[b]	819.45[b]	9.00[b]	107.50[a]

Means with dissimilar superscript in a column are significantly different (P≤0.05)

Discussion

The mean seed yields showed significant differences among the three seed sources. The variation in the seed yields may be attributed to adaptable photosynthetic ability which ultimately resulted in significant differences in the seed yields. It is probable that Ibadan has a more quality site than New Bussa and Kano, a condition that was responsible for the higher leaf morphology culminating into higher photosynthetic activity, greater food reserves and higher seed yield. This result corroborates earlier report by Adeoye *et al.* (2011) who noted that leaf morphology and branching habit influenced the yield of cassava tuber.

The findings of this study showed that Kano seed source produced the highest / higher oil yield relative to Ibadan and New Bussa seed sources even though it had the lowest seed yield. As observed by Daniel and Lorna (2007). *Jatropha curcas* prefers warm climate with respect to accumulation of dry matter; therefore, the location of Kano in the highest temperature among the three sources probably explains why Kano had the highest seed yield. The yield of oils extracted from *Jatropha curcas* from the three seed sources is comparable with what was obtained from previous, similar studies (Shrestha *et al*., 2013).

The seed sources differed significantly in biodiesel weight and yield. This suggests that variations in climatic and soil conditions have effects on the growth as well as yields of the plant species. This may also be the reason for the lower biodiesel yield of this study compared to biodiesel yields of previous studies by Jean *et al.* (2014) and Adebayo *et al* (2011) that were all carried out in semi-arid areas. However, the findings of this study have been confirmed by the investigation of (Tint and Mya, 2009).

The glycerol yields of the three seed sources were significantly low, which was indicative of the low soap content of the feedstock and suitable quality materials for biodiesel production because the lower the glycerol content, the higher the biodiesel yield. The results of this research agree with the reports of Tint and Mya (2009) and Shrestha *et al.* (2013) investigations.

There were significant variations in flash points of biodiesel of the three seed sources. The results fall within the range of American standard for Testing and Materials (ASTM) Standard D6751 for flash point. In accordance with the standard, the lower the flash points the safe the fuel for use in engines. Tint and Mya (2009) recorded similar results for biodiesel produced from *Jatropha* oil.

The biodiesel produced from seeds from Kano seed source had the lowest pour point. The implication is that biodiesel from *Jatropha curcas* from Kano will flow better in engines when in use. Unlike the lowest pour point of the Kano seed source, the smoke point of the biodiesel produced from seeds collected from Kano was highest compared to the other two seed sources respectively. This aspect of the findings is in line with the study of Musa and Aberuagba (2012) whose results reveal that the higher the biodiesel smoke point the better the biodiesel quality.

Conclusion

The Sudan Savannah vegetation zone is the most suitable site for growing *Jatropha curcas* for oil yield and biodiesel production relative to the rainforest (Ibadan) and Guinea Savannah (New

Bussa) vegetation zones. However raw *J. curcas* oil must be refined before it would be qualified as biodiesel for engines regardless of wherever the plant is grown. It is therefore imperative for all tiers of government in northern Nigeria to encourage *J. curcas* plantation establishment in Kano State and other Sudan Savannah areas in the country in preparation for the arrival of hybrid vehicle as well as industrial engines whose use would no doubt contribute to climate change mitigation efforts.

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