IOP Conference Series: Earth and Environmental Science

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To cite this article: A O D Adejumo *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **445** 012051

Biodiesel production from Okra (*Abelmoschus Esculentus* (l) Moench) plant

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Abstract. Several biological plants which substrates can be used in the production of biofuels have been identified in the world. Although most of these plants are used for food which may present a risk of food supply, but will also encourage production and utilization of such plant. Okra is a vegetable plant commonly grown throughout the tropics, especially in West Africa for its tender fruits and sometimes the leaves for soup, thus the necessity for investigating the energy potential of the whole plant (Seed, fruit, leaves, and stem) biomass. Okra is an easily cultivated plant which could yield high return to the farmer if utilize for energy (Biofuel) source. Two replicates of each sample at mass 100, 300 and 500 g, n-hexane volume 500, 750 and 1000 ml and drying time 1,2 and 3 hours were used. Fresh Okra plant was obtained from the field of Institute of Agricultural research and training, Moor Plantation, Ibadan, Nigeria and digested in a laboratory following a standard procedure to obtain ethanol then transesterified to produce biodiesel. The average volumes of diesel obtained from each part of the plant are 18.52, 19.62, 24.07, 28.18 ml for seed, fruit, leave and stem respectively. The overall best percentage of okra plant biodiesel production was 152.6 l / ton (time). Comparing the previously reported values for maize, carrot, cocoyam, cassava, sugarcane and iroko timber to 410, 100, 139, 150, 70 and 130 l / tonnes of biomaterial; shows that okra is also a promising biofuel substrate and future energy plant.

1. Introduction

Production of biodiesel in recent times has significantly gained attention due to the global trend and agreement in greenhouse emission reduction in fossil-based fuel and increase in biofuel level. Various challenges associated with the use of petroleum-based fuel (PBDF) to power compression ignition(CI) engines called for more research in biodiesel [1]. As a result of the increase in population and global industrialization, the world energy demand has significantly increased. According to Adelekan [2], biofuel such as Biogas, bioethanol, and biodiesel are reliable and renewable options to foster worldwide energy security. The most common method of producing biodiesel from plant and animal oils is transesterification. But, the feedstock limited supply and high cost is a challenge to face, particularly for populous developing countries like our Nigeria [3].

Adelekan [2] demanded that efforts should be made by the stakeholders all over the world towards the use of biofuels considering the numerous advantages such as environmental protection and climate change mitigation. Moreover, funds for research should be tailored towards developing the potential of known and other unknown energy-yielding plants in order to contribute towards ensuring global energy security and the need to bring into the mainstream of interest of neglected tropical and nontropical identified crops in conventional agricultural biofuel research.

Before the advent of fossil oil, all energy supplied to the farming system was of renewable origin; unlike modern Tractor powered by diesel. Biodiesel in its pure form (B100) can operate either as a sustainable choice for oil diesel or as a mix with oil diesel proportions such as B20 (20% and 80% of biodiesel and oil diesel ratios respectively). Biodiesel is usually similar to petroleum diesel in terms of engine efficiency, with some benefits and disadvantages with respect to engine emissions [4]. Biodiesel is described as a blend of alkyl esters produced through transesterification of vegetable oils or animal fats with alcohol in the brief chain, typically methanol or ethanol. Biodiesel based on ethyl esters has many benefits over more frequently used methyl esters because it has reduced particulate matter and greenhouse gas emissions, such as coal dioxide and nitrogen oxides (NOx), and is also more biodegradable in water than methyl esters Luu et al. [5] citing Berhman and Hirata [6]. Guo et al. [3] remarked that developing countries face the issue of high price and restricted biomass supply, particularly food-based biofuel, and in the biodiesel manufacturing system, raw materials account for nearly 75% of total biodiesel costs. One strategy to reducing biodiesel production expenses is to use low-cost feedstock that contains fatty acids such as inedible oils, animal fats, waste food oil, and vegetable oils by-products. Renewable biodiesel is made up of easy fatty acid alkyl esters [6]. Biodiesel must compete economically with oil diesel fuels as a potential fuel.

Pattiya [7] recorded dry-based peak yields of liquid bio-oils from cassava stalk biomass residues and cassava rhizome as 62 wt. percent and 65 wt. percent. Furthermore, the findings showed that the quality of bio-oil generated from cassava rhizome was better than that of cassava stalk because the former has reduced oxygen content, higher heating value, and greater stability of storage. Bio-diesel synthesized biomass is more appropriate considering the following key reasons: Biodiesel is renewable, biodegradable, pollution-free 98%, adds less to worldwide warming than oil diesel because of its closed carbon cycle, decreases the country's reliance on imported oil, delivers excellent motor efficiency and can be used without engine alteration, offers the market with biodiesel from adequate vegetable oils and animal fat manufacturing. This improves rural economies, shows a lower combustion profile, particularly SOx, and contributes to increased atmospheric CO_2 emissions. Adelekan [2] recorded a comparison of the output of biofuels (petrol) from different energy crops such as 70 l / tonnes, 150 l / tonnes, 100 l / tonnes, 80 l / tonnes, 410 l / tonnes, 390 l / tonnes and 450 l / tonnes for sugar cane, cassava, carrot, sweet sorghum, corn, wheat and rice respectively. Taufiq-Yap et al. [8] studied the impact of the stoichiometric structure under optimized circumstances at 65 ºC, 4% catalyst dose at 24:1 MeOH to jatropha oil molar proportion, 86.51% of biodiesel output was observed in the transesterification response.

Okra (*Abelmoschus esculentus* (L) Moench) is one of the world's most significant vegetable plants for its tender fruits, young shoots, leaves, and seeds in the tropical and subtropical areas. In Nigeria, it is popularly known as *Ila, Kubewa, and Okwuru* among the Yoruba's, Hausa and Igbos respectively. Okra is widely grown as vegetable covering 1.5 million hectares of land area annually [9]. Indigenously, West African okra is much appreciated because it continues fruiting during the dry season when few other vegetables can be found. It remains green during a period of drought, thus allowing people to eat its young leaves when needed and can easily grow semi-wild without any attention and have a continues supply of fruit throughout the year. Okra is a widely cultivated vegetable and can found in almost every market in Africa. The predominant species are *Abelmoschus caillei* (A. chev.), Stavels (West African okra) and *Abelmoschus esculentus* (L) Moench (Common okra). In Nigeria, some of the common varieties include NHAe- 47, V-35, LD88 UI. , TAe 38, V_2, etc.

The West African okra is cultivated as an annual or bi-annual crop. It may survive for 3 years and shrubs can reach 4 m or even higher, becoming woody at the base, strongly branched with the main stem of up to 7 cm in diameter, varieties found near 11° latitudes and just above. From the farmers' point of view, varieties of okra are divided into two groups: the short duration varieties with short stems and the long duration form with long stems. There is also a wide range of plants of in-between heights. Okra leaves are 3-7 lobed, more or less divided, 20 to 40 cm long, all the varieties have the same shape of a flower, the fruits are green to purple, sometimes black, pointed and furrowed [10]. Okra seed is rich in oil and protein nutrients. Calcium and amino acids found in okra seed compare favourably with those in poultry egg and soybean [11]. A mucilaginous preparation from the capsule can be used as plasma replacement in the blood–volume expander and a good blood sugar level crasher. It neutralizes the acid substances produced in the course of digestion thereby prevents constipation and other gastronomic disorder. It is also used for the treatment of peptic ulcer and its seed powder is used in children food fortification [12].

With the inclusion of woody biomass as part of the reserve resource of which an okra plant is a natural option, the possibility of greater displacement of fossil fuels should be feasible. The fact that the discovery of more energy crops and the development of other renewable energy sources is in line with continuing worldwide study attempts. Fermentation, distillation, transesterification, etc. were the procedures used for this study. These do not contribute to climate change or deplete the Earth's essential resource; the plant is also adaptable and common to the world's tropics and subtropic

Incongruent with Adelekan [2] report, biofuel (biodiesel) production practices would not hamper the production of food and fiber or cause water or environmental problems, it could lead to higher employment in agriculture, since production levels need to be increased to meet demand, biofuel increases the quality of urban air and can decrease CO_2 emissions by 68% for cellulosic ethanol, correctly cultivated feedstocks can reverse CO_2 emissions by removing carbon from the atmosphere and isolating it in enhanced top-soil, improving tilting to increase agricultural yields and biofuel vehicles for better farming, range, and forest methods can also contribute to the achievement of other objectives such as decreased soil erosion and enhanced water quality and dramatically enhance the rural economy. The objective of this research work is, therefore, to investigate the potential of Okra (*Abelmoschus exculentus* (L) Moench) plant for biodiesel production and observe some factors affecting biodiesel production and their rates.

2. Materials and Methods

Transesterification is a popular technique of producing biodiesel from vegetables and animal fats and is generally preferred rather than direct esterification. In transesterification, in the presence of a catalyst, fats, and oils respond with alcohol to form alkyl esters and glycerol. The method of transesterification decreases the viscosity of the oil greater than that of petrol-diesel. A manufacturing method for lipid transesterification is used to transform the base oil to the required esters. Any free fatty acids (FFA) in the base oil are either transformed into soap and removed from the method or esterified using an acid catalyst (giving more biodiesel).

Okra plants were obtained from the Institute of Agricultural Research and training, Moor Plantation, Ibadan, Nigeria, and biodiesel production using Soxhlet extractor was also carried out in the same Institution Central Laboratory. The process of producing biodiesel from okra seeds involves three phases: production of Ethanol, extraction of bio-oil from okra plant and reaction process. Okra plants (V-35) were harvested and rinsed thoroughly in order to remove the dirt. The plants were separated into the sample as seeds, stem, leaves, and fruits. Each sample was divided into two (2), one part was dried and ground into a powder and the other part was soaked in ordinary water for seven days to obtain maximum ethanol solution, and they were mashed using mortar and pestle to form a slurry. The slurry was mixed with H_2SO_4 for the fermentation process. The slurry and H_2SO_4 were thoroughly mixed, covered and kept under room temperature for eight days. After eight days, seeds, stem, leaves, and fruits residues were separated from the fermented solution using 2.00 mm sieve. Later fermented solution was subjected to distillation and pure ethanol was obtained respectively. Then, the dried powdery okra sample was placed in the thimble of the Soxhlet extractor (Plate.1) and n-hexane was added. The process was allowed to dry for 1, 2 and 3 hours respectively. The n-hexane was distilled off using a rotary evaporator while the oil remained in the flask and was allowed to cool at normal room temperature. Finally, the okra oil was thoroughly mixed with the ethanol under the effect of NaOH to form biodiesel at a ratio 1:5:0.25 which is at top and glycerin at the bottom of the conical flask. Sodium hydroxide was added to the solution in order to completely transesterify the oil to form biodiesel. It was heated for 1hour at 60ºC. After heating, biodiesel was separated from the glycerin, and pure biodiesel was produced.

2.1 Statistical Experimental Design and Analysis

A – 3 x 3 x 4 factorial in a Completely Randomized Block Design, (CRBD) experimental design was used with a total of 216 observations (4 plant parts x 3 parameters x 3 levels) replicated 2. The means were separated using Duncan multiple and ANOVA.

Plate 1. Soxhlet Extractor

3. Results and Discussion

The world petroleum reserves are being depleted as a result of the increase in energy demand and environmental concerns. Efforts are therefore focused on exploring other alternative petroleum-based fuels sources. Biodiesel production is now gaining significant ground in the world-wide public sphere. Biodiesel has recently been produced primarily from conventionally grown edible oils such as sunflower, soybean and palm oils, resulting in a reduction of food versus fuel. Exploring some non-food and new vegetable oil resources for the manufacturing of biodiesel is becoming essential not only because of the significantly elevated price of frequently consumed edible oils but also because of their ever-increasing demand.

Biodiesel production from okra plant results is as presented in table 1, 2 and Figures 1 to 3. The maximum biodiesel yield from okra parts was found to be 29.80, 17.50, 37.00, 44.25 ml for seed, fruit, leave and stem respectively. The percentage of biodiesel yield from okra plant was found to be significantly different at all levels except for fruit on mass levels. It is observed that biodiesel yield from okra plant increased as mass, the volume of added n-hexane, drying time increase except for the stem that reduced with increase in mass. The maximum biodiesel yield percentage of 13.85% wet basis was found low to that of cassava stalk (62%) and rhizome (65%) observed by [7]. The biodiesel production from Okra plant variety V-35 at different mass, volume of N-Hexen and drying time are given in Table 1and 2. The effects of mass okra sample on biodiesel yield are present in Figure 1. It is observed that the yield of biodiesel increased with increase in mass (100 to 500 g) for all the parts of okra plant (seed, fruit, leave and stem). Bio-diesel yield for the seed increased from 9.45 to 28.45 ml, fruit increased from 4.8 to 16.6 ml, leave increased from 12.6 to 35.3 ml and stem increased from 15.3 to 40.4 ml respectively. The relationship between the mass of sample and biodiesel yield from okra plant were all polynomial with $R^2 = 1$. Table 2 shows that there is a significant difference between the mean of mass and among the plant parts at $P \leq 0.5$.

The effects of volume of N-hexane on biodiesel yields from okra plant are presented in figure 2. It is observed that the yield of biodiesel increased with increase in the volume N-Hexen (500 to 1000 ml) for all the parts of the okra plant. Bio-diesel yield for the seed increased from 20.8 to 21.5 ml, fruit increased from 10.2 to 11.1 ml, leave increased from 23.7 to 24.2 ml and stem increased from 27.6 to 28.6 ml respectively. The relationship between the mass of sample and biodiesel yield from okra plant were all polynomial with $R^2 = 1$. Table 2 shows that there is a significant difference between the mean of added N-Hexane for seed, no significant difference between means at 750 and 1000ml added n-hexane for fruit, leave and stem respectively.

Effects drying time on biodiesel yield from okra plant are presented in Figure 3. It is observed that yield of biodiesel increased with increase in the drying time (1, 2, 3 hr) for all the parts of okra plant except the leave that increased from 24.6 to 24.8 and then decreased to 22.7 ml. Bio-diesel yield for the seed increased from 20.4 to 21.9, fruit increased from 9.8 to 14.4, stem increased from 26.8 to 29.7 respectively. The relationship between drying time and biodiesel yield from okra plant were also polynomial with $R^2 = 1$. Table 2 shows that there is a significant difference between the mean of drying time for seed, fruit, leave and stem respectively.

As indicated in Table 1, the highest biodiesel (44.2 ml) from okra plant was at 500 g, 1000 ml and 3hr drying time. In all, it was observed that okra stem yield most biodiesel, followed by the leave, the seed and the lease (4.4 ml) from the fruit. Okra is an annual crop that grown mainly for its tender fruits, the seeds for regeneration. Okra stem is not edible and the leaves are really eaten, therefore their utilization in biofuel production does not threaten food security. Excess produced okra seeds and leaves can be utilized in biofuel production. This will encourage farmers and enhance better utilization of the okra plant. This is in accordance with [4], that practices in the manufacturing of biofuels would not hinder the development of meat and fiber or cause water or environmental issues, but would increase jobs in agriculture.

The overall best percentage (13.36%) biodiesel production from okra plant was 152.6 l/ton (time). Comparing the value is 410, 100, 139, 150, 70 and 130 l/tone of biomaterial earlier reported for maize, cocoyam, cassava, sugarcane, iroko timber, show the okra is also a potential biofuel substrate. Okra plant is not only a food crop but also future energy plant.

Table 1. Biodiesel production from okra Plant mean values

Variable	Seed Bio-yield			Fruit Bio-yield			Leave Bio-yield			Stem Bio-yield		
	(g)	(ml)	(%)	(g)	(ml)	(%)	(g)	(ml)	(%)	(g)	(ml)	(%)
$M_1T_1V_1$	7.55	8.6	7.55	3.73	4.25	3.74	11.06	12.6	11.06	12.78	14.6	12.78
$M_1T_1V_2$	7.91	9	7.91	3.85	4.4	3.85	10.66	12.15	10.66	12.86	14.7	12.86
$M_1T_1V_3$	8.14	9.3	8.14	3.91	4.95	3.91	10.88	12.4	10.88	13.13	15	13.13
$M_1T_2V_1$	8.21	9.4	8.21	3.98	4.55	3.98	11.21	12.8	11.21	13.21	15.1	13.21
$M_1T_2V_2$	8.38	9.6	8.38	4.12	4.7	4.12	12.31	14.15	12.31	13.36	15.25	13.36
$M_1T_2V_3$	8.51	9.7	8.51	4.21	4.8	4.21	10.31	11.8	10.31	13.54	15.45	13.54
$M_1T_3V_1$	8.56	9.8	8.56	4.34	4.95	4.34	10.41	11.9	10.41	13.67	15.6	13.67
$M_1T_3V_2$	8.83	10.1	8.83	4.48	5.1	4.48	11.37	12.95	11.37	13.82	15.8	13.82
$M_1T_3V_3$	8.94	10.2	8.94	4.56	5.2	4.56	10.88	12.4	10.88	13.85	15.8	13.85
$M_2T_1V_1$	21.40	24.4	7.14	4.02	7.45	2.19	23.49	26.8	7.83	13.22	27.8	8.12
$M_2T_1V_2$	21.82	24.9	7.28	4.15	9.1	2.69	22.62	25.85	7.54	13.35	28.3	8.26
$M_2T_1V_3$	21.86	25	7.29	4.23	9.45	2.77	24.03	27.45	8.01	13.51	28.2	8.25

$M_2T_2V_1$	22.15	25.3	7.39	6.55	9.55	2.85	23.96	27.35	7.99	24.35	28.55	8.34
$M_2T_2V_2$	22.25	25.4	7.42	8.65	10.2	2.97	23.78	27.15	7.93	24.77	28.9	8.45
$M_2T_2V_3$	22.54	25.7	7.52	8.30	12.7	3.05	23.68	27	7.90	24.74	29.05	8.49
$M_2T_3V_1$	22.81	26.1	7.61	8.40	11.15	3.16	16.87	19.25	5.63	25.01	29.25	8.55
$M_2T_3V_2$	22.47	26.2	7.66	8.89	12.25	3.40	16.84	19.2	5.62	25.34	29.65	8.66
$M_2T_3V_3$	23.16	26.45	7.73	9.15	12.45	3.60	16.84	19.2	5.62	25.45	30	8.76
$M_3T_1V_1$	23.05	26.35	4.64	9.80	16.4	3.32	28.30	32.3	5.66	31.60	36.05	6.32
$M_3T_1V_2$	24.20	27.65	4.84	10.70	16.1	2.80	31.20	35.6	6.24	33.35	38.05	6.67
$M_3T_1V_3$	24.55	28.05	4.91	10.90	16.2	2.83	32.10	36.65	6.42	33.70	38.45	6.74
$M_3T_2V_1$	24.70	28.2	4.76	8.25	16.6	2.88	30.20	34.45	6.04	33.75	38.55	6.75
$M_3T_2V_2$	25.20	28.75	5.04	9.21	16.2	2.93	30.17	34.45	6.03	35.62	40.65	7.13
$M_3T_2V_3$	25.35	28.95	5.07	9.45	16.3	2.95	30.23	34.5	6.04	36.05	41.15	7.13
$M_3T_3V_1$	25.55	29.15	5.11	14.39	16.9	2.96	32.10	35.5	6.33	37.70	43.05	7.54
$M_3T_3V_2$	25.90	29.55	5.18	14.12	17.4	3.05	32.78	37.4	6.55	38.15	43.55	7.63
$M_3T_3V_3$	26.10	29.8	5.22	14.18	17.5	3.07	32.18	36.75	6.44	38.75	44.25	7.75
Min	7.55	8.60	4.64	3.73	4.25	2.19	10.31	11.80	5.62	12.78	14.60	6.32
Max	26.10	29.80	8.94	14.39	17.50	4.56	32.78	37.40	12.31	38.75	44.25	13.85
Mean	18.52	21.17	6.92	7.43	10.62	3.36	21.13	24.07	8.11	23.28	28.18	9.62
Sd	7.45	8.52	1.48	3.48	5.04	0.63	8.58	9.74	2.25	9.95	10.61	2.78

M = mass (100,300, 500g), T1 = drying time (1, 2, 3hrs), V = volume of N-hezen (500,750, 1000ml)

Table 2. Analysis of variance (4way)

Variable	Seed Bio-yield			Fruit Bio-yield			Leave Bio-yield			Stem Bio-yield		
	(g)	(ml)	(%)	(g)	(ml)	(%)	(g)	(ml)	(%)	(g)	(ml)	(%)
Mass (g) 100	8.34^a	9.52^a	4.97^a	4.13^a	4.77^a	4.13^b	11.01^a	12.56^a	6.20^a	13.58^a	15.26^a	13.36^c
300	22.33^b	25.48^b	7.44^b	8.97^b	10.47^b	2.96^a	21.34^b	24.36^b	7.12^b	25.28^b	28.85^b	8.48^b
500	24.96^c	28.49^c	8.34^c	14.67^c	16.62^c	2.97^a	30.98^c	35.29^c	11.01^c	25.41^c	40.42^c	7.08^a
Vol.(l) 500	18.22^a	20.81^a	6.77^a	8.95^a	10.2^a	3.27^a	20.79^a	23.66^a	8.02^a	24.19^a	27.62^a	9.47^a
750	18.61^b	21.24^b	6.95^b	9.35^b	10^b	3.36^b	21.30^c	24.31^b	8.25^c	24.80^b	28.32^b	9.65^b
1000	18.79^c	21.46^c	7.04^c	9.48^c	11.02^b	3.44^c	21.23^b	24.24^b	8.05^b	25.05^b	28.59^b	9.75^c
Dt (hr) 1	17.83^a	20.35^a	6.63^a	8.56^a	9.81^a	3.12^a	21.59^b	$24.64.^b$	8.26^b	23.47^a	26.79^a	9.23^a
2	18.59^b	21.22^b	6.92^b	9.18^b	10.62^b	3.32^b	21.76^c	24.84^c	8.42^c	24.59^b	28.07^b	9.61^b
3	19.20^c	21.92^c	7.20^c	10.02^c	11.43^c	3.62^c	19.97^a	22.73^a	7.65^a	25.97^c	29.66^c	10.03^c
Source of variation												
M	*	*	*	*	*	*	*	*	*	*	*	*
V	*	*	*	*	*	*	*	*	*	*	*	*
Dt	*	*	*	*	*	*	*	*	*	*	*	*
MxV	*	*	*	*	*	*	*	*	*	*	*	*
MxDt	*	*	*	*	*	*	*	*	*	*	*	*
VxDt	*	*	*	*	*	*	*	*	*	N	N	N
MxVxDt	*	*	*	*	*	*	*	*	*	N	N	*

Where, Vnh = Volume of N-Hexen, Dt = drying time. Values within a row followed by the same letter are not significantly different at 5% probability level according to DNMRT

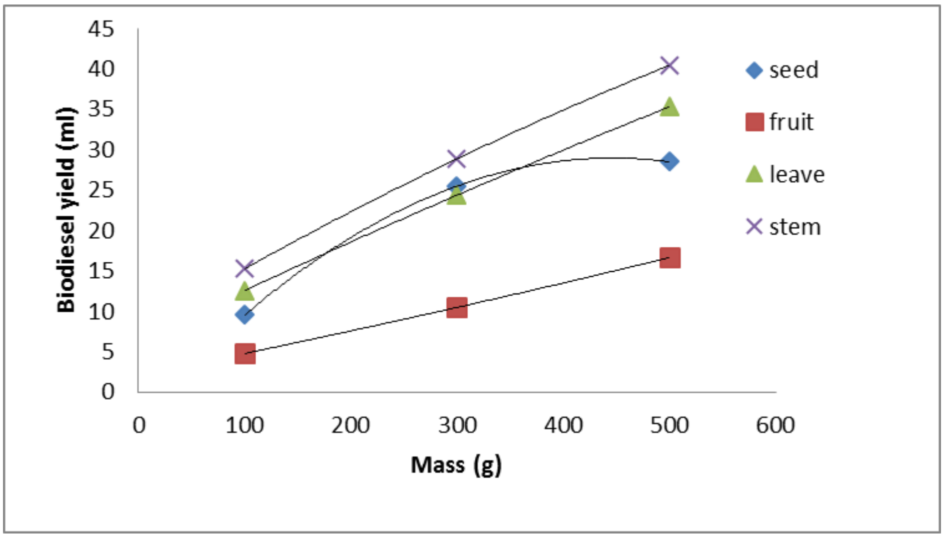

Figure 1. Effects of mass on Biodiesel yield from Okra plant

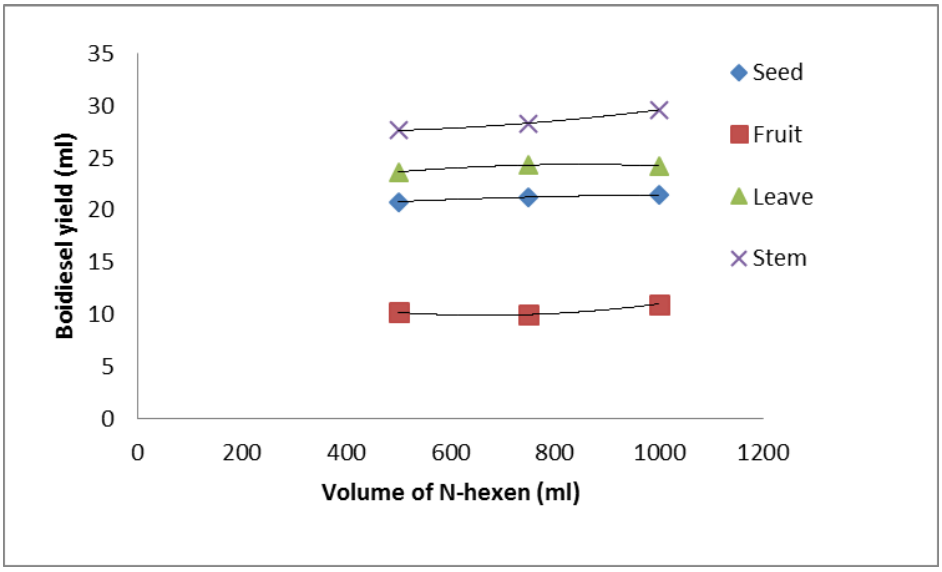

Figure 2. Effects of N-hexane on Biodiesel yield from Okra plant

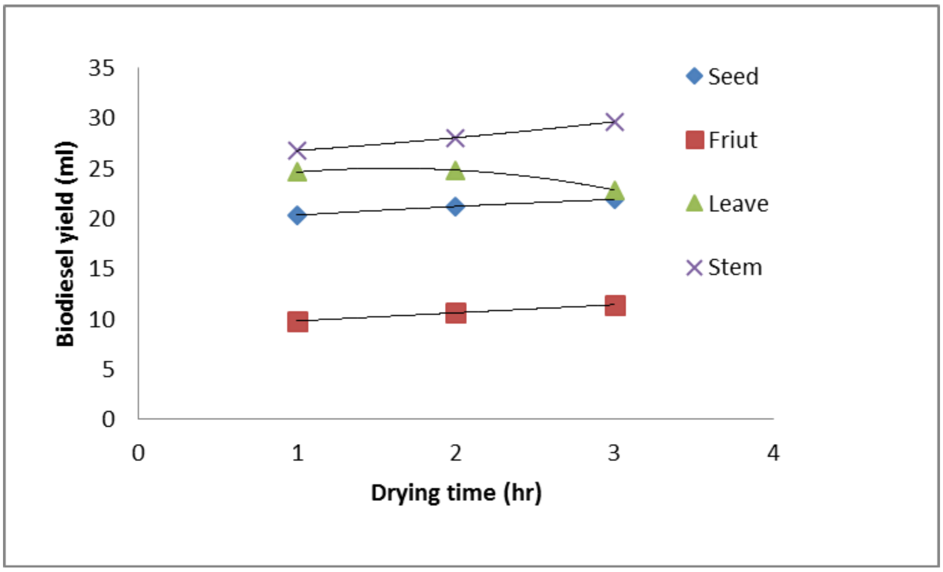

Figure 3. Effects of drying time on Biodiesel yield from Okra plant

4. Conclusions

The following findings have been taken from the outcomes acquired in this research:

i Biodiesel production from Okra plant increased with increase in mass, the volume of n-hexane and drying time. The average volumes of diesel obtained from each part of the plant are 18.52, 19.62, 24.07, 28.18 ml for seed, fruit, leave and stem respectively.

ii Okra stem that is not edible part yielded the highest (44.2 ml) biodiesel, followed by the leave, the seed and the lease (4.4 ml) from the fruit.

iii The percentage of biodiesel yield from okra plant was found to be significantly different at all levels except for fruit on mass levels. The overall best percentage yield was 13.36%.

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