International Scholars Journals

Advanced Journal of Environmental Science and Technology ISSN 2756-3251, Vol. 15 (11), pp. 001-007, November, 2024. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Evaluation of Luffa cylindrica-Derived Biofuel Blends with Diesel: Fuel Property Analysis

A. Isaac Bamgboye[1]* and O. O. Oniya[2]

[1]Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Oyo State, Nigeria. [2]Department of Agricultural Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Accepted 25 June, 2024

Fuel properties of loofah oil and its ethyl ester blended with diesel were experimentally determined. Biodiesel blends (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%) of loofah oil and its ethyl ester by volume with diesel was used. The fuel properties of the biodiesel blends were determined according to American Society for Testing and Materials (ASTM) standards. Pure Automotive Gas Oil (AGO) was used as a reference fuel. The viscosity in the blends of loofah oil and its ethyl ester with AGO from B10 to B100 ranged from 4.5 - 43.1 mm^2/s. It was observed that the viscosities of 10 - 40% loofah ester-diesel blends fell within limit specified by ASTM standards. The cloud points, the pour points and the flash points increased as the percentage of loofah oil and its ethyl ester increased in the blends. The specific gravity of all the loofah biodiesel blends ranged from 0.863 - 0.89 and fell within limit specified by international standards. The heating values of the loofah biodiesel blends decreased from 42.55 - 28.75 MJ/L. All the loofah biodiesel blends had sulphur contents ranging from 9.16 - 13.2% and lower than that of reference AGO. The ash content of all the biodiesel samples produced from loofah oil ranged from 0.01 - 0.02% and were lower compared to AGO obtained as 0.12. The blends of loofah ethyl ester (LEE) of B10 and B20 were found to have acceptable fuel properties to power compression ignition engines.

Key words: Loofah ethyl esters, biodiesel, compression ignition engine, automotive gas oil (AGO).

INTRODUCTION

The escalating prices of petroleum fuels, the uncertainties in their supply and the wreckage of global climate caused by their continual use have rekindled research interests in the use of vegetable oil fuels and other biofuels. However, the most used vegetable oils are competing with local consumption; therefore, there is a need to identify non-edible oil in place of the edible vegetable oil. One of such vegetable oil is loofah oil. Loofah (*Luffa cylindrica* L.) is a plant commonly found in the tropics and the seeds have been found to contain 31.6% oil content, and higher than the oil content of cotton (18.28%) and soya bean (11 - 25%). Ajav and Akingbehin (2002) found out that 5 to 20% blends of ethanol with diesel have acceptable fuel properties for use as supplementary fuel in farm engines. The fuel properties of some biodiesel fuels reported by some previous researchers are shown in Table 1. Moreno et al. (1999) noted that the fuel quality of biodiesel varies in a wide range as a function of the transesterification process, the raw materials used etc. Alamu et al. (2007) reported that palm kernel biodiesel had 85.06% reduction of viscosity over its raw vegetable oil, thus enhancing its fluidity in diesel engine. The specific gravity, distillation range, cloud point and pour point of biodiesel were found to be higher than those for petroleum diesel fuel (Ali and Hanna, 1997; Alamu et al., 2007). Biodiesel has been described as a safer fuel, because the flash point is more

*Corresponding author. E-mail: isaacbam22@yahoo.com or isaac.bamgboye@mail.ui.edu.ng.

Table 1. Fuel properties of some biodiesel fuels.

Property	SME	RME	SEE	REE	MEE	CME	SFME	POME	RSME	JME	PKEE
Cetane Number	50.9	53	48.2	64.9		51.2 - 52	46.9 -50	46.9 - 50	52	51-52	
Flash Point (ºC)	69 - 131	>150	160	185		70	>110	85	130	175 -191	
Specific Gravity at 15°C	0.885	0.882 - 0.884	0.881	0.876		0.874 - 0.885	0.880 - 0.886	0.870 - 0.878	0.874	0.879	0.883
Lower Heating Value, MJ/kg	37.0 - 39.76	37.3				37.5	37.5	37.2	36.5	38.5 -39.2	
Higher Heating Value, MJ/kg	40.4	40.7	40.0	40.5		40.32	40	40.56		41	
Cloud Point (°C)	-2.0 - 1.5	-10 - -4.0	-1.0 - 8.9	-2.0	2.5 - 5.1		1	10	4	13	6
Pour Point (°C)	-3.0 - -0.7	-10 - -12.0	-7.0 - 2.7	-15.0	-10.0	-15			-8	2-4	
Viscosity at 40ºC, mm^2/s	4.08 - 4.3	4.5- 4.83	4.41 - 5.3	6.17	5.7	4.0	4.3 to 4.5	4.5	5.81	4.84-5.2	4.84
Iodine Number	133.2	97.4	123	99.17							
Sulphur (mg/kg)		>3	0.01				0.012			<0.001	
Ash Content(mg/kg)		0.007					0.004			0.013	
Acid value (mg KOH/kg)		0.03						0.11			

(Adapted from Rao et al. (2008); Rahman et al. (2010); Alamu et al. (2007); Antolin et al. (2002); Labeckas and Slavinskas (2006); Holser et al. (2006);Rakopoulos et al. (2006); Ramesh et al. (2008) and Ramadhas et al. (2005). SME, Soybean methyl ester; RME, rapeseed methyl ester; SEE, soybean ethyl ester; REE, rapeseed ethyl ester; MEE, milkweed ethyl ester; CME, cottonseed methyl ester; SFME, sunflower methyl ester; POME, palm oil methyl ester; JME, jatropha methyl ester; RSME, rubber seed methyl ester; PKEE, palm kernel oil ethyl ester.

than 100°F higher than that of diesel and the toxicity is at least 15 times less than diesel (Peterson et al., 1994). Biodiesels from vegetable oils have been found to have cetane number ranging from 46 - 65, and animal fat based biodiesels cetane numbers ranged from 56 - 60 (Midwest Biofuels, 1994).

Loofah oil has been found to be potentially suitable for the production of loofah biodiesel using methanol as the alcohol for transesteri-fication (Ajiwe et al., 2005; Yusuf and Sirajo, 2009). However, no work was reported in literature on the fuel properties of loofah biodiesel using ethanol as the alcohol for transesterification. Hence, this work investigated the potential of loofah oil as an energy source. The result of this work will provide information concerning the use of loofah oil as feed stocks for producing biodiesel and will help to determine the fuel characteristics and blend characterization needed to produce biodiesel from loofah oil.

MATERIALS AND METHODS

Seeds collected from Ogbomoso, Nigeria were removed from dry and mature loofah fruits and oil was mechanically extracted from the seeds. The procedure for extraction was outlined in Bamgboye and Oniya (2009).

Preparation of loofah biofuel blends

Loofah ethyl ester (LEE) samples were prepared by transesterification of loofah oil with ethanol using potassium hydroxide as catalyst in a two-step transesterification process (Peterson et al., 1996; Saifuddin and Chua, 2004). The automotive gas oil (AGO), also known as petroleum diesel (D2), obtained from a petroleum filling station in Ogbomoso town, Nigeria, was used as the reference fuel. Biofuel samples were prepared by blending loofah oil and its ethyl-esters with AGO (at 10 - 100%) mixed with 10% increment by volume in the following proportions (B10 - B100).

Analysis of the samples

Fuel properties such as kinematic viscosity, specific gravity, flash point, cloud point, pour point, free fatty acid composition and heating value of loofah oil and its ethyl ester blended with diesel and the reference diesel fuel (AGO) were determined according to American Society for Testing and Materials (ASTM) standards. A regression equation developed by Bamgboye and Hansen (2008) was used to determine the cetane number of loofah biofuel. The saponification value, iodine value, pH value, ash content, sulphur content and carbon content of the oil samples were determined according to the method prescribed in the *American Oil Chemists' Society* (AOCS) official and tentative methods.

RESULTS AND DISCUSSION

The fuel properties of the blends of loofah oil and its ethyl ester with AGO are presented in Tables 2 and 3.

Table 2. Fuel properties of blends of loofah oil with AGO.

Blends	AGO	B10	B20	B30	B40	B50	B60	B70	B80	B90	B100
Viscosity at 40°C (mm²/s).	2.95	7.10	7.50	8.20	9.70	10.70	13.20	17.60	18.60	21.10	43.40
Lower heating value (MJ/L)	44.68	41.80	39.70	39.30	38.10	36.90	36.70	36.50	32.10	31.40	30.20
pH	2.80	5.30	5.40	4.90	3.90	4.80	4.50	4.40	5.50	4.10	3.20
Specific gravity at 15°C	0.86	0.863	0.863	0.865	0.87	0.88	0.87	0.88	0.88	0.88	0.88
Cloud point(°C)	-12	6	6	6	7	7	7	7	7	7	8
Pour point(°C)	-16	2	2	2	3	3	3	3	3	3	3
Ash content (%)	0.12	0.12	0.11	0.09	0.082	0.067	0.052	0.042	0.032	0.02	0.02
Flash point(°C)	74.00	57.00	60.00	63.00	65.00	69.00	69.00	72.00	72.00	76.00	79.00
Sulphur content (%)	61.80	13.20	13.20	12.90	12.80	11.60	11.60	11.20	10.50	10.60	10.40
Carbon content (%)	13.40	17.10	17.90	23.30	25.60	33.60	33.10	32.10	32.60	35.90	37.50
Iodine value (Wijis)	0.21	0.207	0.208	0.207	0.208	0.208	0.213	0.215	0.29	0.29	0.31
Peroxide value (Meq/KOH)	0.14	0.106	0.106	0.106	0.107	0.107	0.07	0.07	0.07	0.08	0.08
Saponification value (mg KOH/g)	0.17	0.101	0.101	0.101	0.101	0.102	0.092	0.062	0.042	0.042	0.03
Free fatty acid (%)	8.00	7.80	7.20	6.20	5.60	4.80	4.80	3.30	3.30	3.32	3.48

Furthermore, the regression models for the fuel properties of loofah biodiesel based on blending ratios with AGO are presented in Table 4.

Viscosity

The viscosity increased with increase in the blend of loofah oil and its ethyl ester with AGO from B10 to B100. The viscosity ranged from 7.1 to 43.4 mm^2/s for loofah oil blends, and was higher than 4.5 to 25.0 mm^2/s obtained from LEE. However, these values were higher than 2.95 mm^2/s obtained from AGO. It was observed that the viscosities of up to B80 blend increased from 4.5 - 21.10 mm^2/s and were within the range of 4-D grade AGO specified by the American Society for Testing and Materials Standards (1995) as 5.5 - 24.0 mm^2/s for all the biofuels. The implication was that the biodiesel blends produced from loofah oil up to B80 had enhanced fluidity as fuel for diesel engines and that real spray would generate across the combustion chamber and this would be properly mixed with air. The same trend was observed by Rao et al. (2008) and Prasad et al. (2009) for blends of jatropha methyl ester with AGO and blends of castor oil with AGO, respectively, whose viscosity increased as the percentage of biofuel increased in the blends.

The viscosities of LEE-AGO blends up to B40 ranged from 4.5 – 5.9 mm^2/s and were within the preliminary technical specification standard of U.S.A. for biodiesel fuels and the limit specified by ASTM D445 which ranged from 1.9 - 6.0 mm^2/s. The viscosities of all the other blends were more than the limit specified. Also, the viscosities of blends of LEE with AGO of more than B40 gives wide variation from the reference AGO. Therefore, blends of not more than 40% of LEE with AGO will give the best performance in diesel engine without modifying the engine. Similarly, Ajav and Akingbehin (2002) reported that 5-20 % blend of ethanol with AGO have acceptable fuel properties for use as supplementary fuel in farm engines.

Specific gravity

The specific gravity of all the loofah biodiesel blends increased from B10 to B100. It ranged from 0.863 to 0.89; and were within the values obtained for the reference AGO of 0.86. This meant that all the loofah biodiesel blends have good combustion characteristics. Similar results were obtained from blends of jatropha methyl ester with AGO from B50 to B100 and raw castor oil with AGO from B25 to B100 increased from 0.85 - 0.88 and 0.86 - 0.96, respectively. The closeness of the value of specific gravity of the biodiesel blends to that of AGO indicated good ignition property.

Moreover, the correlation developed for specific gravity of LEE-AGO blends were linear relationships, while the correlation developed for loofah oil-AGO blends was polynomial relationship (Table 4). The regression models gave R^2 of 0.88 - 0.96 and can be used to predict the specific gravity of the biofuels at any blend percentage with AGO.

Heating value and carbon content

The heating values of the LEE biodiesel blends decreased from 42.55 - 28.75MJ/L from B10 to B100 and slightly higher than the value of 41.8 - 30.2 MJ/l obtained from loofah oil. However, these values were lower than the values of 44.68 MJ/L obtained from the reference AGO. These results were comparable to the values

Table 3. Fuel properties of blends of loofah oil ethyl ester with AGO.

BLENDS	AGO	B10	B20	B30	B40	B50	B60	B70	B80	B90	B100
Viscosity at 40°C (mm²/s).	2.95	4.50	5.50	5.70	5.90	8.70	8.00	11.30	17.70	18.10	25.00
Lower heating value (MJ/L)	44.68	42.55	35.90	34.86	34.70	34.50	34.10	33.85	33.6	31.4	28.75
pH	2.80	2.91	3.10	3.10	3.30	3.35	3.40	3.42	3.44	3.45	3.50
Specific gravity at 15°C	0.86	0.863	0.864	0.86	0.87	0.87	0.88	0.88	0.88	0.88	0.88
Cloud point (°C)	-12	6	6	6	6	6	6	7	7	7	7
Pour point (°C)	-16	2	2	3	3	4	4	4	4	4	4
Ash content (%)	0.12	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Flash point (°C)	74	80	82	83	83	84	85	85	85	86	86
Sulphur content (%)	61.80	12.10	11.85	11.60	10.70	10.40	9.97	9.90	9.98	9.88	9.16
Carbon content (%)	13.40	13.0	13.34	13.30	13.06	12.91	12.88	12.84	12.73	10.61	10.2
Iodine value (Wijis)	0.21	0.26	0.27	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.3
Peroxide value (Meq/KOH)	0.14	0.07	0.07	0.05	0.05	0.07	0.07	0.07	0.08	0.08	0.07
Saponification value (mg KOH/g)	0.17	0.15	0.15	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Free fatty acid (%)	8.00	7.70	7.20	6.40	6.40	6.0	5.80	5.80	5.60	5.60	5.60

reported by Yusuf and Sirajo (2009) for tigernut oil (34.6 MJ/L), jatropha oil (34.7 MJ/L), soybean oil (34.7 MJ/L) and groundnut methyl ester (25.5 - 40.81 MJ/L). Therefore, all the loofah biodiesel blends have potentials to power a diesel engine. The heating values of loofah biodiesel blends decreased as the percentage of raw loofah oil and LEE increased in the blends. This was because the carbon content of the biodiesel blends decreased as loofah oil and its ester increased in the blends. Ajav and Akingbehin (2002) reported the same trend of decreasing heating value as the percentage of ethanol increased in the blends of ethanol with AGO. A similar trend was also reported for blends of jatropha methyl ester and AGO (Rao et al., 2008).

The correlation developed for heating value of loofah ethyl ester was logarithmic relationship, while that of loofah oil-AGO blends was a polynomial relationship (Table 4). A polynomial relationship was obtained for the carbon content of loofah ethyl ester-AGO blends. The regression models gave R^2 of 0.77 - 0.96 and can be used to predict the heating value and carbon content of the biofuels at any blend percentage with AGO.

Cloud, pour and flash points

The cloud points, the pour points and the flash points increased as the percentage of loofah oil and its ethyl ester increased in the blends. The cloud and pour points of 6 - 8°C and 2 - 4°C obtained from the blends were higher than 12°C and -16°C obtained from AGO. The higher cloud and pour points of the biofuels may involve some complications for their use in diesel engine during cold weather. The flash point of the LEE blends was higher than the AGO, while flash point of loofah oil blend was slightly lower. The high flash points of the biofuels ensure safe storage and transportation free from fire hazards. The results were consistent and agreed with the findings of other researchers for biodiesel produced from mustard, rapeseed and sunflower oils (Shrestha et al., 2005).

The regression model of cloud point of loofah oil at different blends with AGO obtained experimentally gave an exponential relationship. A polynomial relationship described by a quadratic equation was obtained for the regression model of cloud point and pour point of loofah ethyl ester at various blends with AGO. The correlations developed for flash point of loofah oil-AGO blends were linear relationships. Also, the correlations developed for flash point of loofah ethyl ester were logarithmic relationships. The regression models gave R^2 of 0.76 - 0.98 and can be used to predict to some extent the cloud, pour and flash points of the biofuels at any blend percentage with AGO.

Cetane number

The cetane number of esters of loofah biofuel was 51.3. The cetane number of pure linoleic acid was reported as 36.8, while that of oleic acid was reported as 57.2. Therefore, the cetane number of loofah biofuel was within the range of the cetane number of dominating fatty acid constituents. This agreed with the findings of Bamgboye and Hansen (2008) who reported that the cetane numbers of esters of soybean, rapeseed, sunflower, cottonseed, peanut, palm oil, lard, tallow and canola oils were within the range of the cetane number of the dominating fatty acid constituents. The cetane number of loofah biofuel were also close to the values reported by Bamgboye and Hansen (2008) and Moreno et al. (1999) for esters of soybean oil (45 - 60), rapeseed oil (44 - 59),

Table 4. Regression models for fuel properties based on blending ratios of loofah biofuels.

Property	Regression models	R^2	Biofuels
Kinematic viscosity at 40°C (mm²/s).	$y = 4.154e^{0.179x}$	0.92	Loofah oil.
	$y = 0.312x^2 - 1.947x + 7.935$	0.97	LEE.
Heating value (MJ/L).	$y = -0.058x^2 - 0.475x + 42.29$	0.95	Loofah oil
	$y = -5.67\ln(x) + 44.35$	0.80	Loofah ethyl ester
Specific gravity at 15°C.	$y = -0.001x^2 + 0.021x + 0.782$	0.94	Loofah oil
	$y = 0.006x + 0.822$	0.88	LEE
Cloud point (°C).	$y = 5.686e^{0.026x}$	0.76	Loofah oil
	$y = -0.009x^2 + 0.242x + 5.154$	0.94	LEE
Pour point (°C)	$y = -0.026x^2 + 0.418x + 1.416$	0.81	Loofah oil
	$y = -0.053x^2 + 0.750x + 1.232$	0.92	LEE
Flash point (°C)	$y = 2.278x + 55.66$	0.98	Loofah oil
	$y = 2.237\ln(x) + 80.72$	0.84	LEE
Sulphur content (%)	$y = 13.72e^{-0.02x}$	0.90	Loofah oil
	$y = -0.310x + 12.26$	0.91	LEE
Ash content (%)	$y = 0.004x + 0.004$	0.81	Loofah oil
	$y = 0.000x^2 - 0.004x + 0.026$	0.65	LEE
Carbon content (%)	$y = -1.069x + 49.54$	0.92	Loofah oil
	$y = -0.053x^2 + 0.174x + 13.85$	0.91	LEE
Iodine value (Wijis)	$y = 0.004x^2 - 0.027x + 0.109$	0.81	Loofah oil
	$y = 0.011x^2 - 0.130x + 0.408$	0.75	LEE
pH	$y = -0.015x^2 + 0.228x + 2.614$	0.67	LEE
Peroxide value (meq/KOH)	$y = 0.002x + 0.056$	0.85	LEE
Saponification value (mg KOH/g)	$y = 0.001x + 0.007$	0.81	Loofah oil
	$y = 0.004x^2 - 0.058x + 0.201$	0.76	LEE
Free fatty acid (%)	$y = 0.376x^2 - 4.909x + 17.63$	0.77	LEE
	$y = 0.162x + 1.854$	0.98	Loofah oil

y = Fuel property; x = percentage of loofah biofuel in the blend.

sunflower oil (50 - 61.2), cottonseed oil (45 - 55), peanut oil (54), palm oil (58 - 70), lard (63.6), tallow (58 - 64.8) and canola oil (53.9 - 55). The cetane number of loofah biofuel was, however, higher than the minimum biodiesel standard of 49 specified by the Technical Standard of the European Union.

pH value

The pH of all the biodiesel blends were higher, but closer to that of AGO obtained as 2.8. It is noteworthy that the acidic nature of the biofuels was due to the presence of free fatty acid while that of AGO was due to the sulphur content.

Ash content

The ash content of all the biodiesel samples produced from loofah oil ranged from 0.01 - 0.02% and were lower compared to AGO obtained as 0.12%. Since the ash content is a measure of the amount of metal contained in the fuel, therefore this result indicated that the use of Loofah biodiesel blends would reduce injector nozzle clogging, combustion deposits and injector system wear compared to AGO which had higher ash content. The use of the biodiesel fuels would not constitute a corrosion problem in the injection system and pressure chamber of a diesel engine. The results were consistent with the values of ash contents obtained for jatropha oil, rapeseed methyl ester, sunflower methyl ester and jatropha methyl ester obtained as 0.03, 0.007, 0.004 and 0.013 respectively (Rahman et. al., 2010; Labeckas and Slavinskas, 2006; Moreno et al., 1999).

A set of polynomial relationship described by quadratic equations were obtained for the regression models of ash content of loofah ethyl ester at various blends with AGO, while the correlation developed by loofah oil-AGO blends was a linear relationship. The regression models for raw loofah oil-AGO blends gave R^2 of 0.81 - 0.95, while those of loofah ethyl ester-AGO blends gave R^2 of 0.53- 0.65, which implies that the models can only be used to predict the ash content of the raw vegetable oils at any blend percentage with AGO.

Sulphur content

All the loofah biodiesel blends had sulphur contents ranging from 9.16 - 13.2% which were considerably lower than 61.8% obtained from the reference AGO. Hence, sulphur dioxide emissions are expected to be considerably reduced in a diesel engine using the biofuels. The sulphur contents of the biofuels decreased as the percentage of loofah oil and its ester increased in the blends. Moreover, the regression model of sulphur content of loofah oil at different blends with AGO obtained experimentally gave an exponential relationship. The correlations developed for sulphur content of loofah ethyl ester-AGO blends was a linear relationship. The regression models based on blending ratios gave R^2 of 0.86 - 0.93 and can be used to predict the sulphur content of the biofuels at any blend percentage with AGO.

Saponification value

The saponification values of the blends were lower than 0.17 mg KOH/g obtained from the reference AGO. The lower value is an indication that it wil be a good fuel for diesel engine. A polynomial relationship described by a quadratic equation was obtained for the regression model of saponification value of loofah ethyl ester at various blends with AGO. The correlations developed for saponification value of loofah oil-AGO blends was linear relationship. The regression models for loofah biofuels gave R^2 of 0.76 to 0.81, which meant that the correlation developed for loofah biofuels can be used to predict the saponification value of the biofuels at any blend percentage with AGO.

Iodine value

The iodine values are lower than 0.14 Wijis obtained from the reference AGO. A set of polynomial relationship described by quadratic equations was obtained for the regression models of loofah ethyl ester at various blends with AGO. The regression models for loofah biofuels gave R^2 of 0.75 - 0.81, which meant that the correlation developed for loofah biofuels can be used to predict the iodine value of the biofuels at any blend percentage with AGO.

Peroxide value and free fatty acid

The peroxide value and free fatty acid were lower than 0.14 Meq/KOH obtained from the reference AGO. A set of polynomial relationships described by a quadratic equation was obtained for the regression model of peroxide value and free fatty acid of loofah ethyl ester at various blends with AGO. The correlations developed for peroxide value and free fatty acid of loofah oil-AGO blends were linear relationships. The regression models gave R^2 of 0.76 - 0.98, which means that the correlation developed for loofah biofuels can be used to predict the peroxide value and free fatty acid of the biofuels at any blend percentage with AGO. However, there are still other factors that will also affect the peroxide value and free fatty acid that are not captured in this work.

Conclusion

Data for the fuel properties of loofah oil, its ethyl ester and ethyl ester-AGO blends have been determined and found to have good combustion characteristics and good ignition quality similar to that of AGO. Therefore, the blends of loofah ethyl ester (LEE) of B10 and B20 were found to have acceptable fuel properties to power compression ignition engines.

REFERENCES

Ajav EA, Akingbehin OA (2002). A Study of some fuel properties of local ethanol blended with diesel fuels. *CIGR* J. Sci. Res. Dev. Vol. 4.

Ajiwe VIE, Ndukwe GI, Anyadiegwu IE (2005). Vegetable Diesel Fuels from *Luffa Cylindrica* oil, its methyl ester and ester-diesel blends. Chemclass. J. 2:1-4.

Alamu OJ, Waheed MA, Jekayinfa SO (2007). Biodiesel production from Nigerian palm kernel oil: Effect of KOH concentration on yield. Energy Sustain. Dev. 11(3):77-82.

Ali Y, Hanna MA. (1997). In:Cylinder pressure characteristics of heavy duty diesel engine on biodiesel fuel. SAE Technical Paper Series 971683. State of Alternative Fuel Technologies, SAE International, Warrendale R.A. pp. 43-151.

American Society for Testing and Material ASTM (1995). *ASTM Book of*

Standard Test Methods. American Society for Testing Materials, Philadelphia, PA, USA, pp 1-8, 268-271.

Bamgboye AI, Oniya OO (2009). Effect of processing technologies on the chemical and biofuel characteristics of *Luffa* oil. Science Focus. 14(3):390–396.

Bamgboye AI, Hansen AC (2008). Prediction of eetane number of biodiesel fuel from the Fatty Acid Methyl Ester (FAME) composition. International Agrophysics. Institute of Agrophysics, Polish Academy of Sciences. 22:21-29.

Holser RA, Harry-O'Kuru R (2006). Transesterified Milkweed (Asclepias) seed oil as a biodiesel fuel. Fuel. Elsevier Science Limited. Great Britain. 85:2106–2110.

Labeckas G, Slavinskas S (2006). The effect of Rapeseed oil methyl ester on direct injection diesel engine performance and exaust emissions. Energy Conversion and Management. Elsevier Science Direct. 47:1954–1967.

Midwest Biofuels Inc (1994). Biodiesel cetane number engine testing comparison to calculated cetane index number. Overland Park, Kansas.

Moreno F, Mumoz M, Morea-Roy J (1999). Sunflower methyl ester as a fuel for automobile diesel engines. Transaction of the ASAE. 42(5): 1181-1185.

Peterson C, Recee D, Thompson J, Beck S, Chase C (1994). Development of biodiesel for use in high speed diesel engines. Proceedings of the 6th National Bioenergy Conference. Reno-Sparks, NV Western Regional Biomass Energy Program. 1:97-104.

Peterson C, Möller G, Haws R, Zhang X, Thompson J, Reece D (1996). Optimization of a batch type ethyl ester process. United States Department of Agriculture Report, Cooperative State Research Service, Cooperative Agreement No. 93-COOP-1-8627.Final Report, 303:1- 12.

Prasad CS N, Reddy KV, Kumar BSP, Ramjee E, Hebbel, OD, Nivendgi MC (2009). Performance and emission characteristics of a diesel engine with Castor oil. Ind. J. Sci. Technol. 2(10):24 – 31.

Rakopoulos CD, Antonopoulous KA, Rakopoulos DC, Hountalas DT, Giakoumis LL (2006). Comparative performance and emissions study of a direct injection diesel engine using blends of diesel fuel with vegetable oils or biodiesels of various origins. National Technical University of Athens, Athens, Greece.

Ramadhas AS, Muraleedharan C, Jayaraj S (2005). Performance and emission evaluation of a diesel engine fuelled with methyl esters of rubber seed oil. Renewable Energy. Elsevier Science Limited. Great Britain. 30:1789–1800.

Ramesh A, Inyang F, Lunstra DD, Niaz MS, Greenwood M, Kopsombut PM, Jones KM, Hood ER, Archibong AE (2008). Alteration of fertility endpoints in adult male F-344 rats by subchronic exposure to inhaled benzo(a)pyrene. Exp. Toxicol. Pathol. 60:269-280.

Rao YVH, Voleti RS, Hariharan VS, Raju AVS (2008). Jatropha oil methyl ester and its blends used as an alternative fuel in diesel engine. Int. J. Agric. Biol. Eng. 1(2).

Rahman KM, Mashud M, Roknuzzaman M, Al Galib A (2010). Biodiesel from Jatropha oil as an alternative fuel for diesel engine. IJMME-IJENS Int. J. Mech. Mechatron. 10(3):1.

Saifuddin N, Chua KH (2004). Production of ethyl ester (Biodiesel) from used frying oil: Optimization of transesterification process using microwave irradiation. Malaysian. J. Chem. 6(1):077-082.

Shrestha DS, Gerpen JV, Thompson J, Zanadziki A (2005). Cold flow properties of biodiesel fuels. Report of ASAE, Annual International Meeting. Florida.

Yusuf N, Sirajo M (2009). An experimental study of biodiesel synthesis from groundnut oil. Part I: Synthesis of biodiesel from groundnut oil under varying operating conditions. INSI net Publication. Australian. J. Basic. Appl. Sci. 3(3):1623-1629.