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Production and Characterization of Biodiesel from Mango Seed Oil (MSO)

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Abstract
Biodiesel in the past, was once considered a fringe fuel. However today, the production and consumption of this fuel has grown as a sustainable and much more eco-friendly alternative to the Conventional diesel (Petroleum diesel), for diesel engines; if not in pure form, it will be in blends of different ratios, or as a fuel additive, to improve engine performance and ensure longevity. In this research, oil from Mango (Mangifera indica) seed was extracted through Soxhlet solvent process, and converted into biodiesel by the method of Transesterification. This process involved the reaction between the extracted oil and methanol at an optimal temperature of 60°C, and 1%w/v of the catalyst (KOH) concentration for optimal yield of biodiesel. The produced biodiesel was analyzed and evaluated by comparing its physical characteristics to that of Conventional (petroleum) diesel fuel. The properties analyzed were; Density, Heating value, flash point, specific gravity, viscosity, cloud point, water content and pour point. The biodiesel from mango seed oil (MSO) compared excellently well with the values obtained for the commercially available petroleum diesel, dispensed at government approved filling stations in Nigeria. The biodiesel so produced and characterized, was subsequently subjected to an engine test, in a four-stroke internal compression (IC), (diesel) engine loaded between 120 – 200 rpm, to determine its suitability as a fuel. The result was compared with the Conventional diesel characteristics in terms of brake power output, mass flow rate, thermal efficiency, and specific fuel consumption (SFC) and so on. The biodiesel results compared very well with most of the data generated on the conventional diesel, and satisfied the ASTM-D6751 and the EN14214 standard requirements for suitability as working fluid in an IC engine, especially with regard to SFC, which translates to the direct running cost of every diesel engine.

Keywords: Biodiesel, mango-seed oil, heating value, brake-thermal efficiency, specific fuel consumption

1.0 INTRODUCTION

The increasing demand for energy due to the ever-increasing world population, together with the increasing agitation for a safer environment, gave rise to the need for increased sustainable energy generation, from renewable energy sources. This has become necessary, in order to meet the rising global energy demand without sacrificing the environment. Energy experts are projecting that world energy generation from oil and gas, though harmful to the environment, would only last for a very limited time.

Moreover, the energy produced from the combustion of fossil fuel is not only toxic to the environment, but it is also coming at a very high cost, due to pressures from industrialization as well as production inefficiencies. The overdependence on petroleum or hydrocarbon as the major source of energy, has not helped matters in trying to solve the problems associated with that source of energy, instead it has contributed immensely more to the problems of emissions, from the burning of this fuel or hydrocarbon. The emissions like CO, CO_2, NO_2 and sulphur contained in the residue, are the principal cause of global warming, due to their roles in the depletion of the ozone layer. The emissions often include the release of lead oxide to the atmospheric surrounding, which is toxic to the environment. The releases of these harmful substances to the environment cause severe health problems like acute respiratory infections, chronic obstructive diseases, lungs cancer and even eyes problems, to mention but a few.

Many people across the globe including Nigerians have spent huge amounts of money treating them in order to recover from these life-threatening conditions Kaoma and Kasali [18]. Besides the above reasons, there are also the recurrent and persistent increases in price volatility of petroleum products. All these have therefore, made it imperative that going forward, clean, cheap, affordable and sustainable energy will be the bedrock and major catalyst, for future national growth and economic development.

The adverse effects of petroleum energy on the environment and on humans have triggered the search for alternative energy sources. And over the years, in order to tackle the above challenges, much effort has been made through research, targeted at not only discovering new sustainable methods of energy generation, but also towards diversifying the world energy mix.

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This has therefore shifted the attention of the world, and in particular, researchers, to renewable sources of energy. Biodiesel is looked upon as one of the future most likely, reliable sources of renewable energy. Among the various sources of bio-renewable energy, vegetable oils and animal fats have attracted much interest as having the potential resources for an alternative fuel for energy generation. Biodiesel is a mono alkyl of fatty acid from vegetable oils and animal fats. Its colour range varies from golden brown to dark brown, depending on the product's feed stock. Biodiesel is an important eco-friendly biofuel, because it is biodegradable, with generally high flash point (average of 150^0C) [19], with low exhaust emissions, miscible in all ratios and forms a homogeneous liquid solution with petroleum diesel, and also has high lubricity [2].[4].

Biodiesel is renewable, biodegradable, non-inflammable and non-toxic, and also has a favorable combustion emission profile, producing much less carbon monoxide, sulphur and unburnt hydrocarbons, than the conventional or Petroleum diesel [9]. These attractive features of Biodiesel have drawn many people into the business of Biodiesel, leading to the expansion of the global Biodiesel market by the day, and thus, the search for more agricultural crops and other sources from which Biodiesel could be produced. In 2005, a report by the National Biodiesel Board in US projected that with adequate emphasis on growing crops specifically for Biodiesel production, and research on discovering new technological advancement in agricultural industry practices, the production of up to 10 billion gallons annually, could become achievable by 2030 [7]. As part of their strategies towards encouraging the production and use of Biodiesels, various Governments across the globe, have designed key policies which included amendment of energy policy laws, Biodiesel tax incentives and enactment of enabling laws making the use of Conventional diesel blends up to a certain minimum percent, mandatory in their countries [4],[11].

The Mango seed oil is obtained from the Mango fruit produced by a tropical fruit-bearing tree that grows well in Nigeria, Guinea and some parts of Asia. It is reported that mango seed kernel contains between 12% - 15% oil and has a melting point of between 32ºC-36ºC, with the oil content depending on the type or variety Nadeem et al [15]. The oil is rich in saturated fatty acids; oleic acid with 52.22% which even exceeded the 44.7% oleic acid of Jatropha curcus oil, 15.4% of Palm oil, 21.1% of sunflower oil and 23.4% of soybean oil. The chemical characterization of the Mango seed kernel oil showed that it has lower carotenoid content and peroxide value, and an Iodine value of 55, with Palmitic, Stearic acids and, Oleic acids as the major fatty acids, having a solid fat index of zero at human body temperature [15]. The Mango fruit is of great importance and has been used as raw material for many canned fruit products. The mango seed kernel can be used as an alternative to cocoa butter in chocolates and confectionaries and, has a greater phenolic content (majorly of Mangiferin, Chlorogenic acids and Quercetin and Caffeic acids), than many vegetable oils. Hence, it can be used as a substitute for synthetic antioxidants, for the preservation of fats and oils [15]. There is sufficient nutritional information on Mango fruit from the food security standpoint, and besides, it has been reported that Mango seed contains a type of fat known as the Mango Seed Almond Fat (MAF), that is high in stannic acid content [15]. However, it is also vital to maximize the other benefits derivable from the Mango waste, by further processing the mango seed kernel oil into renewable energy fuel or biofuel. Mango seed kernel is a source of many bioactive compounds and antioxidants, with cardio and hepatic protective effects, anti-carcinogenic, and anti-ageing effects of phenolic compounds. It can also be used for the preservation of fats and oils and also for improving the oxidative stability of Sunflower oil and Tallow [15]. The Mango seed is the discarded or the left-over part of Mango fruit, after the fleshy part has been consumed by humans and other animals, leaving only the seed to litter the environment, often releasing offensive odours, and forming breeding spots for all kinds of flies. In Nigeria presently, apart from allowing the seed to decay after a long time and go back into the soil as manure or burning them off with fire, there is no other meaningful use to which, this oil-rich agro-waste material is being put into. The management of agro-waste materials is becoming increasingly problematic, littering the rural and urban areas of the country, during the harvest season of the crop, constituting environmental nuisance, and causing serious threat to the environmental health of the nation. It is in respect of the above, that this research is being conducted to produce Biodiesel, from mango seed. Biodiesel is a fuel produced from biomass. Biomass is a renewable energy source obtained from plants oil and animals fats [13], [14].

The process of converting vegetable oil to methyl ester through Transesterification process was invented by Duffy and Patrick in 1853 [1]. However, Biodiesel was only evaluated seriously in the late 1970's, though not widely adopted at that time, because many people still doubted, whether Biodiesel would be a reliable, and safe fuel to use for diesel engine operation [4]. Today, the increased acceptability of Biodiesel world-wide has led to the expansion of the Biodiesel market globally. And it is expected that in years to come, Biodiesel will reduce the over reliance or dependence of the global community, on fossil Petroleum diesel, which is rapidly being depleted. The Penn State Extension [4] reported that Canola oil, with its high proportion of long unsaturated fats (lots of Oleic acid) is for now, the most preferred oil, for quality Biodiesel fuel production than most of the yet investigated oil-seed crops like, Peanut oil, Coconut oil, Jatropha curcas oil, Castor oil, Cotton oil, Palm oil, Olive oil, Sunflower oil, and Soyabeans oil [7, 14, 15]. It however, concluded that the tropical oils like, palm oil with their high proportion of saturated fats, have shown significant problems with cold- weather performance, because they more readily solidify than many other oils. It is therefore important to continuously, look for other better oil-bearing seeds that can be used for industrial production of biodiesel. Nevertheless, it is also essential to consider the cost of growing or buying the oil, before deciding which crop has better oil; as different crops have different yields and different physiochemical properties, which control their Biodiesel performances [2],[4]. It is reported that different vegetable oils have different concentrations of chemical components (mostly, Fatty Acids), which affect their performance, when converted into Biodiesel.

Furthermore, the chemical structure of the alcohol which is utilized during the conversion of the oil into Biodiesel fuel can also determine the properties of the fuel finally obtained [2],[4]. The chemical properties that mostly determine the behavior of Biodiesel's performance are the degree of 'branching' in the chain, the length of the biodiesel molecule, the degree of saturation of the molecule as well as the cold-starting properties of the diesel [4],[7]. The cold-starting properties of Biodiesel are particularly important and could prove very critical during winter in cold climates. However, these low-temperature properties are essentially unimportant in summer times or even in warm parts of the world [4],[7] and [14].

Presently, there are additives in shops that can improve some of the deficient properties of Biodiesel [4]. It is reported in [2] and [4], that the reduction in lubricity is due to the removal of polar compounds containing Sulphur that are the natural additives by hydrogenation, and the formation of saturated compounds. The longer molecules with more branching, which are more beneficial to the performance of biodiesel are not always present in FAME. Out of the assorted types of Fatty Acids found in vegetable oils, the Oleic acid is the best, the linoleic acid is less undesirable, and the linolenic acid is the most undesirable [4], [7]. High unsaturation (high Iodine number) leads to poor oxidative stability which is highly undesirable in Biodiesel for optimal performance.

It is reported that better cold flow behavior by Biodiesel was exhibited by oil with higher degree of unsaturation, longer chain length, higher degree of branching and with Cis configuration Adewale, et al [8]. The addition of more complex alcohols like, iso-butanol in the transesterification reaction increases the carbon chains to the biodiesel esters, resulting in lower freezing temperatures [17]. Xaun and Leung [20] used range analysis and analysis of variance (ANOVA) to investigate the optimization of the four main process parameters (i.e., methanol quantity, reaction time, reaction temperature, and catalyst concentration) involved in the transesterification of Camelina oil. They concluded that the order of significance of the interplaying parameters in the transesterification reaction for obtaining maximum Biodiesel production yield is catalyst concentration > reaction time > reaction temperature > methanol to oil ratio. In addition, they reported that for that experiment, the maximum Biodiesel yield was at a molar ratio of methanol to oil of 8:1, a reaction time of 70 minutes, a reaction temperature of 50 °C, and a catalyst concentration of 1 wt. % [20]. Gravolos, et al [16] presented a list of the gross calorific values and the net calorific values of methyl esters and blends. The calorific values of some of the vegetable oils and animal fats are in the range of 39 00kJ– 40 000kJ. These values are very close to calorific values of Conventional diesel.

The aim of this research is to produce Biodiesel from waste mango seeds, by extracting oil from mango seed, converting the oil to Biodiesel, characterizing the Biodiesel as well as evaluating its engine performance characteristics in a diesel engine test; in terms of brake-power, specific fuel consumption (SFC) and thermal efficiency, and comparing the produced Biodiesel performance with petroleum-based diesel (Conventional diesel).

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2.0 MATERIALS AND METHOD

2.1. Materials

The discarded mango (magnifier indicia), seeds were sourced from the fruit trees within the University of Nigeria community, Nsukka, Enugu state, Nigeria. About one-and- half bags of the discarded seeds which gave a kernel mass of 5kg, were gathered. The N-hexane as a solvent extractor and Methanol (99.9% purity) as a reactant, used respectively for the extraction of the Mango seed oil and conversion of the oil to Biodiesel, the Phenolpthlein as indicator were sourced from a chemical store at Nsukka; Joechem Ventures Nigeria, 45 Enugu Road Nsukka, Enugu,Nigeria. The KOH catalyst for the conversion of the Extracted oil to Biodiesel was also purchased from the above address. Both the Soxhlet and Transestrification processes for the extraction of the Mango Seed Oil (MSO) and the Subsequent conversion to Biodiesel respectively were performed at the Department of Biochemistry Laboratory, university of Nigeria, Nsukka, Enugu State. Other materials included: Distillation tool, Burette, Conical flask, Glass column, Thermometer, Heater, Magnetic stirrer machine, Hammer (for breaking of the kernel), Roller mills (Grinder) and Decorticator.

2.2. Sample Preparation.

The manual process was used for the sample preparation. The shell of the seed was broken with hammer. The kernel was separated from the seed shell. The useful seed kernel which formed the feedstock (major raw material) was dried, in the sun for a period of one week: to reduce the moisture content of the kernel, from about 48% to 20%. After drying, the kernels were decorticated by hand. The broken kernel was further reduced in size by grinding, in a grinding machine and finally sieved to remove foreign material.

2.3. Apparatus for the engine bed test

The following apparatus were used: DC Source (12V), Hand-held Tachometer, Stopwatch, Thermometers, Rota meters, Torque-rated loads, Hydraulic-Dynamometer, and Air Consumption meter. The dynamometer water intake vane was opened so that the trickle of water stream was fed into the dynamometer to prevent damage to the bearing sealing of the dynamometer. The engine was then turned on. The throttle was slightly opened to start the engine. The throttle was slowly increased to the maximum speed, using hand-held tachometer to vary the speed. By adjusting the water vane on the dynamometer, the engine speed was made to attain a constant value. Readings of the torque and the pressure value in the manometer were taken. Readings were also taking from the dynamometer water inlet, exit temperature and head. Also, readings of engine cooling water inlet, exit and head were taking. The time taking for engine to consume a specific amount of fuel in the pipette ($50cm^3$) was recorded. The last three processes (5-8) were repeated for increasing values of speeds 120rpm, 140rpm, 160rpm, 180rpm and 200rpm. After each selected speed test, the exit and intake water vane were opened to return the engine to idle position.

2.4. Procedure for Oil Extraction.

The solvent extraction process was used for the oil extraction from the seed kernel. To use this method, the prepared sample was heated to soften it and finally fed into a glass column. The kernels were prepared to make it easy for the solvent to permeate the oil content. The prepared raw material was sprayed with N-hexane which dissolved the oil. The whole set-up was allowed to stand for a day to enable maximum oil yield from the feedstock. The oil extracted was heated to a temperature of 100^oC on a hot plate, to remove water and hexane. The dehydrated oil was thereafter drained out and separated from the mixture of the oil and hexane (solution) which formed at the bottom of the glass burette, by opening the tap gradually into a conical flask.

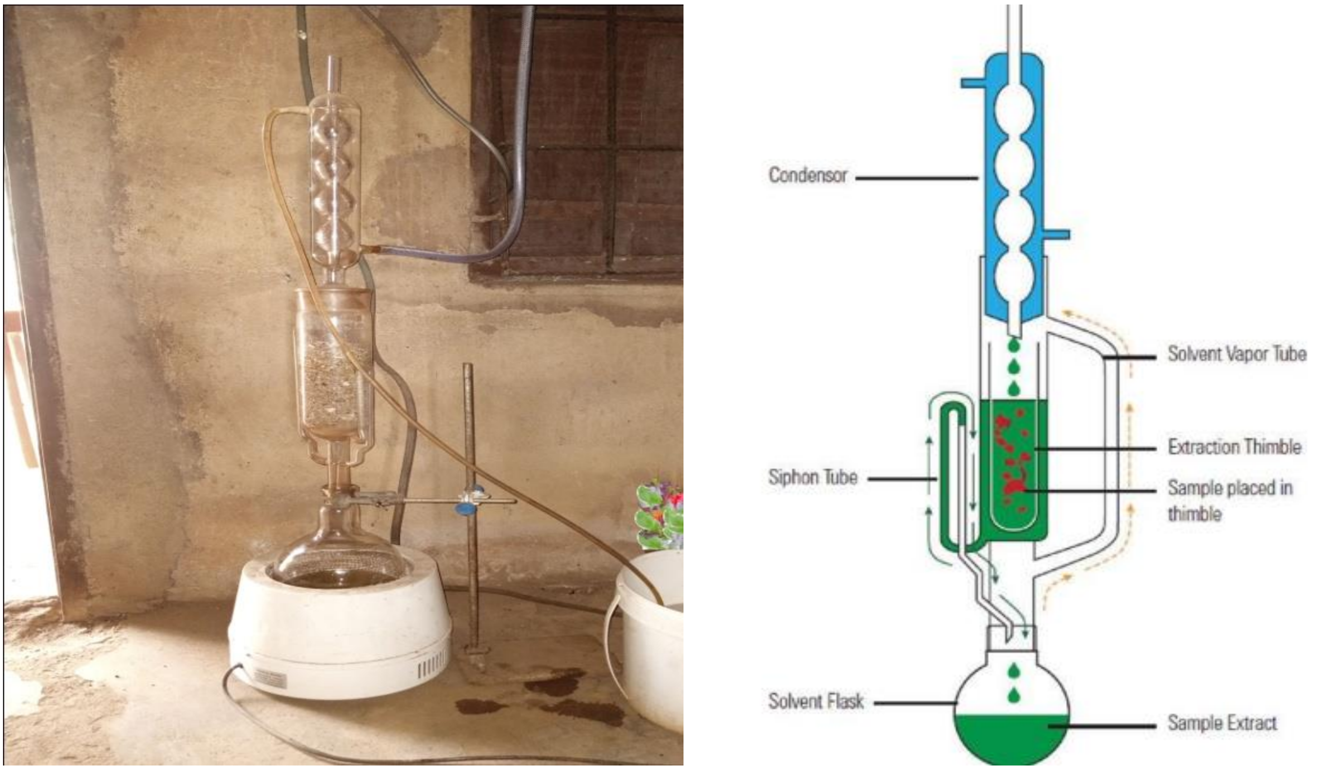

Figure 1: A Soxhlet Oil Extractor ([22])

2.6. Transesterification Procedure for Conversation of Mango Seed Oil into Biodiesel

In order to reduce the percentage of free Fatty acids in the extracted Mango seed oil and convert it into biodiesel, the extracted oil (MSO) was introduced into a 450ml conical flask which is equipped with mercury in glass thermometer and mounted on a magnetic stirrer machine hotplate which rotated at 250 rpm. 240ml of the oil was introduced into the conical flask and a measured quantity of methanol /KOH solution (60ml) which was heated separately to the reaction temperature, was then introduced into the conical flask, with the reaction maintained at 60^oC for one hour. After this agitation for an hour, the reaction product mixture was allowed to stand and settle for 24 hours, in a burette, with the upper light layer containing the Biodiesel and the denser glycerin layer at the bottom. The glycerin layer was tapped off, and thereafter, the Biodiesel, with the methanol recovered from the methanol-water mixture through distillation.

In order to purify the Biodiesel produced, Acetic acid was added to it, followed by warm water to remove impurities. The produced biodiesel which contained some sediment was, thereafter, filtered by passing it through filter paper, to remove the sediment. This filtration process is necessary in order to ensure efficient performance of the Biodiesel in CI engine and prolong the life of the injection system [4], [7].

Figure 2: (a) Mango seeds (b) Mango seeds processing (c) Grinded mango seeds (d) Burette setup for separation of biodiesel from glycerin

2.7. Experimental Precaution

Precautions were taken to ensure that the fuel (diesel) used for the experiment was free of particles. Rapid cooling of the hot engine was avoided. The engine was cooled by three working fluids. They are the diesel fuel, water, and lubricating oil. Error due to parallax was avoided while taking readings from the instrument including dynamometer. It was ensured that all the high-pressure pipes were also firmly tightened.

2.8. Determination of Moisture Content of Seed kernel

Mass of mango seed with moisture = 5kg.
Mass of Dried Sample Mango seed = 4kg
Mass of moisture content left = 1kg

$$\%\,moisture\ content\ = \frac{1}{5} * \frac{100}{1} = 20\% \qquad (1)$$

This 20% moisture content was further reduced to 10% by dehydration process with diluted $H_2\,SO_4aq$.

2.9. *Diesel Engine Performance Test with Conventional Diesel and MSO Biodiesel.*

The Aim of the Engine Bed Test was to determine the brake-power output, thermal efficiency, specific fuel consumption SFC, mass flow rate of fuel at varying speeds of a four-stroke, four-cylinder diesel engine. The four-cylinder diesel engine was loaded at variable engine speed of between 120-200 rpm.

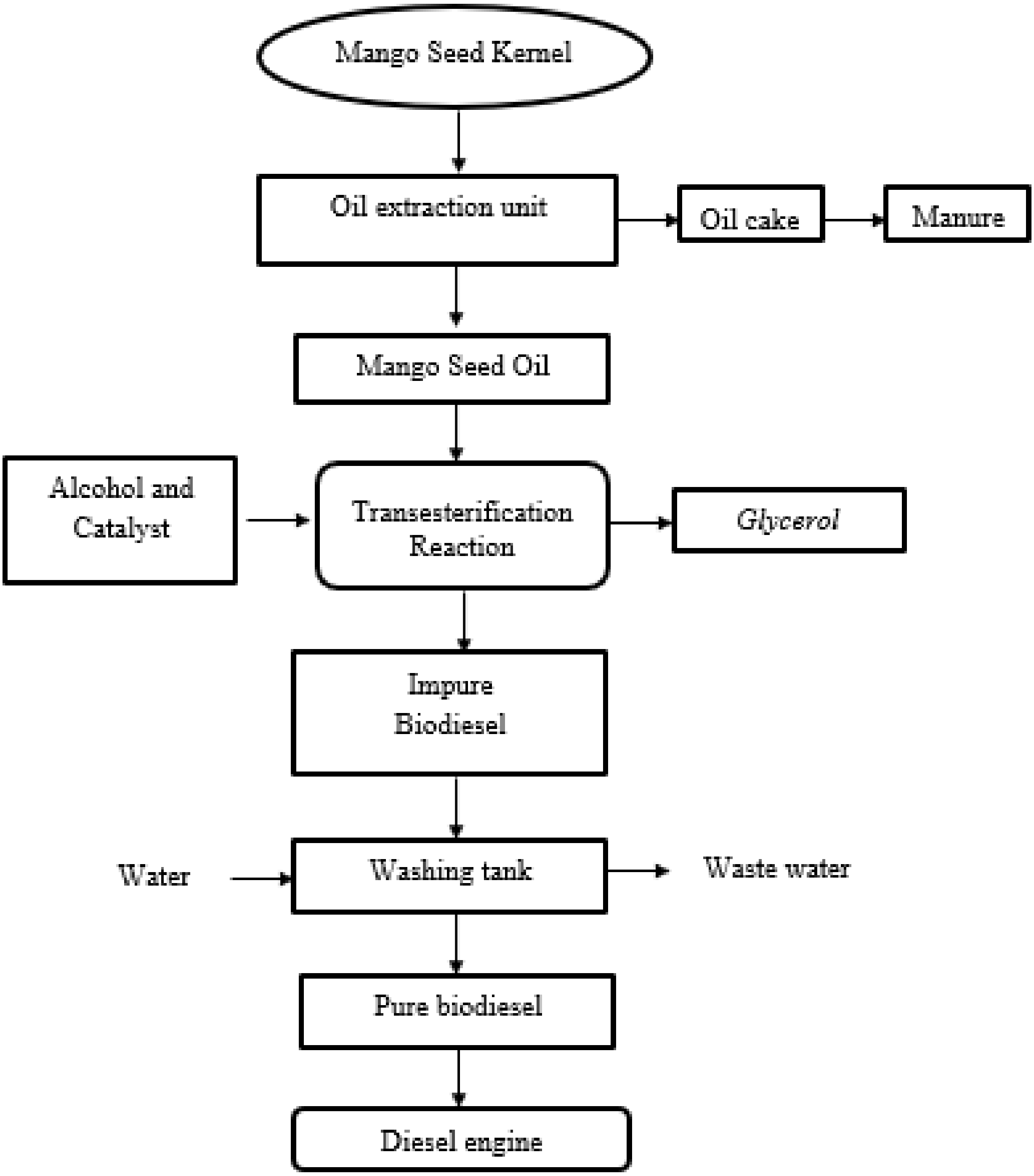

Figure 3: The MSO biodiesel Production flow chart

Table 1: Raw data for varying engine speed for Biodiesel

S/N	Speed rpm	Fuel Consumption			Manometer reading $h_w(mmH_2O)$	Oil pressure (N/m^2)	Oil Temp (ºC)	Exh Temp (ºC)	Dynamometer cooling water			Engine cooling water		
		Time (s)	Volume (cm^3)	Torque (Nm)					inlet Temp (ºC)	Ext. Temp (ºC)	head (cm)	inlet Temp (ºC)	Ext. Temp (ºC)	head (cm)
1	120	158	50	5.0	9	410	100	128	12	30	8.0	12	48	14
2	140	130	50	5.2	15	415	105	150	12	32	8.0	12	43	14
3	160	106	50	6.0	15	420	112	165	12	33	8.4	12	43	14
4	180	88	50	6.8	22	425	115	170	12	37	8.7	12	43	14
5	200	79	50	8.0	25	430	120	174	12	40	8.9	12	43	14

Table 2. Raw data for varying engine speed for conventional diesel

S/N	Speed rpm	Fuel Consumption			Manometer reading h_w (mmH_2O)	Oil pressure (N/m^2)	Oil Temp (°C)	Exh Temp (°C)	Dynamometer cooling water			Engine cooling water		
		Time (s)	Volume (cm^3)	Torque (Nm)					inlet Temp (°C)	Ext. Temp (°C)	head (cm)	inlet Temp (°C)	Ext. Temp (°C)	head (cm)
1	120	85	50	5	9	420	100	130	12	30	8	12	46	14
2	140	78	50	5.2	15	425	110	160	12	33	8.3	12	54	13
3	160	73	50	6	16	430	115	165	12	35	8.6	12	63	12
4	180	68.9	50	6.8	22	435	120	175	12	38	8.9	12	71	11
5	200	60.9	50	8	27	440	125	175	12	42	9	12	90	10

3.0 RESULTS AND DISCUSSION

3.1 Analysis of Mango Seed Oil

The extracted oil (MSO) was analyzed and characterized based on ASTM and EN14214 standards, with the results shown in Table 3.

The biodiesel was analyzed, and the obtained characteristics were compared with that of the Conventional diesel as shown in Table 4

Table 3: Physio-chemical Properties of Mango Seed oil.

Characterization	Result
Oil yield %	14
Saponification value (Mg/KO4/g)	194.72
Peroxide Value (Mg/ng)	0.60
Free Fatly Acid (Mg/KOH/g)	3.92
Specific cavity	0.875
Iodine value (g/100g oil)	39.9
Acid Value	7.84

Table 4: A Comparison between the Properties of Conventional / Petroleum Diesel and (MSO) Biodiesel.

S/N	FUEL PROSPERITIES	DIESEL	BIODIESEL
1	Density (kg/m^3)	835	875
2	Heating value (kJ/kg)	44200	38700
3	Kinematics Viscosity at 40^{O}c	2.75	3.5
4	Flash Point ^{O}C	65	125
5	Cetane Number	47-55	55
6	Pour Point ^{O}C	-20	-3
7	Cloud Point ^{O}C	-15	-13
8	Specific Gravity	0.835	0.875
9	PH Level	0.5	0.75
10	Water content	0.05	0.02

It is seen from Table 4 that the MSO Biodiesel has a Cetane number of 55, which is the optimal value for the Conventional Diesel, and this is in agreement with [5],[8] and [16]. The higher values observed for Density, Kinematic Viscosity, Flash Point, Specific Gravity and PH level for the Biodiesel are in agreement with the trends reported in [2],[4],[5],[7],[8] and [16].

The biodiesel also posted lower water content which is good for better performance of any diesel engine [4,5]. The observed deficiency in Pour Point of biodiesel of -3°C, as against the -20°C, recorded by the Conventional diesel agreed with the reports in [2],[4],[7] and [8].

This shows that, the utilization of the MSO Biodiesel in low-temperature conditions will be limited [4],[7]. However, this challenge with Biodiesel can be adjusted by proper blending with the Conventional diesel [4][13] as well as the use of some other off-the-shop additives [7]. In terms of cloud point, the difference of -2°C, between the values for conventional diesel and Biodiesel is small. Though, this agreed with other reported research in [2],[8],[16] and [17], that Biodiesel has a higher Cloud point. However, it is interesting to note here, that the cloud point of the MSO Biodiesel is only slightly higher than that of the Conventional diesel. Again, this can be corrected with proper blending [4, 7, and 13].

The Biodiesel from MSO reported an increase in Brake thermal efficiency of about 17.4% when compared with Conventional diesel. This can be seen in the lower values recorded in mass flow rate as well as in Biodiesel's specific fuel consumption (SFC). Tables 5 and 6 represented the data generated from the engine bed test.

Table 5: Calculated Data for Biodiesel, for Varying Engine Speed

S/N	Speed rpm	Fuel volume flow rate 10^{-6} m^3/s	Mass flow rate of fuel 10^{-4} kg/s	Brake power bp= TxN/9549.305	Brake thermal efficiency= $bp/m_f x Q_{net} x V\%$	SFC= $3600m_f/bd$ kg/kWh
1	120					
2	140	0.385	3.369	0.096	0.074	1.26
3	160	0.472	4.13	0.101	0.63	1.47
4	180	0.568	4.97	0.128	0.67	1.40
5	200	0.633	5.83	0.168	0.78	1.20

Table 6: Calculated Data for Conventional diesel, for Varying Engine Speed

S/N	Speed rpm	Fuel volume flow rate 10^{-6} m^3/s	Mass flow rate of fuel 10^{-4} kg/s	Brake power bp= TxN/9549.305	Brake thermal efficiency= $bp/m_f x Q_{net} x V\%$	SFC= $3600m_f/bd$ kg/kWh
1	120	0.588	5.145	0.063	0.29	28.1
2	140	0.641	5.609	0.096	0.40	21.1
3	160	0.685	6.00	0.101	0.40	21.4
4	180	0.726	6.35	0.128	0.47	17.1
5	200	0.821	7.18	0.168	0.55	15.0

From the data computed for both Petroleum or Conventional diesel and Biodiesel, and as can be observed from tables 5 and 6, and the graph plots in figures 4 and 5, it can be observed that as the speed increases, the torque also increases. The brake power for the two working fluids is the same, when subjected to the same torque at the same speed.

At low initial speed, the thermal efficiency of the biodiesel was lower than the thermal efficiency of Conventional diesel, and this agrees with [5,7,8 and 16] that Biodiesel experience's average peak power reduction of between 4-7%, compared to Conventional diesel.

However, as the engine speed and torque increased, the Brake thermal efficiency of the engine also increased, with the thermal efficiency of biodiesel being slightly higher (about 17.4%) than that for Conventional diesel at higher engine speeds, and this is in agreement with [21].

The specific fuel consumption (SFC) of the biodiesel was found to be lower than that of Conventional diesel; this can be attributed to the higher Brake thermal efficiency of the MSO Biodiesel and the fact that Biodiesels are always oxygenated, (by about 10-12%) [4],[7],[8] and [13]. Hence, the Biodiesel from Mango seed oil will enable good economic savings to the diesel engine operators, because of its Higher Brake thermal efficiency and lower mass flow rate and lower SFC, in addition to its eco-friendly behavior, which does not adversely compromise the environment in comparison to Conventional diesel.

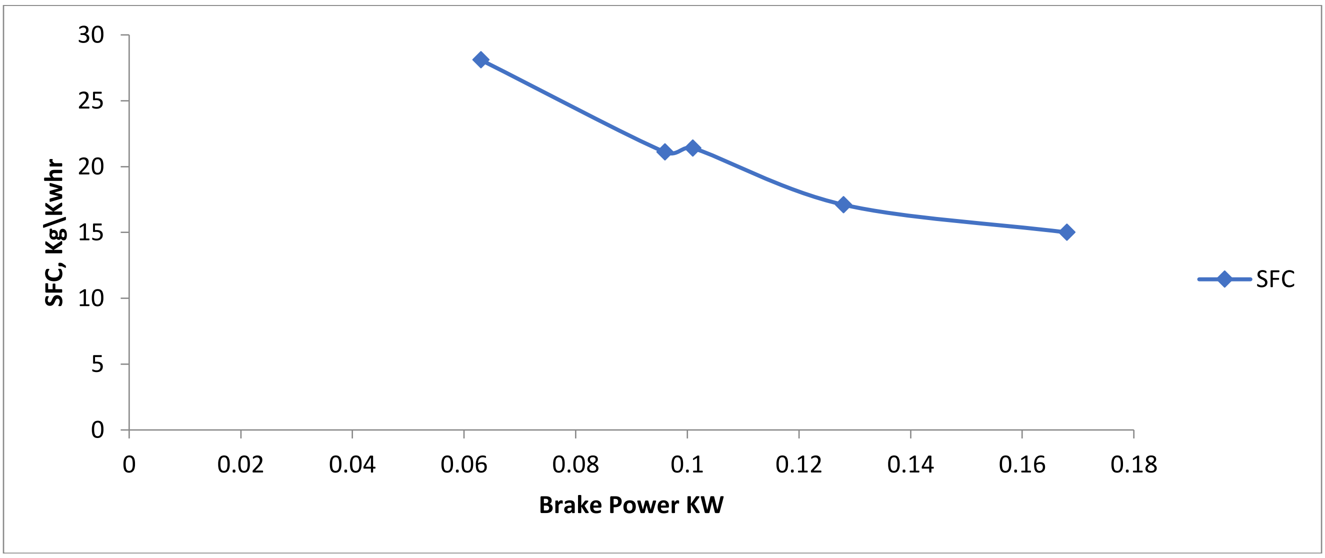

Figure 4: SFC against Brake power for Conventional diesel

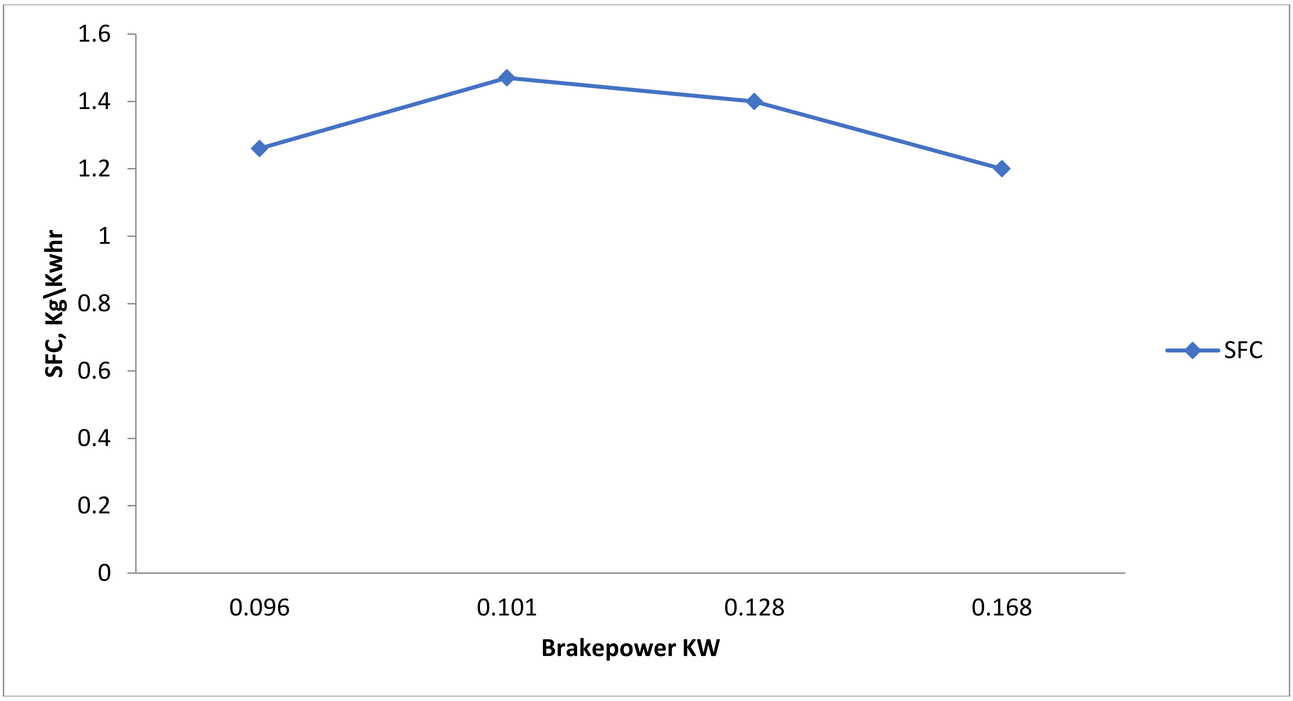

Figure 6: SFC against Brake power for Biodiesel diesel

4.0 CONCLUSION

In this research, neatly, extracted mango seed oil (MSO) was converted into biodiesel (methyl ester) through the alkali-catalyzed Transesterification process under standard conditions. The physio-chemical properties, which determine the quality behavior of Biodiesel when applied to a diesel engine, were characterized using ASTM-D6751 and EN-14214 standards. The Engine Performance Experiment was also carried out using the MSO Biodiesel. The experimental results of the test were compared with the results of a similar test conducted after flushing the fuel lines, with a Conventional or Petroleum diesel, from a standard fuel filling station in Nigeria. The set of experiments was repeated for each of the following diesel engine performance-indicating key parameters; Brake-power, Brake thermal efficiency, and Specific fuel consumption (SFC). The plots for the two working fluids showed that the SFC increased as brake-power increased.

The Biodiesel from MSO, when compared with Conventional diesel during the engine test indicated lower specific fuel consumption (SFC). And the Brake thermal efficiency of Biodiesel was found to be slightly higher (17.4%) than that of Conventional diesel at increased speeds, for various increasing load conditions, which is in agreement with [21].

Hence it is suitable for diesel engines and can be used as an alternative to the Conventional diesel, as an alternative source of energy with low running cost. The production of Biodiesel from mango seed, if properly supported by Governments across the globe, clean environment and green energy campaigners, will help solve the multiple problems of environmental pollution, rapid depletion of fossil energy, rising energy cost and unemployment; as many people would be engaged not only in growing the Mango crop, but also in the production and distribution of the Biodiesel products, either as pure fuel or as various blends, or even as fuel additives.

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