ENGINE PERFORMANCE BEHAVIOR OF WGOEE-DIESEL FUEL BLENDS IN COMPRESSION IGNITION ENGINE

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ABSTRACT

A 2.43 kW stationary compression ignition engine was tested on B5 (5% by volume of waste groundnut oil ethyl ester blended with 95% by volume of fossil diesel fuel), B10, B15, and B20 blended diesel fuel. A benchmark test was conducted on the test bed with 100% fossil diesel fuel (DF) to evaluate the engine performance in terms of brake power, brake mean effective pressure, specific fuel consumption and brake thermal efficiency at maximum engine speed. Engine performance tests were also conducted for B5, B10, B15, and B20 wasted groundnut oil ethyl ester (WGOEE) blended oil samples, and their observed engine performance behaviour was compared with the benchmark test results. The study showed that the engine exhaust temperature for B5, B10, B15, and B20 WGOEE blended oil samples are 5.0%, 6.0%, 16% and 40% higher than fossil DF. The brake power of B5 and B20 blended fuel samples are lower by 3.7% and 24.69%, while B10 and B15 sample produced similar result in brake power as fossil DF. The brake mean effective pressure (b.m.e.p) for B5and B20 blended fuel samples are 3.83 % and 24.61% lower in comparison to the tested fossil diesel fuel, while B10 and B15 blended fuel sample generated similar amount of b.m.e.p as fossil DF. Furthermore, B5 and B10 blended fuel samples exhibited 16.39% and 12.55% lower fuel consumption than fossil DF, whereas B15 and B20 fuel samples generated 19.98% and 14.66% higher specific fuel consumption than fossil DF. The dense and viscous nature of WGOEE in the fuel mixture slightly affects the atomization and spray efficiency of blended oil through injector nozzles, and consequently slows down the combustion process and lowers the brake power and thermal efficiency. This study in effect has revealed that by blending WGOEE with fossil DF at lower *proportions (i.e B5, B10, B15) produced somewhat equal amount of brake power, and slightly higher fuel economy for B5 and B10 blended fuel samples respectively.*

Keywords: waste groundnut oil ethyl ester, fossil diesel fuel, brake power, brake mean effective pressure, specific fuel consumption.

1.0 INTRODUCTION

In the last few years, biofuel have been viewed as a way of meeting the global rising energy demands, climate change and emission challenges by serving as an alternative to fossil fuel (Moore, 2008).

It may have been argued that the growing world's population, weather related issues and high cost of energy, transportation and fertilizers, and the over subsidizing of agricultural output in industrialized nations are largely responsible for scarcity of food and corresponding hike in price (Moore, 2008 and Holmes, 2008). However, in spite of its environmental advantages, cleaner combustion process and energy security potentials, the biofuel/biodiesel program sustained with edible agricultural feedstock no doubt contributes to the global food crises. Hence, the emerging food- energy debacle has aroused research interest in second generation biofuels produced from waste, and agricultural feedstock that are not competed for as food. Amongst these include waste vegetable oil, jatropha seed oil, straw, and algae.

Existing literature has shown that pure vegetable oil-diesel fuel blends produce remarkable results in fuel economy, brake power and minimal combustion chamber wear in compression ignition engines. Nonetheless, in longer term usage some engine durability problems such as clogging of fuel filter and injector tips are evident (Engelmann et al., 1978; Sims et.al 1981; Barsic and Humke, 1981; Worgetter, 1981; Sapaun et.al 1996; Ryan et.al 1984; and Peterson et. al., 1990). However, to surmount these challenges the transesterification of the wasted vegetable oil becomes essential (Al Widyan and Shyoukh, 2002, and Demirbas, A. 2003). It is on record that every year; many millions of tons of waste cooking oil are collected and used in a variety of ways throughout the world (Lele, 2005). These oils that nonetheless contain degradation products and foreign material are often disposed in manners that contaminate our soil and water. To this effect, the effective management and utilization of waste vegetable oil from the nation's thriving fast food and restaurant businesses would ensure a cleaner environment, serve as a veritable source of alternative fuel, and also reduce the nation's over-dependence on fossil fuel.

Furthermore, and in view of the fact that Nigeria's fossil driven economy is under severe pressure of exploitation, an energy transition from crude oil to renewable energy has no doubt become imperative (ECN,2005 and Alamu et. al., 2007). Hence, this paper reports the comparative engine performance analysis of various blends of transesterified wasted groundnut oil and diesel fuel with the aim of generating mechanical power for compression ignition engines, conserving the nation's fast depleting crude oil reserves, reduce environmental pollution, encourage greater energy diversification, and ultimately improve energy security in Nigeria and the world in general.

2.0 MATERIAL AND METHOD.

i. Experimental Materials

Wasted groundnut oil (WGO) is the major feed stock used in this work. The waste oil was collected in Yelwa market in Bauchi from small-scale commercial bean cake (*akara*) friers. The oil was heated to 49 °C (120 °F) to remove water and moisture, and allowed to cool. Unwanted solid particles in the oil was strained and sieved out with fine wire mesh. The reagents used for tranesterification of waste groundnut oil, include ethanol, isopropyl alcohol and alkaline catalyst sodium hydroxide (NaOH), distilled water. The ethanol used was manufactured by BDH Chemicals Limited, England and has a boiling point of 78.5°C, while the NAOH pellets were manufactured by PROLABO, France. The blender used was a dry and wet mill blender 462, product of Nakai, Japan. Other material used for the tranesterification process include; digital beam balance, PH meter, pipette, beakers, watch glass, measuring cylinder, translucent white plastic containers, separation funnels, 2-litre PET bottles, duct tape, thermometer and water bath respectively

ii. Production of Biodiesel

1g of Sodium Hydroxide (NaOH) was dissolved in 1000ml of water to form 1ml solution of NaOH.1ml of WGO was dissolved in 10ml isopropyl alcohol to form the WGO- alcohol solution.With a pipette, the diluted NaOH solution was dropped into WGO mixture a millilitre at a time. After each drop the PH level of the WGO solution was checked with standard litmus paper and an eventual rise in the PH level was observed. NaOH solution was continually added into the WGO solution, a drop at a time, until a PH level of 8-9 was reached (Anonymous, 2008)

200ml of ethanol was measured into a 500ml beaker and subsequently transferred into the blender. 5.5g of NaOH was weighed on a beam balance and introduced into the ethanol. The mixture was blended for 30 seconds until the NaOH dissolved completely to form sodium ethoxide (Lele, 2004; Belser and Hedlund, 2007).

1000ml of dewatered WGO was introduced into the sodium ethoxide solution in the blender and homogenized for 15 minutes. The mixture was then poured into a separation funnel and allowed to settle for about 7-8 hours for complete separation of glycerol from waste groundnut oil ethyl ester (WGOEE). The glycerol which is denser settles at the bottom of the funnel and is drained off leaving behind waste groundnut oil ethyl ester (WGOEE) as biodiesel.

iii. **Washing the Biodiesel**

To remove impurities from the biodiesel such as excess ethanol, soap, glycerin and catalyst, two 2-litre PET bottles were used in succession, with half- litre of tap water added for each of the four washes carried out. A small 2mm orifice was pieced in the bottom corner of each of the two bottles and covered securely with duct tape. The biodiesel was then poured into one of the wash bottles. Half –litre of fresh water was added and the cap screwed on tightly. The bottle was turned on its side and rolled about until oil and water were well mixed and homogenous. After washing and settling, the water was drained off from the bottom of the bottle by removing the duct tape sealing the orifice. The hole was blocked again when it reached the biodiesel. The biodiesel was transferred to the second wash bottle. The first wash bottle was then cleaned and the duct tape replaced. The process was repeated four times (Alamu et al. 2007; Belser and Hedlund, 2007).

iii. **Blending the Biodiesel**

25ml of WGOEE and 475ml of DF were measured with a 500ml measuring cylinder and poured into a 500ml beaker and stirred thoroughly to produce B5 WGOEE blended fuel (i.e. 5% by volume of waste groundnut oil ethyl ester blended with 95% diesel fuel). The mixture was allowed to settle for 4-6 hours for miscibility and homogenous consistency. The procedure was repeated for B10, B15, and B20 WGOEE blended fuel respectively.

iv. **Determination of fuel properties of Biodiesel and Diesel Fuel Samples**

Physical properties of WVOEE and DF were conducted in accordance with standardized ASTM test procedures and these include; ASTM D97-93, ASTM D2015-85, ASTM D 2500-91, ASTM D

97-93, ASTM D 93-94, ASTM D D613, ASTM D 445 for density , higher heating value, cloud point, pour point, flash point, cetane number and kinematic viscosity respectively (ASTM, 1993). These fuel properties are presented in Table 1.

v. Engine performance Test.

A 3.26h.p single cylinder four stroke 165 F compression ignition engine incorporated with a 1.25kVA Honda E 1500 A.C dynamometer with technical specification presented in Table 2 and 3 respectively, was used to conduct the performance test. The engine performance characteristics was monitored within the speed range of 1400rpm and 2600rpm, and varied incrementally by 400 rpm at every two hourly interval. A control test was carried out on DF for an experimental period of 8 hours. Similar test procedure was repeated for B5, B19, B15 and B20 WGOEE-DF fuel samples. Engine performance parameters such as brake power, brake mean effective pressure; specific fuel consumption and exhaust temperature were monitored from displacement of torque arm, fuel flow meter, and exhaust thermometer respectively. The summary of engine performance results are presented in Table 4.

3.0 RESULTS AND DISCUSSION.

From table 4, it could be seen that at maximum engine power, the exhaust engine temperature of B5, B10, B15, and B20 WGOEE –DF fuel samples are 5.0%, 6.0%, 16% and 40% higher than fossil DF. The brake power of B5and B20 WGOEE-DF blended fuel are lower by 3.7% and 24.69%, while B10 and B15 produced similar amount of brake power as fossil DF respectively as shown in figure 1. It could be seen from figure 2 that the brake mean effective pressure (b.m.e.p) increases with engine speed, it was however observed that at

Table 1: Fuel properties of WGOEE and Fossil Diesel

Characteristics	WGOEE	DIESEL
Specific Gravity at 35°C	0.882	0.820
Viscosity m. Pa at 20°C	5.7	3.3
Lower heating value kg/wt	34	42
Flash Point (°C)	110	65
Pour Point (°C)	2	-23
Cetane number	65	48
Water content (% vol)	0.09	0.05
PH test	Slightly alkaline	-
Flame and Odour test	+ve	-

Table 2: Technical specification of engine test rig

Model	165 F
Type	Horizontal single cylinder four stroke, air-cooled
Bore * Stroke	65 mm x 70 mm
Rated output	2.43 kW (3.26 h.p)
Rated speed	2600rpm
S.F.C at rated output	<284.2 g/kW-hr
Method of cooling	Air cooling by blower
Lubrication method	Centrifugal lubrication, combined oil mist and splash
Starting method	Manual cranking
Compression ratio	20.5:1
Net weight	40kg
Dimensions	518mm*321mm*428mm
Manufacturer	Ningbo Tri-circle Power Machinery Co. Ltd. China

Table 3: Dynamometric specification

Type	HONDA Model E 1500
Maximum operating capacity A.C	220V, 50Hz, Single phase
Maximum operating capacity D.C	12V, 8.3A
Maximum speed	4000rpm
Torque arm radius	130mm
Manufacturer	Honda motor, Tokyo, Japan

Table 4: Performance characteristics of Diesel and WGOEE-Diesel blended fuel at 2600 rpm

Performance Characteristics	Manufacturer's Specification	Diesel	WGOEE-Diesel blends			
			B5	B10	B15	B20
Exhaust temperature. (^oC)	-	100	105	106	116	140
Torque (Nm)	-	8.93	8.59	8.93	8.93	6.73
Brake power (kW)	2.43	2.43	2.34	2.43	2.43	1.83
Brake mean effective pressure (kN/m^2)	-	45.71	43.96	45.71	45.71	34.46
Specific fuel consumption (g/kW-h)	< 284.2	82.86	69.28	72.46	99.42	95.01
Brake thermal efficiency (%)	-	28.73	37.98	36.34	26.47	27.69
Air fuel ratio.	-	14.51	12.89	11.86	8.64	14.39
Heat loss in exhaust (kJ)	-	203.15	157.53	160.78	188.75	281.4

maximum speed for B5and B20 WGOEE –DF fuel samples are lower by 3.83 % and 24.61% lower in comparison to the tested fossil DF sample. While, B10 and B15 blended fuel sample generate similar amount of b.m.e.p as fossil DF.

Furthermore, the specific fuel consumption pattern is illustrated in figure 3.It was observed that B5 and B10 WGOEE –DF blends exhibited 16.39% and 12.55% lower fuel consumption than fossil DF. While, B15 and B20 fuel samples demonstrated higher fuel consumption patterns over fossil DF by 19.98% and 14.66% respectively. According to Masjuki and Maleque (1996), this phenomenon could be attributed to the higher specific gravity, higher viscosity and lower heating values of biodiesel in the fuel mixture; even though the higher viscosity of WGOEE is advantageous over fossil diesel in terms of injection system lubrication in compression ignition engines (Sabeena et.al. 2004). It could also be seen from figure 4 and table 5 that WGOEE-DF blends reveal lower brake thermal efficiency than fossil DF. This could be attributed to the lower heating value and combustion temperature of WGOEE-DF blended fuel (Singh et al, 2007). Notwithstanding its high cetane number (as shown in table 1), the dense and viscous nature of WGOEE in the fuel mixture slightly affects the atomization and/or spray performance of the injector system in compression ignition engines, and this slows down the combustion process and lowers the brake thermal efficiency and brake power respectively (Sethl and Salariya, 2004; Pathak, 2004; and Singh et.al. 2007). In addition, the lower heating value of WGOEE in the fuel mixture explains the

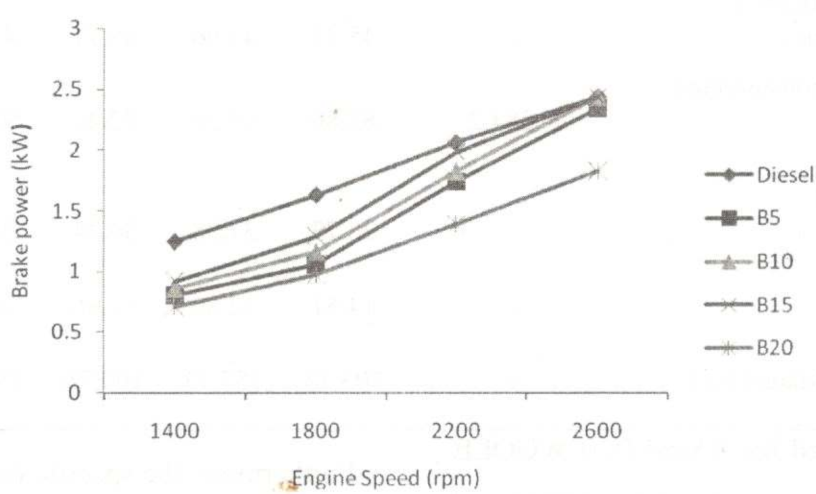

Figure 1: Effect of WGOEE-DF blend on Brake power

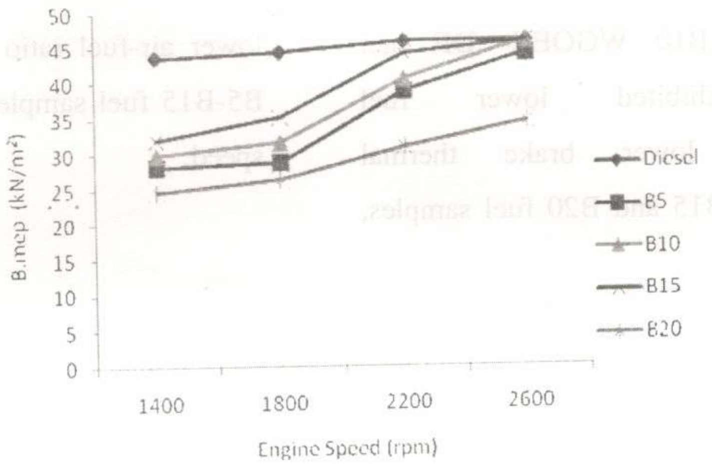

Figure 2: Effect of WGOEE-DF blend on Bmep

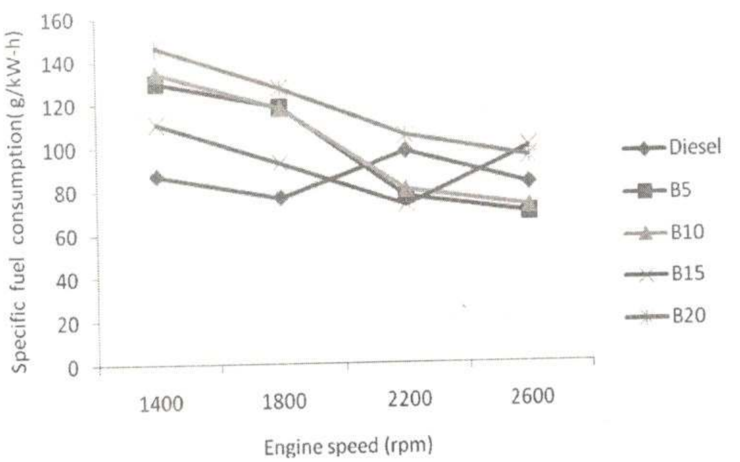

Figure 3: Effect of WGOEE-DF blend on Specific fuel consumption

drop in heat loss in exhaust, while the higher combustion temperature of WGOEE is responsible for the higher exhaust temperature of WGOEE-DF blend. This was achieved as the richer air fuel mixture of WGOEE-DF blends was burnt.

4.0 CONCLUSION

The following conclusion could be drawn from this study;

i. The exhaust temperature of WGOEE-DF fuel mixture is higher in comparison to fossil DF.

ii. The brake power of engine run on WGOEE-DF fuel mixture B5, B10, and B15 are comparable with fossil DF

iii. Brake mean effective pressures of WGOEE-DF fuel samples are lower than fossil DF.

iv. B5and B10 WGOEE- DF fuel mixtures exhibited lower fuel consumption, lower brake thermal efficiency for B15 and B20 fuel samples, lower air-fuel ratio and heat exhaust for B5-B15 fuel samples at maximum engine speed.

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