ISSN: 2449 – 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.14 NO.2, pp 51-58, AUGUST, 2019

EMISSION CHARACTERISTICS OF JATROPHA BIODIESEL - KEROSENE BLENDS USED AS FUEL IN A PRESSURIZED COOKING STOVE

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ABSTRACT

The combustion of kerosene in cooking stoves increases the risk of certain life-threatening health conditions such as cancer; respiratory infections like asthma, tuberculosis (TB) and sight defects like cataract when used indoors. The emission characteristics of jatropha biodiesel- kerosene blends were investigated to ascertain their potential as substitute for kerosene in a pressurized kerosene cooking stove. The assessments were done by comparing some of the emission characteristics of the blends of jatropha biodiesel with kerosene. The blends were categorized as B100 (100% biodiesel), BK20 (20% jatropha biodiesel and 80% kerosene), BK15 (15% jatropha biodiesel and 85% kerosene), BK10 (10% jatropha biodiesel and 90% kerosene), BK05 (5% jatropha biodiesel and 95% kerosene) and BK0 (pure kerosene). The emissions were determined using gas analyzer (NHA-506EN model). The emissions determined were CO, CO_2, SO_2, NOx and HC at various vessel pressures of 0.2, 0.4, 0.6, 0.8 and 1bar for all the fuel blends. The emission results revealed that BK20 blend at 0.6 bar has the least emission of harmful gases of CO=0.02%, CO_2=2.09%, SO_2=0.41%, NOx=5.0ppm and HC =31ppm blend. It is recommended to use BK20 fuel blend as an alternative fuel for kerosene in the pressurized kerosene cooking stove.

Keywords: pressurized stove, kerosene, jatropha biodiesel and gas analyzer.

1.0 INTRODUTION

Kerosene is a light petroleum distillate that is used as fuel in water heaters and cook stoves which is especially suitable for use as a light source when burned in wick lamps. Kerosene is one of the fastest selling petroleum products in Nigeria. It is used extensively in both rural and urban areas for domestic purposes such as cooking, lighting and burning refuse. Prior to the invention of electricity, kerosene happened to be the main way of heating and lighting in the world (Kathleen and Elizabeth, 2008). The kerosene stood out as the most important refinery product until gas grew in popularity and availability in the 1920s. In Nigeria, the affordability and availability of kerosene play important roles in the choice of either cooking gas, charcoal or firewood in cooking. But the use of kerosene as a fuel in cooking stoves increases the risk of several life-threatening health conditions such as cancer; respiratory infections like asthma and tuberculosis (TB) and sight defects like cataract when used indoors (Lam et al., 2012). Kathleen and Elizabeth (2008) reported that, the direct effect of gases emitted from cooking stoves in households may cause asthma. The disgusting odour from cooking stoves may impair human health and pollute natural environment with consequences, such as greenhouse effect enhancement, ozone layer destruction and acid rain production (Lin and Pan 2001). This evidence does not support kerosene as a clean fuel in cooking stoves. Thus, these attractive characteristics motivated this study of the blends of biodiesel with kerosene as a cleaner fuel over kerosene in pressurized kerosene stoves. The proposed biodiesel that would be used for this study is Jatropha biodiesel.

Biodiesel (mono- alkyl ester of long chain fatty acid) is a promising alternative or extender to conventional petroleum based diesel fuel. Biodiesel is a clean, renewable burning fuel. In recent years, biodiesel has gained international attention as a source of alternative fuel due to characteristics like high degradability, no toxicity, low emission of carbon monoxide, particulate matter and unburned hydrocarbons Vicente et al., (1998) and Alzuhair (2007). Biodiesel has also the following advantages- it is derived from a renewable domestic resource (vegetable oil), reduces carbon dioxide emission by 78% when compared with diesel fuel on a life cycle basis, and is biodegradable, making it a more environmentally friendly fuel (Tyson, 2001).

Jatropha curcas linnaeus is a multipurpose plant which contains a high amount of oil in its seeds, which can be converted to biodiesel. *Jatropha Curcas* is reported as the most highly promoted oil seed crop at present in the world (Gubitz et al., 1999). The seed of this plant contains 30 – 40% of oil that can be easily processed (trans esterification) and refined to produce biodiesel (Gubitz et al., 1999, Akintayo 2004, Mahanta 2008). The vegetable oil cannot be used directly in the cooking stove due to its high viscosity, high density and low calorific value. So it needs to be converted into biodiesel or blended with a petroleum product like kerosene to make it consistent with fuel properties of kerosene Babu and Devaradjane (2003). The use of pure vegetable oils as fuels in cooking stoves causes some problems such as poor fuel atomization, low volatility due to their high viscosity and high density (Nagaraju and Gopal 2013). Ajide and Abu (2012) in their study of biodiesel as alternative energy resource reported that, the use of alternative fuel sources such as biodiesel can make a significant reduction in certain exhaust emissions, thus reducing air pollution.

Biofuels are liquid fuels that have been derived from other materials such as waste plant and animal matter. The two types of biofuels currently in production are bioethanol and biodiesel. Bioethanol is used as a replacement for petrol and biodiesel is used as replacement for diesel. Biofuel represents an immense growth opportunity round the world and have an important role to play in displacing the fossil fuels, the world has relied upon offering a cleaner, renewable alternative. The environmental benefits of biofuel use have been widely documented (Parawira, 2010). The reduction in greenhouse gas emissions resulting from the use of biofuels and biofuel blends is closely aligned with Government's "Direct Action" approach to climate change. Biodiesel has the potential to reduce emission by over 85% in comparison to diesel while ethanol can reduce emissions by approximately 50% (Parawira, 2010). Nigeria is a net importer of vegetable oils; edible oils cannot be used for the production of biodiesel. Nigeria has the potential to be a leading world producer of biodiesel, as biodiesel can be harvested and sourced from non-edible oils like Jatropha curcus, Pongamia Pinnata, Neem, Mahua, Castor, Linseed etc. Nigeria is focusing on Jatropha Curcas and pongamia pinnata, which can grow in arid and wasteland. Oil content in Jatropha and Pongamia seed is around 30-40%. Nigeria has millions of hectares of wasteland which can be used for massive production of Jatropha (Parawira, 2010).

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used in this study includes;

i. Pressurized kerosene cooking stove: The pressure stove consists of a fuel tank of 2 liter capacity, a burner assembly, jet, air screw, spirit cup which was located just below the burner (Emel model).
ii. Kerosene fuel: The kerosene used in the various tests reported in this work was obtained from an NNPC filling station in Kaduna State.
iii. Jatropha biodiesel: the Jatropha biodiesel was obtained from National Research Institute for Chemical Technology (NARICT), Zaria, Kaduna State.
iv. Gas Analyzer (NHA-506EN model): It is used for analyzing gases such as CO, CO_2, NOx, SO_2 and HC emanating from the pressurized kerosene stove.

The test liquid sample was the blends of jatropha biodiesel with kerosene. The blends was categorized as in Table 1. below

Table 1.Samples of experimental liquid blends used

Blend Code	Percentage of the blends
BK0	Pure kerosene
BK05	5% jatropha biodiesel and 95% kerosene
BK10	10% jatropha biodiesl and 90% kerosene
BK15	15% jatropha biodiesel and 85% kerosene
BK20	20% jatropha biodiesel and 80% kerosene
BK100	100% jatropha biodiesel

2.2 Determination of Effect of Pressure and Biodiesel Variations on the Emission Characteristics

The materials used for the above mentioned experiment were listed and described in 2.1 above.

Experimental Procedure:

The emission characteristics of the fuel blends were determined by the use of an instrument called gas analyzer. The emission characteristics determined by the gas analyzer incudes: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NOx), sulphur dioxide (SO_2) and hydrocarbon (HC). The gas analyzer was used for determining the exhaust emission that was emitted from the pressurized cooking stove for the various blends operated under varied vessel pressure. The probe of the gas analyzer was positioned to intercept the combustion emission from the pressurized stove (i.e at the exhaust). The readings for the various blends operated under varied vessel pressure were recorded. As such the products of the combustion were analyzed and their environmental impacts were investigated while measuring the level of emission. This procedure was repeated for all the fuel blends.

3.0 RESULTS AND DISCUSSION

3.1 Results

The result of emission gas emanating from the jatropha biodiesel blended with kerosene are shown on the figures below.

Figure 1 below shows the variation of hydrocarbon emissions versus pressure for the fuel blends.

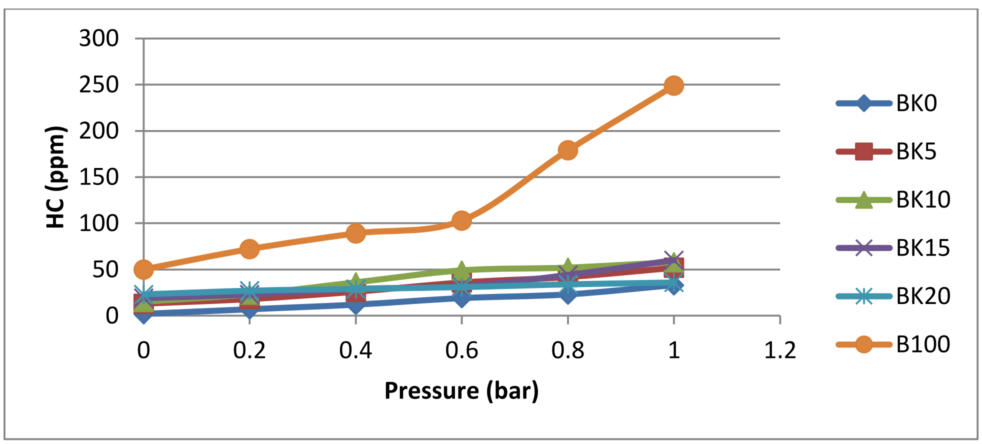

Figure 1: Relationship between Hydrocarbon emissions and Pressure

Figure 2 below depicts the variation of Carbon monoxide emissions with pressure for all the fuel blends.

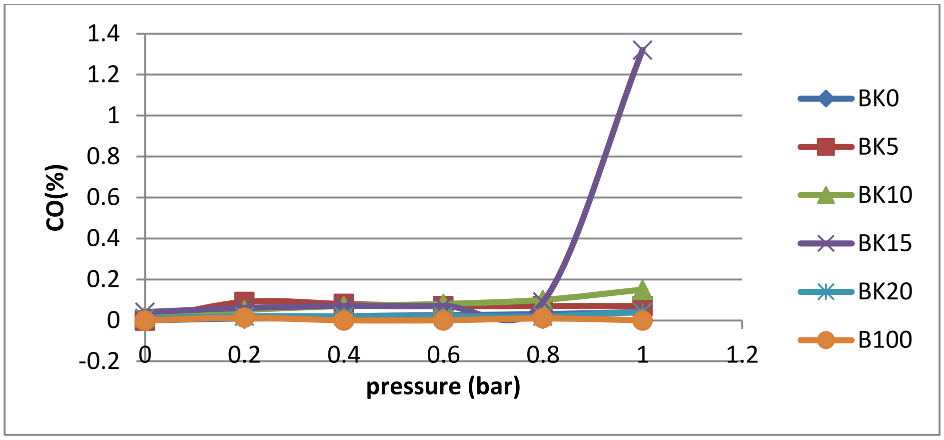

Figure 2: Relationship between carbon monoxide emissions and pressure

Figure 3 below presents the variation of Carbon dioxide emissions with pressure for the five fuel blends.

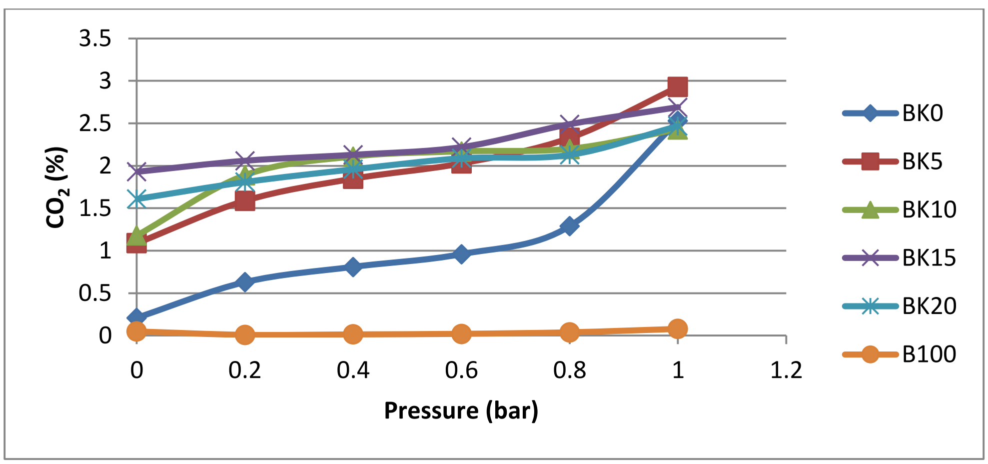

Figure 3: Relationship between carbon dioxide emissions and pressure.

Figure 4 below illustrates the variation of Sulphur dioxide emissions with pressure for the fuel blends

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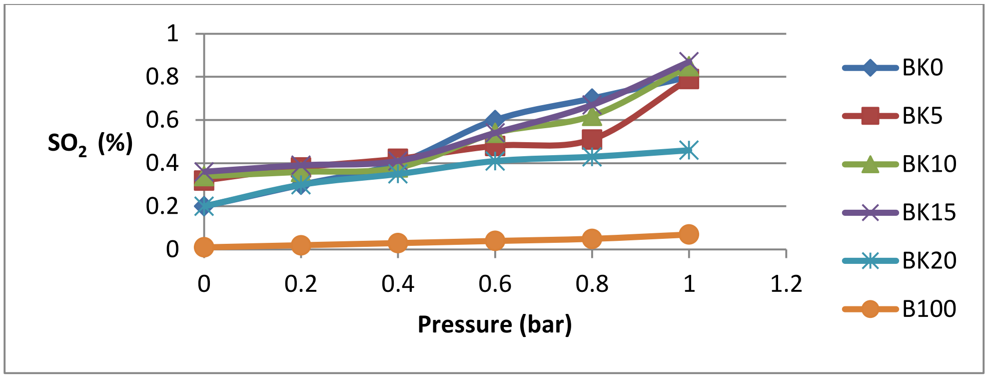

Fig 4: Relationship between sulphur dioxide emissions and pressure

Figure 5 below demonstrates the variation of Nitrogen dioxide emissions with pressure for the fuel

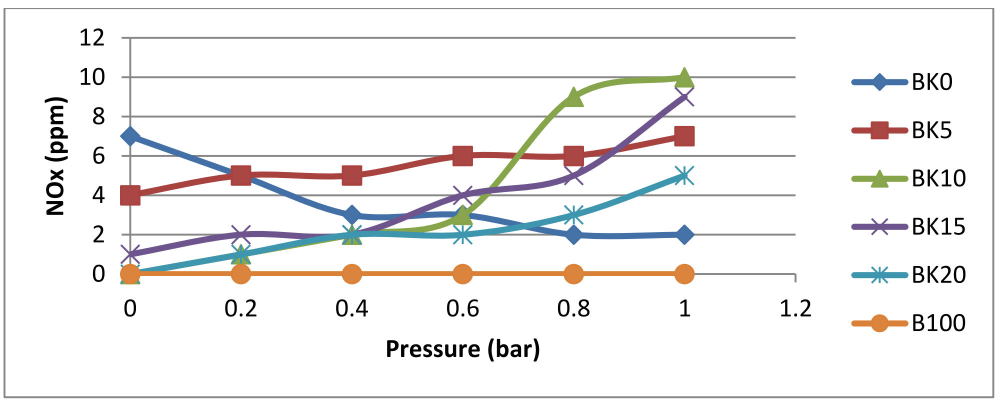

Fig 5: Relationship between nitrogen oxide emissions and pressure

3.2 Discussion of Results

Carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), sulphur dioxide (SO_2) and nitrogen oxide (NOx) are considered to be the major exhaust emission from the pressurized stove. It could be seen from figures 1 to 5 that, as vessel pressure increased emission properties also increases with the exception of Nitrogen oxide. From the above mentioned emissions, NOx and SO_2 are the most significant emissions from a kerosene stove that has to be controlled efficiently due to higher flame temperature and diffusive combustion during the combustion process.

The oxides of nitrogen in the exhaust emission are a combination of nitrogen oxide (NO) and nitrogen dioxide (NO_2). The formation of NOx is highly dependent on the flame temperature and oxygen concentration in the fuel tank. Oxides of nitrogen are mostly created from the nitrogen in the air and in fuel blends. In addition to nitrogen atoms, the fuel may contain ammonia (NH_3) and hydrogen cyanide (HCN), which would contribute to minor degree in the NOx formation. This reduced NOx emission for biodiesel when compared to kerosene may be due to reduced premixed combustion rate leading to lower NOx emission for Jatropha biodiesel. Moreover, Jatropha biodiesel fuel had exhibited high viscosity during tests in comparison to kerosene fuel, which primarily resulted in a lower amount of air entrainment and to poorer combustion leading to lower combustion temperatures. Measuring emission of gases like CO, CO_2, NOx and unburnt hydrocarbon is of utmost importance. The results obtained for kerosene fuel at high pressure of 1.0bar the CO emission was found to be 0.04%, CO_2 = 2.53%, NOx = 2ppm, SO_2 = 0.8% and hydrocarbon = 33ppm. The vessel pressure increases as the emission properties increases. For the BK20 blend at a pressure of 0.6 bar emitted less emissions of CO_2= 2.09%, CO=0.02%, SO_2= 0.41%, NOx= 5ppm and Hydrocarbon = 31ppm. The harmful gases CO, SO_2 are higher in conventional kerosene compared to the BK20 blend. These indicate that, the harmful gases are higher in kerosene fuel than BK20 fuel blend among all the fuel blends. The results is similar to that of Ejilah et al. (2013). This result showed that higher percentage of Jatropha biodiesel content in kerosene fuel reduces the emission of harmful gases. This may be due to high viscosity and density of the Jatropha biodiesel-kerosene blends that lead to poor vaporization and slow combustion of the fuel. The B100 (i.e 100% Jatropha biodiesel) was found poor in terms of performance due to incomplete combustion

4.CONCLUSION

This research investigated the emission characteristics of jatropha biodiesel – kerosene blends used as fuel in a pressurized cooking stove. Carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), sulphur dioxide (SO_2) and nitrogen oxide (NOx) are considered to be the major exhaust emission from the pressurized stove. It could be seen from figures 1 to 5 that, as vessel pressure increased emission properties also increases with the exception of Nitrogen oxide.

The emission characteristics of the fuel blends showed that, as the vessel pressure increases the emissions also increase in terms of CO_2, SO_2 and CO. There was a little decrease in the emission of the BK20 blend. Finally, among the blends, BK20 (i.e 20% Jatropha biodiesel and 80% kerosene) was found to be the best blend that can perform on the pressurized stove with less emission of greenhouse gases such as CO, SO_2, NOx and unburned Hydrocarbons as compared to that of kerosene. The B100 (i.e 100% biodiesel) has poor performance on the pressurized kerosene stove, because there was incomplete combustion. In addition, fuel blends with lower percentage of biodiesel would exhibit better combustion properties.

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