INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 2, Issue 2, 2011 pp.331-336
Journal homepage: www.IJEE.IEEFoundation.org

First performance assessment of blends of jatropha, palm oil and soya bean biodiesel with kerosene as fuel for domestic purposes in rural-Ghana

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Abstract
Performance assessments of jatropha, palm oil and soya bean based biodiesel were carried out to investigate their potential use as conventional substitute for kerosene for domestic purposes in rural-Ghana. The assessments were done by comparing some of the combustion characteristics of blends of the biodiesel with kerosene. The blends were categorised as B100 (100% biodiesel), B80 (80% biodiesel and 20% kerosene), B60 (60% biodiesel and 40% kerosene), B40 (40% biodiesel and 60% kerosene), B20 (20% biodiesel and 80% kerosene) and B0 (pure kerosene). The results showed that the calorific values of the B100s were less than that of the B0 and decreasing in the order of jatropha, soya bean and palm oil. The wick wastage results for both the B100s and B0, revealed higher rates in the WTL than the BB even though the BB recorded low fuel consumption rates than the WTL for both B100s and B0. Similarly, the luminous intensity test with the B100s showed low values in WTL than the BB in a decreasing order of jatropha, soya bean and palm oil. However, B0 recorded higher luminous intensity values that were quite comparable in both WTL and BB.

Keywords: Biofuel, Energy assessment, Jatropha, Palm oil, Soya bean.

1. Introduction
In Sub-Saharan Africa, a large percentage of the population, about 500 million people do not have electricity in their homes and rely on the unsustainable forms of solid biomass (fire wood, agricultural residues, animal waste etc) [1]. For instance in Kenya reports suggest that the main fuel wood sources for such communities were farmlands trees, indigenous forests, woodlands and timber off-cuts from plantations. In 1997, about 15.4 million tons of firewood (air-dried) was consumed and an equivalent of 17.1 million tons round wood wet weight (w/w) was converted to charcoal [2]. Babanyara and Saleh indicated that the reasons for the loss of 35.7% or around 6,145, 000 hectares of Nigeria's forest covers between 2000 and 2005 were due to rural-urban migration, urbanization, poverty, hikes on prices of kerosene and cooking gas amongst others [3]. Furthermore, it is estimated that 90% of household energy demand in Chad is wood and charcoal [4].
In Ghana, it has been reported that the gross national wood fuel consumption is at 18 million tons per annum with about 90% obtained directly from the natural forest [5]. It has also been revealed that about 56.25% of the national population resides in the rural areas and about 50.1% of the total number of Ghanaian households uses kerosene as their main source of fuel for lighting and cooking [6]. With the

recent increase in the prices of crude oil coupled with the projected increment in Ghana's petroleum fuel consumption from 1.6 million tons in 2000 to 4.5 million tons in 2020, it has become imperative that Ghana as a developing economy reduces her over reliance on crude oil and petroleum product [7].

Lighting in most rural-Ghana is generally provided by the wick-type lantern (WTL) and most especially the traditional prototype called "bobo" (BB) while candles and flashlights are used intermittently as portable sources of light. However, some reports e.g. [8] on biodiesel as fuel for domestic use suggest that pure jatropha biodiesel alone cannot sustain combustion in the WTL and BB. Nevertheless, lower percentage by volume of jatropha biodiesel in the fuel blends (i.e. jatropha and kerosene) resulted in high calorific values, high luminous output, high wick burning as well as high fuel consumption rates. This suggested that blends with lower percentage of jatropha would exhibit better combustion properties.

It is reported that the government of Ghana spent as much as 20-30% of its export earnings to import crude oil and petroleum products [9]. These huge economic implications associated with the over dependence of fossil fuel and its products have necessitated the switch from the use of fossil fuels to fuels derived from renewable sources.

Currently, the government of Ghana and some Ghanaian based private organisations (e.g. Jatropha Ghana Ltd, Galten Global Alternative Energy and ScanFuel) have made efforts to develop alternative sources of fuel preferably biodiesel, from jatropha curcas, soya bean, palm oil etc. [7]. These laudable initiatives have the potential to serve as alternative fuel in running diesel powered grain mills in rural and remote areas. In addition, it is hoped that this can reduce the foreign exchange used on the importation of crude oil and its products since most of the raw materials needed for the production of the biodiesel can be grown locally. It has been estimated that about 55% of Ghana's agricultural lands, representing about 13.6 million hectares are underutilised. Hence, there are enough virgin agricultural lands available to grow the raw materials needed for making the biodiesel [8]. Nonetheless, not many research works have been conducted in the combustion characteristics of biodiesels as fuel for domestic use. Most researches have rather been conducted in the areas of combustion performance and emission characteristics in automobile engines e.g. [10, 11].

The goal of this study is to compare the performance of blends of three biodiesel types (jatropha, palm oil and soya bean) with kerosene as fuel in the WTL and BB, and investigate the process of their potential use as a conventional substitute of kerosene for domestic purposes. The assessments carried out in this study included: viscosity, luminous outputs, calorific values, fuel consumption rates and the wick wastage rates.

2. Material and methods

2.1 Materials

The materials used for the experiments included the bomb calorimeter, the BB and WTL, ammeter, the Redwood No.1 Viscometer and photocells. The test liquid samples were blends of jatropha, soya bean or palm oil biodiesel with kerosene. The blends were categorised as in Table 1.

Table 1. Samples of experimental liquid blends used

B0	B20	B40	B60	B80	B100
100% kerosene	20% biodiesel 80% kerosene	40% biodiesel 60% kerosene	60% biodiesel 40% kerosene	80% biodiesel 20% kerosene	100% biodiesel

2.2 Determination of viscosity and calorific values of the test liquids (fuel blends)

The Redwood No. 1 viscometer and the bomb calorimeter were employed in the determination of the fluid viscosities and the calorific values of the test liquids respectively. The calorific values were calculated using the method described in McConkey, [12] as shown in equation (1).

$$W_f \times Q = (W_w + W_a) \times \Delta T \times 4.2 \qquad (1)$$

where W_f is the mass of fuel blend (kg), W_w is the mass of water in the calorimeter (kg), ΔT is the temperature change of water (^oC), W_a is the water equivalent of the "bomb calorimeter" i.e. the amount of water that would absorbed the same amount of heat as the calorimeter per degree temperature increase (kg), Q is the calorific value (kJ/kg) and 4.2 the specific heat capacity of water (kJ/^oC).

2.3 Determination of luminous output, wick wastage rate and the fuel consumption rate values of the test liquids

The luminous output of the test liquids used in the WTL and BB, were determined in a dark room with photocells. The difference in lengths of the wick before and after burning for 3 hours was used to determine the wick wastage rate. The fuel consumption rate, M_f (g/h) was calculated by:

$$M_f = \frac{(M_2 - M_1) - (M_3 - M_1)}{3} \quad (2)$$

where M_1 is the mass of empty WTL or BB (g), M_2 is the mass of WTL or BB plus fuel (g) and M_3, the mass of WTL or BB plus fuel after 3 hours burning period (g).

The fuel consumption and wick wastage rates in the WTL and BB were determined by weighting them with the test liquids as fuel and leaving them to burn for 3 hours to room temperature and normal pressure of 25 °C and 100 hpa respectively.

3. Results and discussion

The luminous outputs from jatropha, soya bean and palm oil biodiesel blended fuel with kerosene are shown in Figure 1. The results showed a general decrease in luminous output with a decrease in kerosene content in all the blends for both the WTL and BB. Studies from the WTL (Figure 1a) revealed that pure kerosene (B0) gave luminous output of 3.05±0.03 A, while that for the pure biodiesel (B100s) i.e. jatropha, soya bean and palm oil were 1.43±0.13, 1.5±0.1 and 1.38±0.02 A respectively. However, BB gave a much higher luminous output of 4.04±0.02 A for sample B0 while that of the B100s were 2.865±0.115, 2.585±0.585, 2.225±0.325 A for jatropha, soya bean and palm oil respectively (Figure 1b). This indicated that blends with lower percentage of the biodiesels can support illumination when used in the WTL. The reason for the higher values in the luminous output for the BB as against that for the WTL may be attributed to the nature of the wick used in the BB, which was loosely woven and stranded enabling it to soak up more of the oil and hence burning with more brightness.

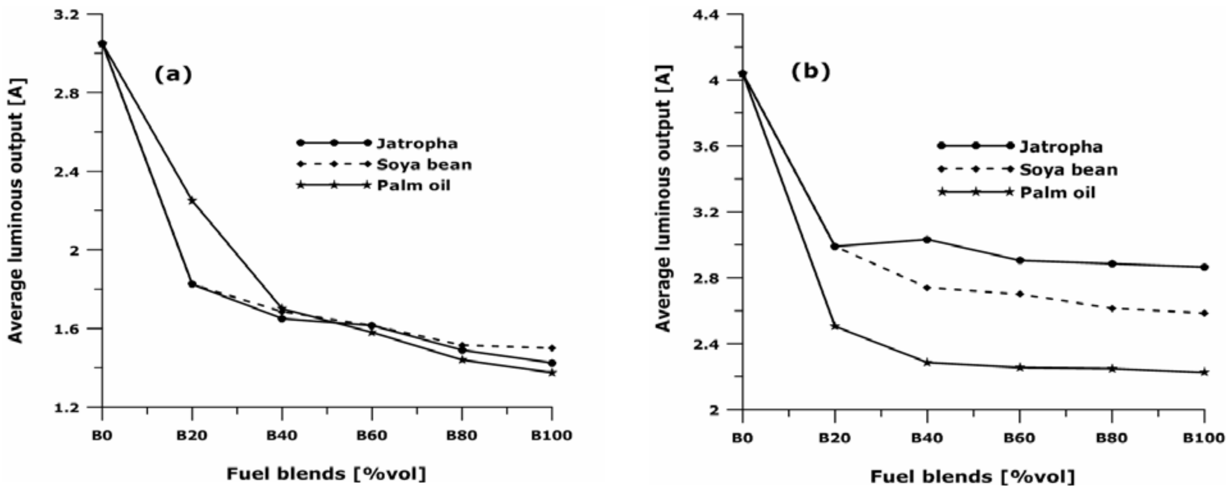

Figure 1. Relation between fuel blend volume and luminous output (a) WTL and (b) BB values

Investigation of the wick wastage and fuel consumption rates of the fuel blend ratios used Figure 2 showed that for the 3 hours that the blends were burnt in the WTL, B0 recorded less wick wastage rate of 0.067 cm/h while that of the B100s were 9.10, 9.77 and 10.33 cm/h for jatropha, soya bean and palm oil respectively (Figure 2a). However, in the case of the BB (Figure 2b), wick wastage rate for B0 was 0.67 cm/h while that for jatropha, soya bean and palm oil were 2.65, 3.15 and 4.83 cm/h respectively. There was a gradual increase in rate of wick wastage as kerosene content decreased in the blends for both the WTL and BB. Similarly, for the same burning period, the trend showed a decrease in rate of fuel consumption with decrease in kerosene content and was more pronounced in the BB than the WTL. Pure kerosene gave 8.46 g/h fuel consumption rate while those for the B100s, i.e. jatropha, soya bean and palm oil were 8.58, 7.82 and 6.55 g/h respectively for the WTL (Figure 2c). The consumption rate for pure kerosene in the BB (Figure 2d) was 26.73 g/h while the consumption rates for the B100s were 8.58, 7.82 and 6.55 g/h for jatropha, soya bean and palm oil respectively. Again the high values in the fuel consumption rates for the BB may be attributed to the nature of the wick used which was loosely woven and hence could soak up more fuel. However, the high values in the wick wastage rates for WTL as against that for the BB may be attributed to the fact that the wick used in the WTL was compact and tightly woven, such that it did not allow easy flow of fuel as compared to that used in the BB. Hence, more wick is burnt in the absence of enough fuel. The results indicated that the pure biodiesels or the kerosene with high biodiesel blend ratios cannot support combustion in the BB, WTL and kerosene stoves, since more wick will be required to do so even though they produced less fuel consumption rates.

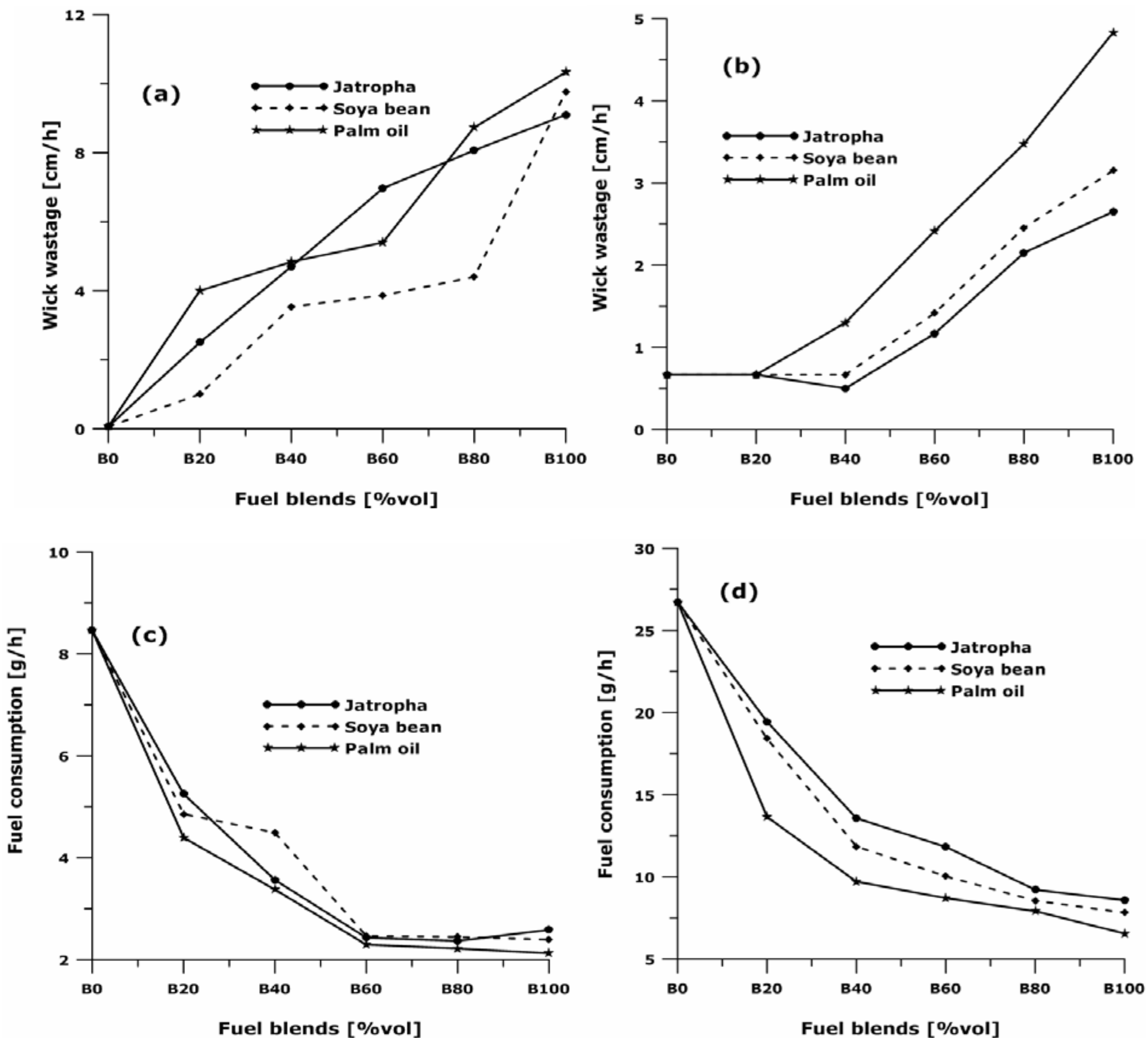

Figure 2. Trends of wick wastage rates for WTL and BB [(a) and (b)] and fuel consumption rates for WTL and BB [(c) and (d)] for the different fuel blends used.

The viscosity values for the biodiesel blended fuels with kerosene are shown in Figure 3. The results revealed an increase in viscosity as the kerosene content decreased. Pure kerosene had viscosity value of 0.4277±0.0015 Nsm^{-2} while that of jatropha, soya bean and palm oil were 0.543±0.019, 0.628±0.032 and 0.501±0.013 Nsm^{-2} respectively. This suggested that the pure biodiesels had low flow rates than pure kerosene and this was more pronounced in soya bean followed by jatropha and palm oil.

The calorific test (Figure 4) showed that pure kerosene had high calorific value of 51562.20±185.57 kJ/kg as compared to that of 41582.01±217.16, 39919.12±379.86 and 34929.04±579.27 kJ/kg for pure jatropha, soya bean and palm oil respectively. These values compared well with that of the kerosene. Thus pure biodiesels possessed quite appreciable combustion potential as kerosene with jatropha being more preferable among the three biodiesels. In addition, blends with lower percentage of the biodiesels would exhibit better combustion properties.

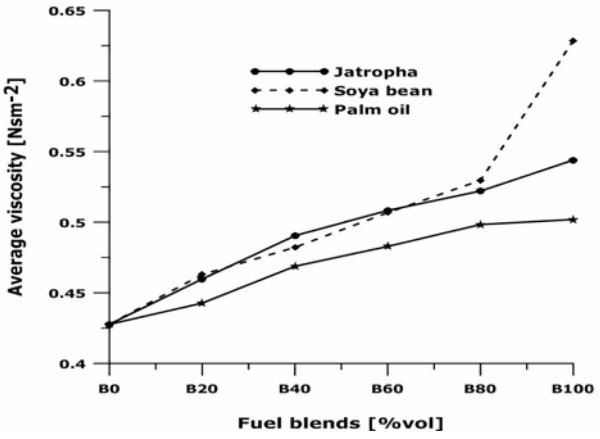

Figure 3. Average viscosities for the various fuel blends

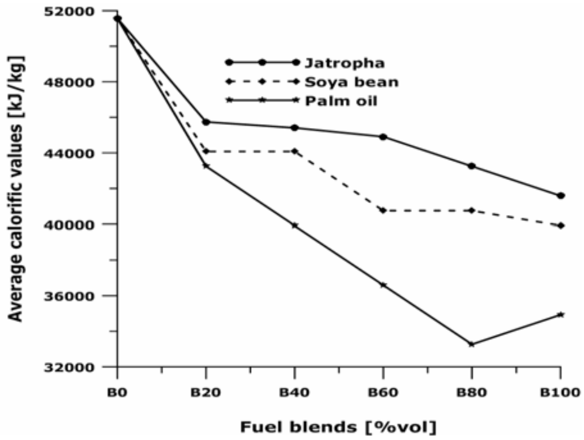

Figure 4. Trends in calorific values for the fuel blends

4. Conclusion

The performance assessments carried out on blends of jatropha, soya bean and palm oil biodiesels with kerosene revealed that the B100s of jatropha, soya bean and palm oil biodiesels recorded low calorific values 41582.01±217.16, 39919.12±379.86 and 34929.04±579.27 kJ/kg respectively and pure kerosene 51562.20±185.57 kJ/kg. This indicated that the B100s possess quite appreciable combustion potential to be use as a substitute for kerosene.

The fuel consumption and wick wastage test performed with the WTL and the BB on the B100s of jatropha, soya bean and palm oil biodiesels recorded relatively high wick wastage rates of 9.10, 9.77 and 10.33 cm/h respectively for the WTL while that for the BB were 2.65, 3.15 and 4.83 cm/h respectively. This was in contrast with the fuel consumption rates, which were as low as 2.53, 2.39 and 2.12 g/h for jatropha, soya bean and palm oil respectively for WTL and 8.58, 7.82 and 6.55 g/h respectively for the BB. Although the fuel consumption rates were low, the high values obtained in the wick wastage rates for higher blend ratios and the B100s suggested that they could not sustain continuous burning in both the WTL and BB because continuous upward adjustment of the wick must be made to sustain burning.

The luminous intensity test for the WTL and BB showed values of 1.43±0.13, 1.5±0.1 and 1.38±0.02 A for B100s of jatropha, soya bean and palm oil respectively in WTL, while in the case of the BB, the values were 2.865±0.115, 2.585±0.585 and 2.225±0.325 A for jatropha, soya bean and palm oil respectively. However, the pure kerosene unlike the B100 biodiesels was favoured by its relatively low viscosity and so can flow very well through the wick of the WTL and that of the BB more easily to support burning leading to high luminous output of 3.05±0.03 A and 4.04±0.02 A for WTL and BB respectively. The appreciable performance of the B100 biodiesels in the BB could be attributed to the nature of the wick used which was loosely woven and more stranded compared to that used in the WTL and therefore enhancing the flow of the pure biodiesels in spite of their high viscosities.

With this background we are of the view that the B100 of jatropha, soya bean and palm oil biodiesel cannot support burning continuously in the WTL, but since they performed fairly well when used in the BB, there are still chances for them becoming a very good substitute for kerosene if the wick used in both the WTL and BB could be made more capillary active by modifying the way they are woven as well as their texture so as to enhance the flow of the biodiesels in spite of their high viscosities. A study is being carried out to determine the flush point and sulphur content or emission characteristics of the biodiesels and their blends.

Acknowledgements

The authors are grateful to Mr. Anokye and Mr. M. Baah Mensah of the Departments of Mechanical Engineering and Chemistry respectively of KNUST Ghana for their support. Also Jonathan Fred Nanevi and Morkeh Robert also of the Physics Department, KNUST.

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