PRODUCTION OF BIODIESEL FROM ANIMAL FATS AND EVALUATING ITS POTENTIAL AS AN ALTERNATIVE FUEL

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Abstract

With the increasing trend towards the use of renewable energy resources, the use of biodiesels is highly emphasized. This paper reports findings of a survey which involved data gathering from 13 meat processing plants and slaughter houses near Nairobi City to establish the potential for animal fat production in Kenya. The paper also reports results of activities aimed at demonstrating the production and utilization of biodiesel from animal fats. In this aspect, a 100-litre animal fat biodiesel processing unit was fabricated and used for producing biodiesel from animal fat. The suitability of the produced biodiesels as alternative fuels was evaluated by carrying out engine performance tests.

The results indicated that beef cattle and camels can produce 5.67kg of animal fat, while pigs, sheep and goats can produce 7.8 kg, 2 kg and 1 kg, respectively. This would provide an approximated total of 180,498 tonnes of animal fat production potential in Kenya as at 2009. From the actual animal slaughter figures, a total of 21,265 tonnes of animal fat can be produced annually in the country. With an 70% biodiesel yield from the 100-litre processor, a total of 14,886 tonnes of biodiesel can be produced. The biodiesel produced from lard and tallow feedstocks adhered to the required density and viscosity limits of 0.87894g/ml; 0.87884g/ml and 5.7379mm2/s and 5.7479mm^2/s respectively. Observations for flash point and ash content were 59^{o}C; 60^{o}C; and 0.007% and 0.009% respectively. Water content of 0.001% and pour point of less than 0^{o}C for both lard and tallow biodiesels were observed. Contents of sediments were undetectable for both lard and tallow biodiesels. Engine test results showed that at 100% load, the specific rate of fuel consumption (sfc) for B100 Lard and B100 tallow were 119.79% and 124.43%, respectively as compared to fossil diesel while at 25% load, the rates reduced to 1.64% and 1.22% respectively. For the B10 blends, the specific rate of fuel consumption figures were lower than fossil diesel at 4.82% and 7.29% for B10 Lard and B10 Tallow respectively at 100% load. At 25% engine load, the consumption for B10 lard was 0.60% above fossil diesel while that of B10 tallow was 6.81% lower than fossil diesel.

Key words: Evaluating, animal, fat, biodiesel, potential, alternative, fuel

1.0 Introduction

The object of energy systems is to provide energy services. Energy services are desired and useful products, processes or services that result from the use of energy (UNDP, 2009). In the provision of energy, biofuels become a carrier in the chain that produces the required services. It is expected that there will be a 36% increase in demand for energy between 2008 and 2035 globally, with the largest increase found in the third world countries (World Energy Outlook, 2010). Oil will remain the dominant fuel in the primary energy mix to 2035, but with a rapid increase of modern renewable energy to 14%. The Renewables 2010 Global Report, indicates that the world is moving towards a cleaner, efficient and competitive energy future, as compared to years earlier. The report indicates that there was more funds invested in renewable energy capacity, manufacturing plants and research and development.

In Kenya, the per capita energy consumption, according to the Kenya Energy Policy (Sessional Paper No. 4 of 2004 on Energy) was 89.4 kilograms of oil equivalent (koe) in 2000, which is congruent with the IOE, 2006 report. This can be compared with 517 koe/capita for Sub-Saharan Africa and 5694 koe/capita for high income countries (OECD) for the same year, 2000. Kenya suffers the burden of importing petroleum products, which deplete the country's foreign exchange (Muok, 2008).

The growth of biodiesel industry in Kenya is hampered by lack of information, clear policy and regulatory frameworks and lack of institutions specifically charged with the role of developing it. There are a number of biodiesel initiatives throughout the country, however they are scattered, they are small and duplicated, and lack coordination. There is a need to create a specific institutional framework to address the development of this industry in Kenya.

A draft policy on strategy for the development of the bio-diesel industry in Kenya (2008-2012) is in place (Ministry of Energy, 2008). Its objective is development of bio-diesel in conformity with broad national objectives and has the following major objectives

(i). To increase security of energy supply by reducing vulnerability resulting from dependence on imported fossil fuels. It is estimated that a 5% reduction in imported diesel can be achieved by year 2012 through substitutions with biodiesel.

(ii). To diversify rural energy sources by promoting substitution of kerosene with biodiesel and the use of decentralized energy systems. The number of people using kerosene for lighting can be reduced from 76.4% in 2005/06 to 50% by 2012 through this substitution.

(iii). To contribute to efforts to address global warming through substitution of petroleum fuels. The biodiesel industry is expected to contribute to a 6% reduction of poverty incidence by 2012. A poverty incidence of 46.6% was recorded in 2005/06 according to the Kenya Integrated Household Budget Survey (KIHBS).

(iv). To contribute to poverty alleviation through diversification of income sources. Through rural agricultural mobilization, especially in the marginal semi-arid areas, bio-diesel industry can increase household income levels by 30% by 2012.

Research activities involving the use of animal fat for biodiesel production are in line with the objectives of the draft policy and hence the justifications of the herein reported work results.

2.0 Materials and Methods

2.1 Data for Animal Fat Production Potential

The data was collected using a questionnaire comprising of 20 questions, which was administered on a face-to-face contact with the plant managers. The areas that the questionnaire queried were; details of the locations of the plants; number of animals processed; size of animal processed; amount of raw animal fat produced; amount of rendered animal fat (tallow) produced; current uses for the raw animal fat and tallow; availability of animals seasonally and annually and knowledge on biofuels.

2.2 Fabrication of the 100-liter Biodiesel Processor

The 100-liter biodiesel processor shown on figure 1 was designed and fabricated by the authors at the Jomo Kenyatta University of Agriculture and Technology. Hands on local metal fabricators were also involved where it was deemed necessary. The processor consisted of a pump and two mixing units namely the methoxide and animal fat mixing units. A sight tube was installed on the side to ensure that fluid levels and volumes were easily noted.

Figure 1: The fabricated biodiesel processor used during the study of animal fat biodiesel production and evaluating its potential as an alternative fuel.

2.3 Biodiesel Production and Analysis

Lard and tallow were the two most commonly available animal fat feedstocks and were used in the production of biodiesel using the fabricated processor. The feedstocks were purchased from local meat processing plants in rendered form. Methanol, sodium hydroxide and potassium hydroxide, alongside chemicals required for titration were sourced in local laboratory supply shops. The production of biodiesel used a two step process where a base catalyst (NaOH) was utilised (Wan, 1991). The resulting biodiesel was analysed to ascertain its properties, using the standards of Kenya Bureau of Standards (KEBS) for density, kinematic viscosity, flash point, ash content, water content, sediments and pour point. For the purposes of this research these properties were considered as being the most important.

2.3.1 Biodiesel Production

In order to prepare biodiesel from 40 liters of lard, 800ml of methanol and 80g of NaOH were required. 40liters of lard was poured into the biodiesel processor and heated using the installed heater. The lard was circulated in the processor to ensure uniform heating and then 80g NaOH and 800ml Methanol were mixed together to form Sodium Methoxide. The mixture was done in a well ventilated area, since the methoxide is a highly toxic chemical compound. The lard was heated to 70^{o}C and the mixture of sodium methoxide was added. The processor heat was maintained at 70^{o}C for one hour in circulation then allowed to cool for 8hours. Glycerine was decanted from the processor and biodiesel was also poured out into separate containers It was noted that there was form production at the top of the biodiesel, resulting from the mixing. This was scooped out from the top of the processor.

2.3.2 Density

The determination of density was carried out using the test method TES/04/TM/19 of March 2011 with normative references to ISO3838:1983. The test defines density as the mass of a substance divided by its volume with the units reported either as g/ml or kg/m3 at a given temperature. Three samples were tested. 100% Biodiesel (B100), 10% Biodiesel in fossil Diesel (B10) and 100% diesel. These variations were considered necessary since blending of fossil diesel with biodiesels is necessary sometimes. The measuring cell was cleaned and dried. The density method was selected on the screen. The sample was drawn using a syringe, ensuring that there are no bubbles trapped in the syringe. The measuring cell was filled with the sample. Once the conditions was deemed valid, the results were recorded. The process was repeated thrice for each sample.

2.3.3 Kinematic Viscosity

The determination of kinematic viscosity was carried out using the test method TES/04/TM/10 with normative reference to ASTM 05.01 D446. Three samples were tested. 100% Biodiesel (B100), 10% Biodiesel in fossil Diesel (B10) and fossil fuel. The automatic viscometer was switched on. The sample beaker was filled with 18ml of sample fluid. Any residue was wiped off on the side and neck of the sample beaker. A measuring point was selected with the temperature set at 40oC. The sample was placed in the loading position on the charger. A start window opened on the screen and sample details were entered. The measurements were displayed on the screen

2.3.4 Flash Point

The determination of flash point was done by using the Pernsky Martens closed cup method, using the test method TES/04/TM/37 with normative references to ASTM 05.01 D93 1991. The test defines Flash Point as the lowest temperature corrected to barometric pressure of 101.3lPa (760mmHg) at which application of test flame causes the vapour of a specified sample to ignite under specific conditions of test. Three samples were tested. 100% biodiesel (B100), 10% biodiesel in fossil diesel (B10) and fossil fuel. The cup was cleaned thoroughly and filled with the sample to the required mark. The cup was placed on a stove and locked into place. The thermometer and stirrer was turned on. The sample was heated to 40^{o}C which is approximately 20^{o}C below the expected flash point. The test flames was lit and adjusted to 4mm and applied to the sample. The observed flash point was recorded. The barometric pressure was measured. Calculation was carried out using the formular as given on equation 1 below:

$$\text{Corrected Flash Point } (^{o}C) = C + 0.25\,(101.3 - P) \qquad (1)$$

where

C = Observed flash point (^{o}C),

P = Barometric Pressure (kPa)

2.3.5 Ash Content

The determination of ash content was carried out using test method ASTM D482.
Three samples were tested. 100% biodiesel (B100), 10% Biodiesel in fossil Diesel (B10) and fossil fuel. The crucible was heated to 700˚C for 10min and then cooled to room temperature and weighed. A sample of 100g was put into the crucible and heated till the it ignited and allowed to burn uniformly leaving only a residue. The residue was heated in a muffle furnace at 700 degrees centigrade to eliminate carbonaceous materials. The crucible was cooled to room temperature and weighed. The heating in the muffle furnace was repeated three times for each sample. The calculation of the weight of the ash was given as a percentage of the original sample weight, in the following formula:

Ash Content (%) = (w/W) X 100 (2)

Where
w = weight of the ash, g
W = weight of the sample, g

2.3.6 Water and Sediment Content

The determination of the content of water and sediments in the samples was done using the ASTM D96 test method. Three samples were tested, 100% Biodiesel (B100), 10% Biodiesel in fossil Diesel (B10) and fossil diesel. The centrifuges were filled to the 50ml marks with the sample and then to 100ml mark with toluene. The tubes were whirled for 3min and then stopped to take readings. The process was repeated three times for each of the samples.

2.4 Engine Testing

The engine testing was done using an eddy current dynamometer consists of a Yanmar NSA BK, single-cylinder, water cooled, 4-stroke horizontal type engine. The cylinder of the engine had a bore of 75mm and 75mm stroke with a piston displacement of 331cc. The engine is connected to an eddy current brake DYE-3 dynamometer, having a maximum force of 117.7 N with an arm length of 250mm and compression ratio of 23. The engine tests carried out were torque; brake power; specific rate of fuel consumption; brake thermal efficiency; brake mean efficiency pressure; volumetric efficiency (charging efficiency) and heat loss to cooling water.

The calorific value was among the parameters determined and reported in the major work of the research part of which is hereby reported. However, for purposes of this paper it was decided that it is adequate to report the values of the Brake Thermal Efficiencies of the diesels. The brake thermal efficiency is a function of the rate of fuel consumption and the calorific value of the fuel. It is inversely proportional to the product of the rate of fuel consumption and the calorific value of the fuel and is considered the best measure of how much of the fuel is turned into useful work. The dynamometer used is shown on figure 2.

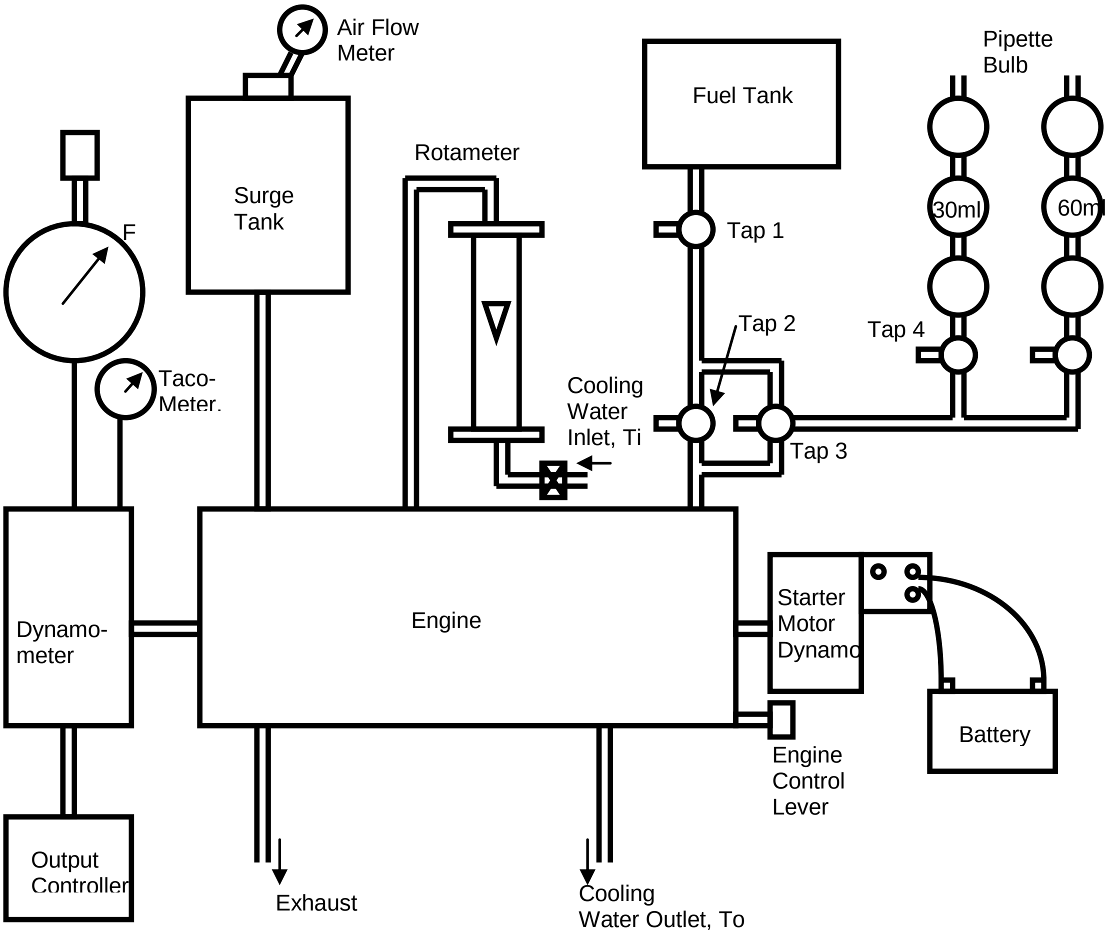

Figure 2: Schematic of the eddy current dynamometer used during the study

2.4.1 Engine Starting Procedure

The lubricant oil level was checked and found sufficient. Fuel amount was checked and added using fossil diesel. Cooling water flow was controlled by adjusting the water tap till the rotameter level read about 1.0 liters per minute. Taps 3, 4 and 5 were closed. The battery terminals were connected to the self starting motor using booster cable, red (+) to starter motor and black (-) to engine block.

2.4.2 Operations

The fuel taps 1 and 2 were open. Engine speed control level was adjusted to the START position. The decompressor lever was pushed to the left and held in position with the left hand and the engine started using ignition key. Once the engine was running the decompressor lever was slowly released to its original position. The engine control lever was adjusted to the middle of the STOP range. The ignition key was turned to off position and the booster cables removed without causing a short circuit. The speed of the engine was adjusted by the speed control lever to about 800rpm. At this speed, the engine was left to run for 5 minutes to warm up. After warming up, the engine was adjusted to 1500rpm. The dynamometer was switched on and allowed to move freely and then adjusted so that it lay in the horizontal position. A load of 39.24N was used. The fuel level in pipette bulbs for 30ml was adjusted using taps 3, 4 and 5 and the fuel from the tank stopped by closing tap 1. Tap 2 was opened to allow the fuel in the pipette to be drawn into the engine. The time duration for the consumption of 30ml of fuel was recorded using a stop watch. 4 readings were taken. Intake air pressure was recorded at the end of the duration of consumption of 30ml of fuel. Intake air temperature was recorded at the end of the duration of consumption of 30ml of fuel. Intake cooling water temperature and cooling water outlet temperature was recorded at the end of the duration of consumption of 30ml of fuel. The procedure was repeated at loads of 29.43N, 19.62N, 9.81N and at no load. At the end of the readings taken using the fossil diesel sample, the engine was switched of and the fuel tank emptied of the fossil diesel. The fuel tank was then filled with a new sample of fuel B10 tallow biodiesel (10% tallow biodiesel to 90% fossil diesel). Steps 1 through 13 were repeated. The same was done for the B100 tallow biodiesel, B10 lard biodiesel and B100 lard biodiesel. At the end of the readings, the fuel tank was filled back with fossil diesel and left to run at 800rpm for 15minutes, to flush out the B100 lard biodiesel from the engine.

3.0 Results and Discussion

3.1 Animal Fat Production Assessment

3.1.1 Animals Slaughtered

The study looked into the total animals slaughtered in the plants visited. This was disaggregated into small animals consisting of goats, sheep and pigs and large animals consisting of cattle and camels. This data was collected to ascertain the production trends as well as gather the information for comparing the animal production vis a vis fat produced. The daily total animals slaughtered are 1879 animals, which are disaggregated into 1047 small animals (or 55.7%), and 832 large animals (or 44.3%).

3.1.2 Animal Fat Production and Rendering

The respondents of the questionnaire indicated an average of 5.67 kg of animal fat per large animal, while the average animal fat produced by small animals is 3.25 kg. Only 46.52% rendered fat production.

3.1.3 The Choice between Rendering and Not Rendering

When queried on the reasons why the plants did not render the animal fat, 61.5% of the respondents indicated that this was not part of the services that they offered. In the meat processing plants the respondents, representing 23.1% indicated a range of reasons for not rendering animal fats. 7.7% indicated that they felt there were no customers to utilise the rendered animal fats. Another 15.4% noted that they used the animal fat for other uses such as mixing with locally made dog food and mixing with other meat products within the plant.

3.2 Use of Animal Fat

The respondents indicated that the largest use of animal fat was cooking at 54%, followed by 31% at soap making and 15% noted that the animal fat was used for other uses, such as dog food production and uses in other meat products.

3.3 Animal Availability

All the respondents indicated that there was a reduced amount of animal during the rainy seasons, when the livestock farmers choose to fatten their animals. The reduction is an approximate 25% during the months of March, April, May and October. During the dry season and in instances of prolonged drought, the animals are in plenty. This is occasioned by lower prices in the market. It is noted that most animal come from the province where the meat processing plants are located which shows 31% of animals come from around the district and another 31% come from the province. In the busier slaughterhouses and meat processing plants, the animals come from all over the country and even outside the country (Somalia, Tanzania and Sudan) according to 23% of the respondents. The respondents also indicated that 15% of the animal are availed from selected ranches and own farms. These are used in specialised meat processing plants that have a focus on the export market as well as a sensitive market requiring an uninterrupted availability of animals throughout the year at a guaranteed quality. It was also reported that animal production was decreasing with time, as indicated by 46% of the respondents in figure 9 below. However, 23% felt that the animal production was increasing, while one-third felt that there was no change in the availability of animals over time.

3.4 Biodiesel Knowledge

The study sought to understand the level of knowledge of the meat sector actors on biofuels. 92% of the respondent had no knowledge of biofuel and in particular biodiesel. 8% had heard about vegetable biodiesel from jatropha but not about the potential to utilise animal fat in the production of biodiesel. 92% of the respondents felt that the use on animal fat for biodiesel production would be beneficial to their plants, while 8% felt that the biodiesel produced would be too expensive as compared the fossil fuel diesel

3.5 Potential for Animal Fat P roduction in Kenya

In the population census carried out in 2009, the total population of animals was determined as shown in Table 1 in column 2 below and using the information from the survey carried out in this study, the amount of fat that can be extracted from the various animals was computed as indicated in column 3 of Table 1 below, thus providing the potential of animal fat available within the population of animals in Kenya.

Table 1: Total Potential of Animal Fat in Kenya

Animal	Numbers, 2009	Animal Fat per animal (Kg}	Total Potential {Kg}
Beef Cattle	17,467,774	5.67	99,042,278.58
Goats	27,740,153	1.00	27,740,153.00
Sheep	17,129,606	2.00	34,259,212.00
Camel	2,971,111	5.67	16,846,199.37
Pigs	334,689	7.80	2,610,574.20
Totals	65,643,333		180,498,417.15

Source: Ministry of Planning 2009

The Ministry of planning in the government of Kenya indicated in 2009 the number of animals slaughtered annually as indicated in table 2 below. It can therefore be deduced that the annual potential of animal fat production at the slaughterhouse, using the current methods would yield 21,265 tonnes of animal fat annually. This animal fat is edible animal fat. In the case of production of inedible animal fat, then bigger yields can be expected.

Table 2: Total Annual Potential of Animal Fat Production in Kenya

Animal	Total Population of Animals in 2009	% slaughtered	Total Annual Animals Slaughtered	Animal Fat Yield per animal (kg)	Total Annual Potential Yield of Animal Fat (kg)
Beef Cattle	17,467,774	11	1,921,455	5.67	10,894,650.64
Goats	27,740,153	11	3,051,416	1.00	3,051,416.83
Sheep	17,129,606	11	1,884,256	2.00	3,768,513.32
Camel	2,971,111	11	326,822	5.67	1,853,081.93
Pigs	334,689	65	217,547	7.80	1,696,873.23
Totals	65,643,333		7,401,498		21,264,535.95

Source: Ministry of Planning 2009

It should be noted that the process of animal fat production mentioned in table 1 and 2 above is lower than what advanced meat processing plans are able to produce. For instance, Kenya Meat Commission, the largest meat processing plant in Kenya, slaughters 450 animals in a day (30% of its capacity) and produces 5 tonnes of inedible animal fat from an animal, which translates to an approximate

11kg per animal. In this case then improvement in animal fat rendering processes can yield twice the amount of animal fat indicated in tables 1 and 2 above.

3.6 Biodiesel Production and Analysis

The production of biodiesel using the processing unit, yielded 80% biodiesel from lard feedstock and 75% biodiesel from tallow feedstock as shown on tables 3 and 4.

Table 3: Products % observed for Lard Animal Fat

Product	***Quantity (litres)***	Quantity (%)
Biodiesel	32	80
Glycerine	7	17.5
Foam	1	2.5

Table 4: Products % observed for Tallow Animal Fat

Product	***Quantity (litres)***	Quantity (%)
Biodiesel	30	75
Glycerine	8	20
Foam	2	5

From tables 3 and 4 above there is an 80% and 75% yield of biodiesel from lard and tallow, respectively. This is similar to the findings of Canakci and Van Gerpen, 2001 and Babcock, et al, 2006, for caustic pre-treatment of high free fatty acid feedstock. The pre-treatment produces a soap-stock from the free fatty acids resulting in the large amount of glycerine and foam produced. Results for Lard and Tallow biodiesels in comparison with fossil diesel are tabulated in Tables 5 and 6.

Table 5: Results of Lard biodiesel Compared to fossil diesel

Samples	***Density at 20°C. (g/cm³)***	***Kinematic Viscosity at 40°C (mm/sec)***	***Flash Point (°C)***	***Ash Content (%)***	***Water Content (%)***	***Sediment***	Pour Point (°C)
B100	0.87884	5.7379	59	0.007	0.001	Not detected	<0
B10	0.84453	3.8149	69	0.004	0.009	Not detected	<0
Fossil Diesel	0.84078	3.6633	77	0.0042	Not detected	Not detected	<0

Table 6: Results of tallow biodiesel Compared to fossil diesel

Samples	***Density at 20°C. (g/cm³)***	***Kinematic Viscosity at 40°C (mm/sec)***	***Flash Point (°C)***	***Ash Content (%)***	***Water Content (%)***	***Sediment***	Pour Point (°C)
B100	0.87894	5.7479	60	0.009	0.001	Not detected	<0
B10	0.84553	3.8249	69	0.005	0.009	Not detected	<0
Fossil Diesel	0.84078	3.6633	77	0.0042	Not detected	Not detected	<0

3.7 Engine Testing

Out of the engine tests carried out, two of them are often used in the indication of the impact of fuel on engine performance. These tests are specific rate of fuel consumption and brake thermal efficiency. The results for these are given on tables 7 and 8 and graphically represented on figures 3 and 4.

Table 7: Specific rate of fuel consumption (g/kWh)

Load (L) in N	***Fossil Diesel***	***B10 Tallow***	***% difference from Fossil Diesel***	***B10 Lard***	***% difference from Fossil Diesel***	***B100 Tallow***	***% difference from Fossil Diesel***	***B100 Lard***	***% difference from Fossil Diesel***
39.24	0.125533	0.116385	-7.29	0.119477	-4.82	0.135649	8.06	0.127883	1.87
29.43	0.132435	0.103765	-21.65	0.120032	-9.36	0.125214	-5.45	0.110516	-16.55
19.62	0.161927	0.132955	-17.89	0.142057	-12.27	0.131874	-18.56	0.131859	-18.57
9.81	0.230081	0.214419	-6.81	0.231452	0.60	0.207668	-9.74	0.207645	-9.75

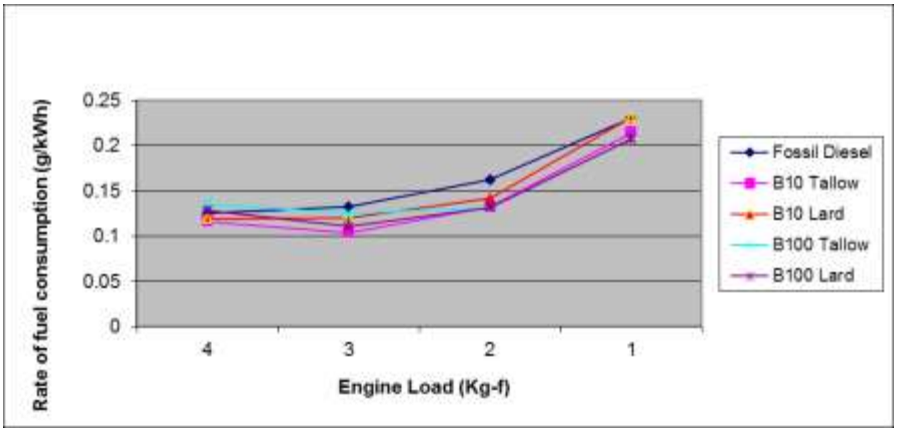

Figure 3: Specific rate of fuel consumption for the diesels at 1500 rpm engine speed

In the figure 3, it can be deduced that the specific rate of fuel consumption increased with a reduction in engine load. At highest load, 100% lard and tallow biodiesel indicated an increased specific rate of fuel consumption by a margin of 119.8% and 124.4% respectively compared to fossil diesel. At full load, the 10% blend of biodiesel to fossil diesel, the specific rate of fuel was lower than fossil diesel by 4.8% for B10 lard biodiesel and 7.3% for B10 tallow biodiesel. At ¾ engine load, the specific rate of fuel consumption for B100 was 2.4% higher than fossil diesel for B100 lard biodiesel and 13.9% higher for B100 tallow biodiesel. At the ¾ load, the B10 blend was lower than fossil diesel by 9.4% for B10 lard and 21.7% for B10 tallow. At ½ engine load, the difference between fossil diesel and B100 biodiesel was 8.5% less in B100 lard and 3% less in B100 tallow. At ¼ of the load, there was almost an insignificant increase of specific rate of fuel consumption for B10 lard biodiesel at 0.6%, in contrast with B10 tallow biodiesel that have a decrease in the specific rate of fuel consumption at 6.8%. For the B100, the increase in specific rate of fuel consumption was 1.6% for B100 lard and 1.2% for B100 tallow biodiesel.

These results correspond to Canakci (2001), Monyem (1998), MacDonald *et al*., (1995) who found an increase in the specific rate of fuel consumption increased with an increase in the blend of biodiesel with fossil fuel. This increase was attributed to the lower heating values of biodiesel compared to fossil diesel. Table 9 compares Percentage differences between Thermal Efficiencies of the biodiesels with that of fossil diesel.

Table 8: Brake thermal efficiencies for the various diesels (ratios)

Load (L) in N	*Fossil Diesel (10^{-4})*	*B10 Tallow (10^{-4})*	*B10 Lard (10^{-4})*	*B100 Tallow (10^{-4})*	*B100 Lard (10^{-4})*
39.24	1.9027	2.1552	2.0994	1.9642	2.0835
29.43	1.8035	2.4178	2.0897	2.1279	2.4109
19.62	1.4750	1.8866	1.7657	2.0205	2.0207
9.81	1.0381	1.1698	1.0837	1.2830	1.2832

Table 9: Percentage differences between brake thermal efficiencies of biodiesel and fossil diesel

Load (L) in N	**Fossil Diesel (10^{-4})**	**% Difference B10 Tallow**	**% Difference B10 Lard**	**% Difference B100 Tallow**	**% Difference B100 Lard**
39.24	1.9027	13.27	10.34	-50.29	-49.24
29.43	1.8035	34.03	15.87	-2.09	8.93
19.62	1.4750	27.90	19.71	15.01	21.97
9.81	1.0381	12.69	4.39	10.22	9.75

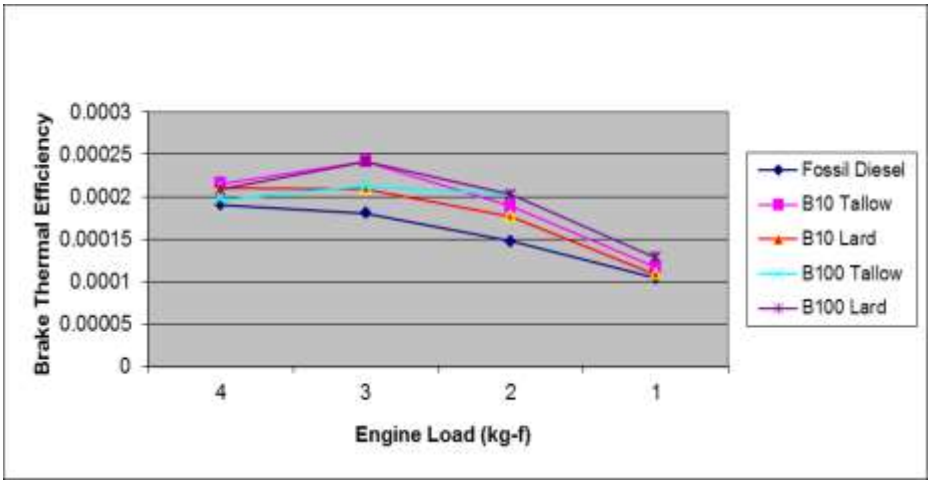

Figure 4: Brake Thermal Efficiencies for the diesels at 1500 rpm engine speed

From table 8 and figure 4 above, it can be deduced that break thermal efficiency will reduce with decreasing load on the engine at constant speed. With the B100 biodiesel the Brake Thermal Efficiencies were significantly lower with the maximum load of the engine and almost matched the fossil diesel at ¾ of the load. Biodiesel had better efficiencies at ½ and ¼ engine loads. Throughout the engine loads, the B10 blend had better thermal efficiencies than fossil diesel. The little difference in the thermal efficiencies was also experienced by Canakci (2001), Monyem (1998), Chang and Van Gerpen (1997), Yahya (1988) who attributed it to the fact the engine was converting the chemical energy in the fuel to mechanical energy in the same way. The results have indicated that research and development activities in animal fat biodiesels can result in practical applications of these fuels. Blending of these biodiesels with the fossil diesels should be encouraged.

4.0 Conclusion and Recommendations

The following conclusion can be made;

(i). The production of biodiesel from animal fats using an adopted small scale processor and using already available processes of caustic pre-treatment is possible and can yield 70% biodiesel from animal fat.

(ii). Kenya has a current potential of producing 21,265 tonnes of animal fat per year that can be used in the production of biodiesel.

(iii). Kenyan slaughterhouses have the potential of producing twice the amount of animal fat if advanced fat rendering processes are in place, as proven by the Kenya Meat Commission (KMC) that is able to produce twice the amount of animal fat per animal as compared to the slaughterhouses.

(iv). Currently, Kenya can produce 18,886 tonnes of biodiesel from animal fat and have the possibility of doubling this amount if advances are made in animal fat rendering.

(v). Biodiesel from animal fats made using a small scale processor has properties closer to those of fossil diesels that enable it to be used as a viable fuel in a fossil diesel engine without any modification.

The recommendations resulting from this research mainly include:

(i). The biodiesel processor should be improved by having sealed reaction tanks for better safety and less energy loss.

(ii). It is necessary that carbon dioxide emissions from the processed animal fat biodiesel be evaluated to see how they compare with those from the fossil diesels.

(iii). Future research should include field testing where the fuel is used over a period of time and the data collected to include the conditions of the engine over time.

(iv). Research on animal fat biodiesel from other animals including chicken and fish should also be carried out.

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