EXPERIMENTAL PERFORMANCE EVALUATION OF MIXTURE OF CASTOR AND WASTE COOKING OIL BIODIESEL AS ALTERNATIVE FUEL FOR DIESEL ENGINE

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1.ABSTRACT:

Depletion of fossil fuel source and fluctuating fuel price led researchers to focus on developing new agro-based alternative fuels, which will provide sustainable solution to the energy crisis. Research on using vegetable oil as an alternative fuel for diesel engine continued until now due to its benefit. Straight oils could be used directly but they need modification in order to minimize their effect on the engine life. The advantages of biodiesels and vegetable oils are renewability, biodegradability and they are oxygenated. Although many researches pointed out that it help to reduce greenhouse gas emissions, promote sustainable rural development, and improve income distribution, there are still some resistances exist for using them. Experimental evaluation of several vegetable oils as potential fuel sources is giving a promising result. From previous studies, few works have been conducted by mixing different biodiesel with the combination of diesel as an alternative fuel. In this context, this study have been investigated the performance of the mixture of castor and waste cooking oil biodiesel with the conventional diesel in diesel engine. The transesterification was performed by using methanol, sulfuric acid and potassium hydroxide through two stage transesterification methods. The performance test of biodiesel blends and petro diesel were done by air cooled single cylinder four stroke diesel engine.The blend were prepared as pure diesel (B_0),castor biodiesel blend (B_{15}CB and B_{20}CB), waste cooking oil biodiesel blend (B_{15}WB and B_{20}WB) and mixture of waste cooking oil and castor biodiesel blends (B_{15}CWB and B_{20}CWB). From the performance test results the mixture of castor and waste cooking oil biodiesel blend (B_{20}CWB) shows reduction of 4.8% of brake torque and 4.5% of brake power compared to pure diesel. It concluded that the mixture of castor and waste cooking oil biodiesel blend (B_{20}CWB) can become an alternative source of fuel in the future to reduce the production cost of castor biodiesel and improve low performance of waste cooking oilbiodiesel.

Key words: *biodiesel, castor oil, waste cooking oil, transesterification, diesel engine, brake power, brake torque*

2. INTRODUCTION

1.1 Background

Energy is the basic need for economic development of any country. The development of societies has accompanied through an increase in growing energy needs and their power requirements have performed through the combustion of different materials such as oil, charcoal and natural gasoline which are categorized under fossil fuels. However, fossil fuels are non-renewable energy sources and increase in consumption of these resources are becoming empty in short duration of time. Due to the development and growth of transport automobiles and agricultural machineries the production and consumption of petroleum oil will increase consistently [1].
Around worldwide most of the energy source is provided with the aid of fossil fuels, which are taken as non-renewable. So fossil sources are depleted. Currently world yearly energy uses exceed 9 billion tons of oil. Transport energy is responsible because of 1.8 billion tons (20 %) and results over 6.3 billion tons on carbon dioxide (CO_2) emissions [2]. The growing consciousness of the depletion on fossil fuels asset and the environmental benefits concerning biodiesel fuels have more attractive to recent times. Its fundamental benefits treat including the most valuable renewable fuels currently accessible and additionally non-toxic and biodegradable. Biodiesel can be used directly by diesel engines without doing any engine modifications. However,

the cost of biodiesel is the primary barrier as compared to petroleum based diesel fuel. The manufacturing of biodiesel from desert plants provides financial and environmental friendly fuels [3].
According to the necessity for greater sustainable forms of energy and many new technologies have been introduced. In many countries the use of biofuel focused on ethanol and biodiesel has improved substantially in recent years. Recent trends also show that interest in biofuels is increasing towards developing countries where manufacturing cost is particularly cheaper and offers the opportunity for biofuel production offossil fuel prices [2]. It has motivate the use of presently accessible biofuels as transitional ladder for world financial system by giving extra efficient alternative energy sources. Renewable fuels from biological resources are acceptable and increase attention to minimize dependence on fossil fuels [4].

3. MATERIALS AND METHODS

In this chapter, the materials and methods used during production of biodiesel are listed below. This chapter proceed in describing details of the procedures used to carry out the production processes with various experimental works present in the study. It includes collect and filter waste cooking oil, extraction of the oil from the castor seed, extraction of biodiesel from castor and waste cooking oil, characterization of the biodiesel, blending and performance testing of the blended fuels in the diesel engines.

3.1 Materials

Chemistry laboratory materials used for this research includes volumetric flasks, beakers, measuring cylinders, separator funnels, thermometer, hot plate with magnetic stirrer, oven and digital balance. And performance testing done by Air-cooled single cylinder four stroke diesel engine at Dilla University, Automotive Engineering Department laboratory.

- Waste cooking oil collected from Rakev cafe and restaurant, Teshe cafe, and chips sellers (deep fried potatoes) on the street (Addis Ababa).
- Castor seed were obtained from Bako Agricultural Engineering Center.
- Methanol purchased from Volumetric Educational Supply PLC, Addis Ababa.
- Potassium hydroxide and sulfuric acid purchased from Atomic Educational Materials Supply PLC, Addis Ababa.
- Distilled water were bought from Yegna Lab Trading PLC, Addis Ababa.
- Diesel fuel was purchased from Oilibya,Addis Ababa.

3.2 Engine Performance Testing

The performance of fuel was measured by using diesel engine for pure diesel, waste cooking oil biodiesel blend, castor biodiesel blend and mixture of waste cooking oil and castor biodiesel blends. Brake torque, brake power and brake specific fuel consumption of the tested fuels were compared with each other as well as with petro diesel. The performance with different blends of biodiesel with petro diesel can be evaluated by measuring torque and power rate at different speeds. The torque, power, speed and specific fuel consumption was read from computer directly. The blends of biodiesel and the diesel fuel which taken as a performance comparator for other blends which were tested by the setup.
The performance and emission of the fuel was tested by using CT 100.22/24 four-stroke (bio) diesel engine for CT 110 testing setup. The 4-stroke diesel engine CT 100.22 /CT 100.24 is part of an equipment series thatfacilitates tests on combustion engines. To perform the experiments, the engine is placed in the CT 110 Test stand for small engines. During the experiments, full and partial load characteristic curves can be recorded, amongst other items. The CT 100.22 / CT 100.24 engine is suitable both for practical work during training in vocational colleges, and also for laboratory experiments in technical colleges and universities. The engine CT 100.24 is designed for use with special types of biodiesel.
Apart from an engine (CT 100.22 /CT 100.24), a functional experimental setup includes the CT 110 test stand for small size engines. If the experimental setup is assembled, experiments on the recording of engine characteristic curves can be performed. For this purpose, the combustion engine is connected to the asynchronous motor in the CT 110, which is operated as a dynamometer. The CT 100.22 / CT 100.24 engine is an air-cooled, single cylinder, 4-stroke diesel engine. The flywheel fitted with fan blades is used for cooling the engine. The engine is started using the asynchronous motor in the CT 110 as a starter motor. The engine have temperature sensor for the measurement of the exhaust gas temperature. This is connected to the CT 110 test stand as are the connections for electrical shut down and the fuel supply. The engine can be placed in the test stand CT 110 with only a few actions. Power is transmitted between the engine and braking device via dog coupling.

Figure CT 110 test stand setup*(Source: own)*

The equipment will be performed under full load and partial load working conditions. The engine standard in all its parts is braked on a test rig at operating temperature and with fully activated injection pump using a braking device. Full load is defined as the stress that an engine can overcome without a reduction in speed. In this case the largest possible quantity of fuel is made available. The values determined over the entire speed range under different loads are the basis for the curve progression of torque, power and specific fuel consumption. Because an engine in daily use is rarely under full load, measurements under partial load are just as important. Several measurements are carried out at constant speed and under various loads of the engine. The availability of a sufficient amount of data makes it possible to establish performance characteristics for the engine, for example, using the partial load curves. To record the output power curve related to the full load characteristic curves, with the engine running the speed regulator is set to the maximum amount of fuel. Using the dynamometer on the CT 110 test stand, the engine is then loaded by turning the speed potentiometer to maximum. By reducing the speed set on the potentiometer in steps, torque values are displayed on the CT 110 test stand from which the output power curve can be drawn up .

For fuel performance test the following test procedure was used.

- Check all connections between the engine and the test stand.
- Before starting the engine, the fuel line to the engine and the measuring tube must be filled.
- The fuel line and return line for the engine is connected to the supply connection on CT 110 test stand.
- The engine was warmed up to its operating temperature before starting the test.
- Start the engine by asynchronous motor after starting switch off the motor.
- Properly fit the safety cover for the coupling.
- Set the required parameters on the computer to be measured.
- By rotating speed lever start the experiment from speed 1000 rpm to 2500 rpm.
- The engine performance characteristics torque, speed and specific fuel consumption were measured within the given speed and values are displayed on computer.
- Data was measured starting from 1000 rpm to 2500 rpm at 250 rpm intervals.

Following the above procedure, first the base fuel (B_0) performance was done and then followed by other blend fuels B_{15}WB, B_{15}CB, B_{15}CWB, B_{20}WB, B_{20} CB and B_{20}CWB.

4. RESULTS AND DISCUSSIONS

4.1 Extraction of Castor oil

Castor oil was extracted through mechanical pressing of the castor seed by human operated hydraulic pressing machine. The machine extracts totally 6 liters of oil from 20 kg castor seed. This mean 30 % (mass/mass basis) of oil was extracted. At each batch 0.25 kg of seed was fed into the machine and it delivers 75 ml (0.075 liter) of oil which provides that from 1 kg of castor seed, 300 ml (0.3 liter) of oil was obtained. Since the hydraulic pressing machine is human operated, the extraction method consumed more time as well as more human power. Therefore, it needs modification of machine and use modern extraction technology like chemical extraction method to get more oil yield.

4.2 Characterization Result

The property of the fuel were characterized by Ethiopian Petroleum Supply Enterprise and tabulated below in Table 4.1. Mainly diesel standard are used to evaluate some characteristics of this castor biodiesel, waste cooking oil biodiesel and diesel blend B20. There are standard limits which the company (Ethiopian Petroleum Supply Enterprise) use to compare if the fuel is suitable for diesel engine or not. However, the most important properties of the fuel used in the study were characterized by ASTM standard test methods and the results are given below.

Table 4.1 Characterization Result

No	Property	Test method ASTM	Diesel limit	Test Results		
				100% COB	100% WCOB	10% COB, 10% WCOB & 80% diesel blend
1	Density @ 15 °C, g/ml	D 4052	Report	0.8859	0.8852	0.8498
2	Density @ 20 °C, g/ml	D 4052	Report	0.8825	0.8817	0.8463
3	Flash point,°C	D 93	Min. 60	>155	>155	103
4	Kinematic viscosity @ 40 °C	D 445	1.9-6.0	4.98	5.48	5.14
5	Total acidity, mg KOH/g	D 974	--	0.67	0.66	0.2

(Source: Experimental result done by Ethiopian Petroleum Supply Enterprise)

In this thesis some of the main diesel fuel properties are not characterized due to the expensiveness of the test which could be provided at Ethiopian petroleum Supply Enterprise. But for this research work few properties has been selected. From the above table, the density was measured at 15^{o}C and 20^{o}C. Astest result, the density ofcastor biodiesel was higher than waste cooking oil biodiesel. The density observed for both biodiesel was within the range given by European standard.

According to the result, kinematic viscosity for both biodiesel and diesel fuel blend of 20/80 at 40^{o}C found betweendiesel limit of 1.9 and 6 mm^2/s. The viscosity of waste cooking oil biodiesel was somewhat higher than castor biodiesel. The viscosity of castor oil is higher in actual case butdue to acid pretreatment before the transesterification the value become reduced. Due to this higher kinematic viscosity of the fuel the engine may be affected by the flow pattern of the fuel through the injectors and the atomization process of the fuel will be decreased. If there is a poor atomization of fuel an efficient burning of fuel could not be achieved.

Flash points of the castor and waste cooking oil biodiesel were within standard. The test was conducted through ASTM D 93 method. Compared to the castor biodiesel the blend of waste cooking oil and castor biodiesel gives less density and lower acid value. The flash point of their blend was within the standard. Since the fuel with the flash point more than 60^{o}C is considered as a safe, the results of all samples of biodiesels are considered to be safe to store and to use in the engine.

It observe that total acidity of castor biodiesel is almost similar to that of waste cooking oil biodiesel. The results are below 0.8 Mg KOH/g which are given by ASTM D 664 of biodiesel standard. Depending on the crude source or the vegetable oil source the acidity of the fuel can also create corrosive acidic oxides on combustion. These can cause high rates of engine wear and rapid depletion of engine components.

4.3 Engine Performance Testing

Engine performance was measured in terms of brake power, brake torque and brake specific fuel consumption. The engine performance of standard diesel fuel was compared with blend of B_{15}WB, B_{15}CB, B_{15}CWB, B_{20}WB, B_{20} CB and B_{20}CWB with diesel.

4.3.1Brake Torque

The brake torque recorded for $B_{15}$is almost near to neat diesel fuel. Pure diesel fuel havehighbrake torque than other biodiesel blends. And castor biodiesel which has a little increment of torque as compared towaste cooking oil biodiesel. The mixture of waste cooking oil and castor biodiesel blends results become between reading of castor biodiesel and waste cooking oil biodiesel.

Table 4.2Brake torque of B_0, B_{15}CB, B_{15}WB and B_{15}CWB

Speed (rpm)	Brake Torque (Nm)			
	B_0	B_{15}CB	B_{15}WB	B_{15}CWB
1000	21.3	20.5	20	19.7
1250	24.2	23.4	21.8	23.5
1500	25	24.4	23.5	24
1750	24.11	23.3	22.2	22.8
2000	21.78	21.2	20.5	20.9

2250	19.5	18.9	18.3	18.8
2500	16.8	16	15.2	15.6

From above tabulated table it can draw the following figure to compare the performance. It shows the variation of brake torque relative to the engine speed for all tested fuel samples of B_0, B_{15}CB, B_{15}WB and B_{15}CWB.

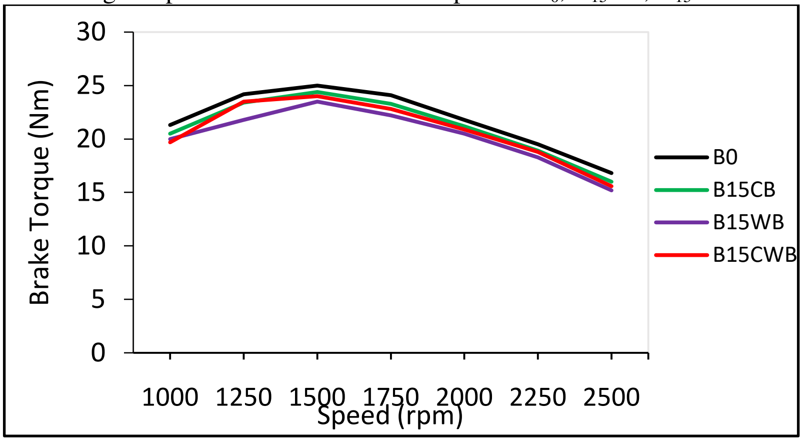

Figure 4.1Braketorque vs. engine speed for B_0 and B_{15}

From the figure 4.1 the maximum brake torque observed by B_0 was 25 Nm at 1500 rpm of engine speed. For B_{15}CB it was 24.4 Nm at same engine speed. The curve shows that the same trend with the curve perceived by B_0. But the value of torque observed by B_{15}CB was lower than B_0. And for B_{15}WB it was 23.5Nm which is lower than B_0, B_{15}CB and B_{15}CWB. Thebrake torque observed by B_{15}CWB was 24 Nm which is lower than $B_0$and B_{15}CB while compared to B_{15}WB it was higher. According to result shown, at lower speed the value of brake torque was slightly smaller and as the engine speed increases the torque of the engine become reduced.

Next to B_{15}, the following table shows the experimental results achieved for B_0 and B_{20}. The data is almost near to the values recorded for B_{15} but it have little reduction.

Table 4.3Braketorque of B_0, B_{20}CB, B_{20}WB and B_{20}CWB

Speed (rpm)	Brake Torque (Nm)			
	B_0	B_{20}CB	B_{20}WB	B_{20}CWB
1000	21.3	20.12	19.25	20
1250	24.2	23.06	22.3	21.56
1500	25	24.25	23.25	23.8
1750	24.11	23.25	22	23.14
2000	21.78	20.9	19.8	20.4
2250	19.5	18.78	18	18.61
2500	16.8	15.65	14.7	15.2

Below figure shows the variation of brake torque relative to the engine speed for all tested fuel samples of B_0, B_{20}CB, B_{20}WB and B_{20}CWB.

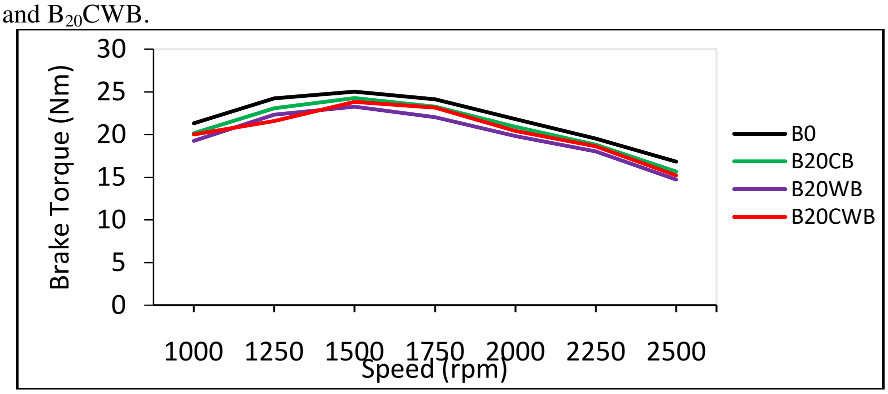

Figure 4.2Brake torque vs. engine speed for B_0 and B_{20}

From the figure 4.2 the maximum brake torque observed by B_{20}CBwas 24.25 Nm at 1500 rpm of engine speed. It have little difference as compared to $B_0$and B_{15}CB. For B_{20}WB it was 23.25 Nm at same engine speed. And for B_{20}CWB result become 23.8 Nm which isfound between B_{20}CB and B_{20}WB values.

From both figures the curves of the brake torque versus engine speed has almost similar trends with neat diesel fuel (B_0) for all tested fuel samples. It can be seen that brake torque is minimum at low speed and increases as engine speed increases. As engine speed increases further, brake torque reaches a maximum and then decreases. The

reason is that at very low engine speed, the cylinders don't take in all the air they can. As increase in engine speed and get to peak torque, the engine is sucking in peak amount of air. After peak torque, as engine speed gets high the air is restricted by the inlet, so torque begins to drop.
Also brake torque reduced at lower engine speeds is due to heat losses. The percentage heat rejected to coolant is more at lower speed. When engine is running at low speed, there is a relatively longer time for heat conduction to engine parts and then to the coolant; this will reduce the heat available for doing work. But as engine speed increases there is a relatively shorter time for heat loss and torque reduction due to heat loss will be minimal, thus brake torque rises up to certain point.
From results, the brake torque of B_0 fuel is higher than that of B_{15}WB, B_{15}CB, B_{15}CWB, B_{20}WB, B_{20}CB and B_{20}CWB. The maximum brake torque was recorded at 1500 rpm, and it was 25 Nm, 24.4 Nm, 23.5 Nm and 24 Nm for B_0, B_{15}CB, B_{15}WB and B_{15}CWB respectively. The brake torque reduction for B_{15}CB, B_{15}WB and B_{15}CWB as compared to B_0 was 2.4%, 6% and 4% respectively. And for B_{20}CB, B_{20}WB and B_{20}CWB brake torque reduced by 3%, 7% and 4.8% respectively. The reason of reduction of brake torque with the blended fuels is due to the higher viscosity and lower calorific value of the biodiesel fuel. But castor biodiesel blend produces large amount of torque than waste cooking oil biodiesel. Also, the mixture of waste cooking oil biodiesel and castor biodiesel blend produces the higher torque than waste cooking oil biodiesel blend.

4.3.2Brake Power

The brake power founded relative to the engine speed for all tested fuel samples of B_0, B_{15}CB, B_{15}WB, B_{15}CWB, B_{20}CB, B_{20}WB and B_{20}CWB are given below. Pure diesel fuel have high amount of brake power than other biodiesel blends. And castor biodiesel which has high brakepower as compared to waste cooking oil biodiesel and their mixtures. The mixture of waste cooking oil and castor biodiesel blends results become between reading of castor biodiesel and waste cooking oil biodiesel.

Table 4.4Brakepower of B_0, B_{15}CB, B_{15}WB and B_{15}CWB

Speed (rpm)	Brake power (kw)			
	B_0	B_{15}CB	B_{15}WB	B_{15}CWB
1000	2.23	2.14	2.09	2.06
1250	3.16	3.06	2.85	3.07
1500	3.92	3.83	3.69	3.76
1750	4.41	4.26	4.06	4.17
2000	4.56	4.44	4.29	4.37
2250	4.59	4.45	4.31	4.43
2500	4.39	4.18	3.97	4.08

The following figure shows the variation of brake power relative to the engine speed for all tested fuel samples of B_0, B_{15}CB, B_{15}WB and B_{15}CWB.

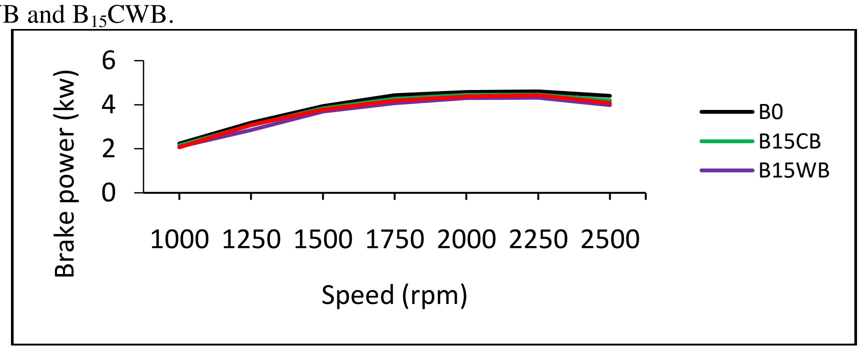

Figure 4.3Brakepower vs. engine speed for B_0 and B_{15}

From figure 4.3 above the maximum power produced by B_0 is 4.59 kW at engine speed of 2250 rpm. For B_{15}CB it was 4.45 kW at same engine speed. The curve shows that the same trend with the curve perceived by B_0. But the brake power observed by B_{15}CB was lower than B_0. And for B_{15}WB it was 4.31 kW which is lower than B_0, B_{15}CB and B_{15}CWB. The power of B_{15}CWB was 4.43 kW which is lower than B_0 and B_{15}CB while compared to B_{15}WB it was higher. The curve shows that at lowest engine speed the power is lower, but as the engine speed increasing the power was also increased until it reaches its maximum and then start to fall down at higher engine speed.
The table 4.5 below shows the value of brake power for B_0, B_{20}CB, B_{20}WB and B_{20}CWB with respect to the engine speed.

Table 4.5Brakepower of B_0, B_{20}CB, B_{20}WB and B_{20}CWB

Speed (rpm)	Brake power (kw)			
	B_0	B_{20}CB	B_{20}WB	B_{20}CWB
1000	2.23	2.1	2.01	2.09

1250	3.16	3.01	2.91	2.82
1500	3.92	3.81	3.45	3.73
1750	4.41	4.26	4.03	4.24
2000	4.56	4.37	4.14	4.27
2250	4.59	4.42	4.28	4.38
2500	4.39	4.29	4.10	4.23

The figure shown below provides variation of brake power relative to the engine speed for tested fuel samples of B_0, B_{20}CB, B_{20}WB and B_{20}CWB.

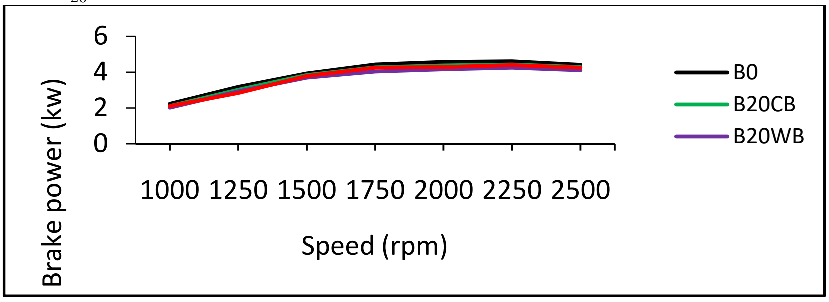

Figure 4.4Brakepower vs. engine speed for B_0 and B_{20}

From above figure the maximum brake power produced by B_0 is 4.59 kW at engine speed of 2250 rpm. For B_{20}CB, B_{20}WB and B_{20}CWB it was 4.42 kW, 4.28 kW and 4.38 kW respectively at the same engine speed. The curve shows that the same trend with the curve observed by B_0. But the brake power observed by B_{20} was lower than B_0 and B_{15}. At lower engine speeds brake power is minimum but as the engine speed increases the power increases continuously and as the engine speed keep increasing the power start to decrease.

According to experimental results, the maximum brake power produced by B_0 is 4.59 kW at engine speed of 2250 rpm. For B_{15}CB, B_{15}WB and B_{15}CWB it was 4.45 kW, 4.31 kW and 4.43 kW respectively. The brake power reduction for B_{15}CB, B_{15}WB and B_{15}CWB as compared to $B_0$was 3.05%, 6.1% and 3.48% respectively. For B_{20}CB, B_{20}WB and B_{20}CWB it was 4.42 kW, 4.28 kW and 4.38 kW in which power reduced by 3.7%, 6.75% and 4.5% respectively.

From figures 4.3 and 4.4 at low engine speed the friction power is relatively low and therefore brake power increases with speed. As engine speed increases, the friction power starts to increase at continuously greater rate and therefore power reaches a peak and starts reducing. As engine speeds above the usual operating range, friction power increases very rapidly. Another reason for the falling off power at high speed is less complete filling of the cylinder consequent on greater reduction of pressure. As engine speed increases there is relatively shorter opening duration for the intake valves, the valves close before the cylinder is fully filled with air fuel mixture, consequently brake power starts to fall.

4.3.3Brake Specific Fuel Consumption

From different experimental results, the specific fuel consumption of biodiesel blends is higher when compared to pure diesel. This is due to biodiesel is an oxygenated fuel it consumed quickly. The higher fuel viscosity also reduce the fuel atomization, and could effect in higher unburned HC emission and fuel consumption. At lower engine speed there is a higher fuel consumption of the engine and it reduced at medium speed. At the higher engine speed the fuel consumption was also increased. The table given below show brake specific fuel consumption B_0, B_{15}CB, B_{15}WB and B_{15}CWB with engine speed.

Table 4.6Brakespecific fuel consumption for B_0, B_{15}CB, B_{15}WB and B_{15}CWB

Speed (rpm)	Brake Specific fuel consumption (kg/kwh)			
	B_0	B_{15}CB	B_{15}WB	B_{15}CWB
1000	0.1602	0.1695	0.1761	0.1747
1250	0.1206	0.1255	0.1552	0.1406
1500	0.1153	0.1308	0.1454	0.1352
1750	0.1256	0.1319	0.1518	0.1466
2000	0.1295	0.1354	0.1476	0.1409
2250	0.1517	0.1672	0.1809	0.1654
2500	0.1921	0.2217	0.2114	0.2027

The following figure shows the variation of brake specific fuel consumption relative to the engine speed for all tested fuel samples of B_0, B_{15}CB, B_{15}WB and B_{15}CWB.

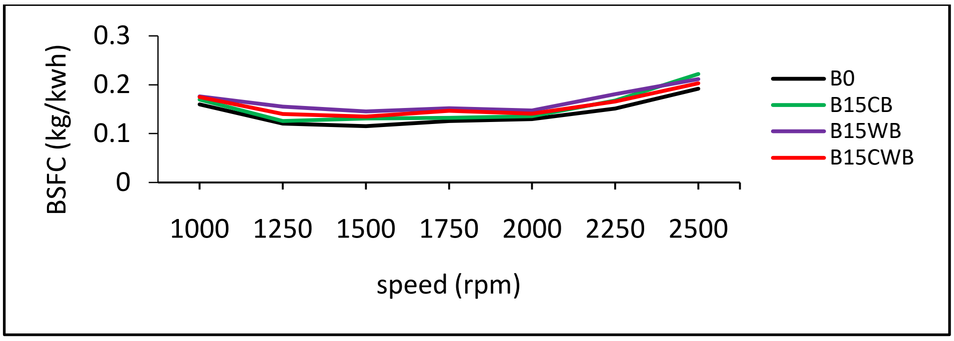

Figure 4.5Brakespecific fuel consumption vs. engine speed for B_0 and B_{15}

From figure 4.5 above the average brake specific fuel consumption for B_0 is 0.1421 kg/kWh. For B_{15}CB, B_{15}WB and B_{15}CWB it was 0.1546 kg/kWh, 0.1669 kg/kWh and 0.158 kg/kWh respectively. The curve shows that the same trend with the curve observed by B_0. But the value of specific fuel consumption observed by B_{15} was higher than B_0. At lower engine speeds specific fuel consumption is higherand as the engine speed increases the specific fuel consumption increases continuously.

Next to B_{15}, the following table shows the experimental results achieved for B_{20}. The data is almost near to the values recorded for B_{15} but it have increment. [5] discussed a project, in this venture a Bubble-Type humidification technique is utilized as a part of a PEM energy unit examination to enhance the effectiveness of the framework and the life time of the film is made strides. It likewise expands the dampness content in the layer and influences the reactant to gas stream ceaseless. Because of humidification, the moistness proportion can be balanced effortlessly and furthermore the power module setup turns out to be little and less weight. Proton Exchange Membrane (PEM) energy unit are progressively being refered to by governments as a conceivable pathway to the lessening of ozone harming substance discharge. It is one of the imminent power hotspots for car applications, train appliances, stationary cogeneration frameworks, and portable electronic gadgets. In any case, the dryness of the layer of a PEM power module diminishes the ionic conductivity, bringing about execution lessening. The applications where energy unit innovation is utilized can be partitioned into three primary classifications: versatile power era (for cell phones and convenient helper control), stationary power era (conveyed control era, go down power sources, and network associated control stations), and transportation (autos, open transportation, and overwhelming hardware). Prepare apparatuses like Fans, lighting may likewise keep running on PEM fuel cell. This new hydrogen prepare is along these lines ideal for shorter, calmer extends of the system that charge hasn't yet come to.

Table 4.7Brakespecific fuel consumption for B_0, B_{20}CB, B_{20}WB and B_{20}CWB

Speed (rpm)	Brake Specific fuel consumption (kg/kwh)			
	B_0	B_{20}CB	B_{20}WB	B_{20}CWB
1000	0.1602	0.1705	0.1807	0.1755
1250	0.1206	0.1404	0.1645	0.1571
1500	0.1153	0.1377	0.1544	0.1473
1750	0.1256	0.1401	0.1704	0.1471
2000	0.1295	0.1445	0.1689	0.1505
2250	0.1517	0.1714	0.1885	0.1814
2500	0.1921	0.2257	0.2063	0.2118

The figure shown below provides variation of brake specific fuel consumption relative to the engine speed for tested fuel samples of B_0, B_{20}CB, B_{20}WB and B_{20}CWB.

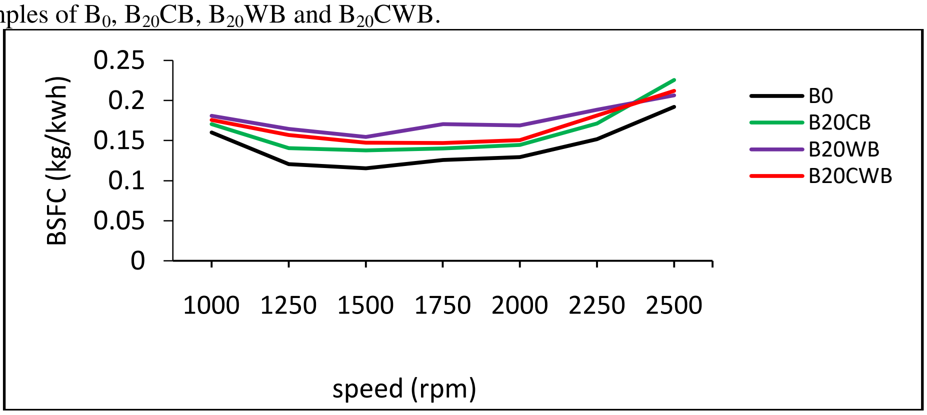

Figure 4.6Brakespecific fuel consumption vs. engine speed for B_0 and B_{20}

From figure 4.6 above the average brake specific fuel consumption for B_{20}CB, B_{20}WB and B_{20}CWB was 0.1615 kg/kWh, 0.1762 kg/kWh and 0.1672 kg/kWh respectively. The average brake specific fuel consumption value of

B_{20}WB is higher which followed by B_{20}CWB and B_{20}CB.From both figures 4.5 and 4.6 the average brake specific fuel consumption for B_{15}CB, B_{15}WB, B_{15}CWB, B_{20}CB, B_{20}WB and B_{20}CWB was 0.1546, 0.1669, 0.158, 0.1615, 0.1762 and 0.1672 kg/kWh respectively. The average brake specific fuel consumption increment for B_{15}CB, B_{15}WB, B_{15}CWB, B_{20}CB, B_{20}WB and B_{20}CWBwas 8.74%, 17.42%, 11.16%, 13.59%, 20.98% and 14.65% respectivelyas compared with diesel fuel.

From the figure 4.5 and 4.6 shown above since biodiesel has lower calorific value than diesel fuel, the specific fuel consumption of biodiesel blended fuels become higher compared to the diesel. The brake specific fuel consumption is higher at low speed because at this speed incomplete combustion of fuel ishappen. Brake specific fuel consumption has little reduction at middle speed, because at middle speed the best cylinder filling occur and good engine breathing is taken at these speeds. At higher engine speed the fuel consumption increase, because the friction loss and energy loss exists.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Under this study a lot of activities has been done from starting to end which includes extraction and collection of oil, production of biodiesel, characterization of biodiesel, engine performance test of castor biodiesel, waste cooking oil biodiesel and mixture of castor and waste cooking oil biodiesel blends were done. As it is observed important conclusion that can be drawn from the work done is that the biodiesel oils can’t be used directly in the diesel engine. Several problems happen if unmodified fuel is used and viscosity was the major factor. It has been found that blending biodiesel oil with diesel could be an appropriate way to reduce the viscosity of vegetable oils and to make them fit for their use in the present diesel engines without any modification.

From each results the following conclusions were formulated.

- Biodiesel was prepared from castor oil and waste cooking oil with methanol, sulfuric acid and KOH through transesterification method in the laboratory scale production.
- The oil extracted from the castor seed was 30% mass by mass ratio.
- To reduce the free fatty acid and viscosity values, two-step transesterification process was performed.
- Biodiesel produced from castor and waste cooking oil is completely miscible with each other and with diesel fuel thus allowing the use of blends of diesel and biodiesel in any percentage.
- From characterization result, fuels produced at laboratory scale show the density and total acidity of castor biodiesel was higher than waste cooking oil biodiesel. The kinematic viscosity of waste cooking oil biodiesel is higher than castor oil biodiesel. The mixture of both biodiesel gives less viscosity and density.The flash points of castor oil, waste cooking oil and blend of both biodiesel were within standard.
- Brake torque for mixture of B_{15}CWB blend is higher than B_{15}WB but lower than B_{15}CB. The brake torque produced by B_{15}CWB is 4% less than that of petro diesel. It is the same forB_{20}CWB which have higher torque than B_{20}WB but lower than B_{20}CB. The percentage reduction of brake torque for B_{20}CWB is 4.8% as compared to pure diesel.
- The brake power observed by B_{15}CWB is higher than B_{15}WB but lower than B_{15}CB. It is 3.48% less than pure diesel. And B_{20}CWB show higher power than B_{20}WB but lower than B_{20}CB.The brake power of B_{20}CWB is 4.5% less than as compared to pure diesel.
- The average brake specific fuel consumption for B_{15}CWB is higher than B_{15}CB but lower than B_{15}WB. It shows 11.16% increment than pure diesel. Also the average brake specific fuel consumption for B_{20}CWB is14.65% higher than pure diesel.
- From performance test result, the brake power and torque somewhat decrease as compared with petrol diesel because biodiesels are less energy contentsthan petro diesel. Whereas the brake specific fuel consumption increase for biodiesel blends since biodiesel fuels are oxygenated fuels, it consumed quickly than petro diesel.
- The mixture of castor and waste cooking oil biodiesel at 20/80 blend (B_{20}CWB) have almost similar performance characteristic as 15/85 blend (B_{15}CWB) in diesel engine. Therefore, to use more biodiesel blend, B_{20}CWB can become an alternative source of fuel in the future to reduce the production cost of castor biodiesel and improve low performanceof waste cooking oil biodiesel.

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