STUDY OF JATROPHA CURCAS BIODIESEL BLEND WITH FOSSIL DIESEL THERMAL CHARACTERIZATION, ENGINE PERFORMANCE AND EMISSION COMPARE TO FOSSIL DIESEL

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Muhammad Zaki Bin Mohd Zin 14066

ABSTRACT

Alternative fuels research gain interest among researchers these recent years due to the world today is faced with serious global warming and environmental pollution. Besides, fossil fuel will become rare and faces serious shortage in the near future. Biodiesel as a cleaner renewable fuel has been considered as the best substitution for diesel fuel due to it being used in any compression ignition engine without any modification. Biodiesel can be produced and derived from the plant oil such as Jathropa Curcas, Calophyllum inophyllum, Palm Oil and etc. In order to utilized biodiesel the characteristic of the fuel need to be understand, this is because the composition of the fuel is different from the fossil diesel. This study has been conducted in order to investigate the effect of biodiesel blending on combustion at different percentages to diesel. The methodologies for conducting this research analysis project are divided into four categories which are based on past research papers, journal and articles related to this topic, testing and analysis the biodiesel with fossil diesel blend 20% and 10% at different percentage exposed to the isothermal heating with heating rate of 10°C/min using TGA, engine performance analysis and lastly the emission analysis both based on past research in order to compare it between Jatropha Curcas Biodiesel Blends with fossil diesel. The result will be shown to the readers in the term of comparison between Jatropha Curcas Biodiesel Blends with fossil diesel in term of thermal characterization, engine performance and the emission produced compared to the fossil diesel in order to justify the similarity between those fuels. By doing this, the conclusion can be made either Jatropha Curcas Biodiesel Blends can be used as a substitute to the fossil diesel or not.

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ABBREVIATIONS

JCB – Jatropha Curcas Biodiesel

CHAPTER 1: INTRODUCTION

BACKGROUND OF STUDY

In order to reduce the dependency of using fossil fuels, the interest among researchers in search of alternative fuels raise this recent years. This is happened due to the increasing price of fossil fuels, depletion of fossil fuel resources and increasing of environmental pollution awareness of using fossil fuels as the main energy sources. One of the interesting alternative fuels is biodiesel. Biodiesel is one of the promising alternative fuels to substitute the fossil diesel using nowadays. Biodiesel made from renewable sources range from the edible Palm Oil, and Soy to the inedible Jatropha Oil and some of them come from the animal fat such as Catfish Fat. Furthermore, biodiesel emit less pollution thus it is environmental friendly. However, before biodiesel can be used to substitute fossil diesel, the characteristic of the biodiesel need to be investigate and test.

Biodiesel need to meet certain requirement before it can be used without any problem. The main criteria such as calorific value, viscosity, and Cetane number need to be consider so that the figure will be as near as possible or to the fossil diesel. Many ways of experiment was conducted to study the behavior of biodiesel such as thermal characterization by using Thermogravic analysis, engine performance testing, and emission analysis. The main objective to study the behavior of the biodiesel roughly to measure whether it is worth to use biodiesel as an alternative energy to substitute the fossil diesel and to gain less optimization need to be done on the conventional internal combustion engine that lead to the cost saving.

PROBLEM STATEMENT

Investigations on alternative fuels are conducted due to several reasons such as environmental pollution and global warming, increasing cost and the predicted reduction of conventional petroleum-derived fuels etc. Biodiesel as a new energy source has drawn attention of many researchers. In order to utilized biodiesel the characteristic of the fuel need to be understand, this is because the composition of the fuel is different from the fossil diesel. This study has been conducted in order to investigate the effect of biodiesel blending on combustion at different percentages to diesel. Therefore, fossil diesel and blend of JCB with fossil diesel at different percentages will be exposed to isothermal heating with heating rate of 10°C/min by using Thermogravimetric Analysis, engine performance analysis, and lastly the emission will be analyse.

OBJECTIVES

The main aim of the study is to analyses Jatropha Curcas Biodiesel blend with fossil diesel thermal characterization, engine performance and emission analysis compare to fossil diesel in order to justify either JCB blends can be utilized as new source of fuel.

SCOPE OF THE STUDY

The scope of the study will be narrow down in comparing the JCB blends with fossil diesel with the fossil diesel in order to find the similarities by using the Thermogravic Analysis, engine performance and the emission analysis produce by using 3 samples which was fossil diesel, 10% JCB blends with fossil diesel and 20% JCB blends with fossil diesel.

CHAPTER 2: LITERATURE REVIEW

Due to the several reasons such as environmental pollution and global warming, increasing cost and the predicted reduction of conventional petroleum-derived fuels etc, it have driven interest among scientist and researcher in alternative fuels research this recent years. Dependence on petroleum derived fuels need to be reduce for better economy and environment because 80% of the primary energy supply today still comes from fossil fuels [1]. In extent, Biodiesel as a new energy source has drawn attention of many researchers.

Biodiesels can be made using many sources of edible and inedible plant oil including Jathropa and it also can be derived from animal fats [2-6].However, the use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with human food chain.In addition, it is impossible to justify the use of edible oil for biodiesel production as the demand for vegetable oils for food has increased tremendously in recent year. Moreover, it is expensive to use edible oil for fuel. Hence, the contribution of non-edible oils such as Jatropha will be significant for biodiesel production. Therefore, in some countries like India which faces a deficient of edible oil, Jatropha oil becomes the choice for biodiesel [1,8].

Figure 1 : Jatropha fruit and it seeds

Jathropha Curcas is a large shrub or small tree and it is belong to the genus Euphorbiaceae. This plant producing seed containing with oil seed ranges from 30% to 50% by weight and the kernel ranges from 45% to 60%. Jatropha plants are native in Tropical America and abundantly found in many tropical and sub-tropical regions throughout Africa and Asia [9,10]. It can be grown in low to high rainfall areas commercially or as hedge on the boundaries of field and requires very little irrigation and grows in all types of soils. Furthurmore, Jatropha is well adapted to semi-arid conditions, however for better crop performance jatropha need more humid condition. In addition, Jathropa plant is drought resistance and capable to grow and survive on marginal soils and can reclaim fallowed agricultural which give it an extra advantage over other non-edible oil sources [11,13].

Jatropha oil is belongs in non-edible vegetable oil triglycerides type which have methyl ester properties close to diesel fuel and able to reduce CO_2 to the atmosphere when it is utilized in diesel engines making it a potential alternative diesel fuel [14]. However, before diesel can be substitute with biodiesel, firstly the parameters that affect the combustion phenomenon of the biodiesel need to be understood as it has direct impact on the thermal efficiency and emission. This is because, in present energy scenario lots of efforts focusing the improvement of the thermal efficiency of IC engines with reduction in emission. Biodiesels can be directly used in diesel engine, yet there are many issues related to optimum performance and emission need to be addressed [15]. Hence, the potential of using Jatropha as a feedstock for biodiesel production has attracted much attention [16]. Due to these attractive advantages, a lot of research on the effects of biodiesel combustion has been conducted, using various methods [17, 18].

Biodiesel has combustion characteristics similar to diesel and the engine power output and brake power efficiency was found to be equivalent to diesel fuel. In addition, biodiesel blends has shorter ignition delay, higher ignition temperature and pressure as well as peak heat release compare to diesel fuel [19]. Table 1 show the comparison of important properties of commonly used biodiesels with diesel. Interestingly, it can be seen in both tables that Jatropha biodiesel has similar properties with fossil diesel especially the calorific value,density and cetane number[15,21].

Comparison of biodiesel properties.

Fuel	Density at 15 °C (kg/m³)	Cetane number	Viscosity at 37.8 °C (cSt)	Calorific value (MJ/kg)
Rape seed biodiesel	865–886	51–54	4.5–4.7	36.5–40.5
Soy bean biodiesel	872–885	37–45	4.3–4.5	33.5–39.8
Sunflower biodiesel	860–878	45–52	4.6	33.5–40.6
Jatropha biodiesel	878–880	50–51	4.4–5.6	38.5
Diesel	815–863	45–57	2.0–5.0	35.3–44.6

Table 1 Comparison of biodiesel properties [15, 21]

From the Table 2 Major difference of Jatropha biodiesel compared to fossil diesel is the higher viscosity that will cause durability problems as it will contribute to higher carbon deposit in engines. Nevertheless, Jathropha Biodiesel has lower calorific value than the fossil diesel but the different is not significantly higher [1].

Physico-chemical properties of different biodiesels.

	Rape seed	Rubberseed	Sunflower	Cottonseed	Soybean	Neem	Linseed	Palm	Jatropha	Diesel
Property	[11–15]	[16]	[17–18]	[18]	[17–18]	[4]	[17]	[17]	[10,19–20]	[11–21]
Calorific value (MJ/kg)	36.55–40.5	36.5	40.56	40.32	39.76	40.1	40.37	40.39	38.5–42	42–45.9
Relative density	0.882	0.874	0.878	0.874	0.885	0.87	0.874	0.87	0.878–0.885	0.82–0.867
Kinematic viscosity at 40 °C (cSt)	4.5	5.81	4.5	4	4.08	7.2	3.59	4.5	3.7–5.8	2.5–5.7
Cetane number	49–52.9	n.a	49–52	51.2–55	40–53	51	52	50–65	46–70	45–55
Flash point (°C)	170	130	85	70–110	69	63	172	174	170–191	50–86
Fire point (°C)	183	n.a	n.a	n.a	n.a	84	n.a	188	178–197	60–92
Cloud point (°C)	−4	4	1	1.7	−2	n.a	1.7	8 to 14	(−11 to 16)	(−15 to 5)
Pour point (°C)	−12	−8	−15	−3	−3.8	n.a	−15	6	(−15 to 13)	(−35 to −15
Sulfur content (%wt)	0.01	n.a	0.0047	0.01	0.01	0.004	50 ppm	n.a	0.0024	1.2–2

n.a – not available.

Table 2 Physico-chemical properties of different biodiesel [1]

Thermal efficiency and the engine performance run on Jatropha Biodiesel are comparable to pure diesel fuel but the fuel consumptions of engines are slightly higher [23].The experimental results of the engine performance fuel with Jatropha biodiesels and its blends similar to the engine performance fuel with fossil diesel [1].

Compared to neat jatropha biodiesel, using Jatropha Biodiesel blend with fossil diesel in the compression ignition engine shows a significant improvement and the specific fuel consumption reduced due to the decrease in viscosity of Jatropha bidiesel. For 50% blends of jatropha biodiesel with fossil diesel, acceptable thermal efficiency of 26.1% of engine achieved. For lower percentage blending of Jatropha Biodiesel with fossil diesel showed slightly higher exhaust gas temperature yet still much lower than neat Jatropha Biodiesel [10]. Reddy and Ramesh [21] experiment with neat jatropha biodiesel with fossil diesel into modified diesel engine for optimization shows that thermal efficiency of the modified engine with neat jatropha oil lower (28.9%) than fossil diesel (32.1%). Nonetheless, emission of HC, NO and smoke were lower than fossil diesel by 33.3%, 33.9% and 25.9% respectively at full load [23]. Sahoo et al. [22] study of characterisitics of Jatropha based biodiesel as fuel in compression ignition engine shows that maximum increase in power is 50% Jatropha Biodiesel at 2000 and 2100rpm while the brake specific fuel consumptions for all blends increases with the blends ratio and decrease with speed. 20% Jatropha Biodiesel blends resulting the best brake specific fuel consumption improvement [22]. Forson et al. [23] tested diesel fuel, jatropha oil and blends of diesel and jatropha oil in proportions of 97.4/2.6,80/20, and 50/50% by volume on a single-cylinder direct injection engine resulting increase in BTE, brake power and reduction of specific fuel consumption [24].

Investigation on suitability and evaluation of the performance and emission characteristics of the compression ignition engine running on unheated and preheated jatropha biodiesel shows that the engine performance fueled with unheated Jatropha Biodiesel is little less to the performance with fossil diesel fuel.Yet the thermal efficiency of the engine was higher and brake specific energy consumption was lower when fuelled with preheated Jatropha Biodiesel compared to diesel fuel [25]. By heating the Jatropha oil between 90°C and 100°C is enough to reduce the viscosity and close range to diesel. In the other hand, viscosity of Jatropha blends (up to 30%) was also close to diesel. Brake specific fuel consumption increase to with the higher percentage of jatropha biodiesel blends compared to fossil diesel in all load condition but the thermal efficiency is lower for higher percentage of Jatropha Biodiesel blends rather than fossil diesel [26]. Biodiesel is an environmentally benign source of energy, as it is biodegradable, non-toxic and “carbon neutral” [27].This is a promising alternative to fossil fuels [26].

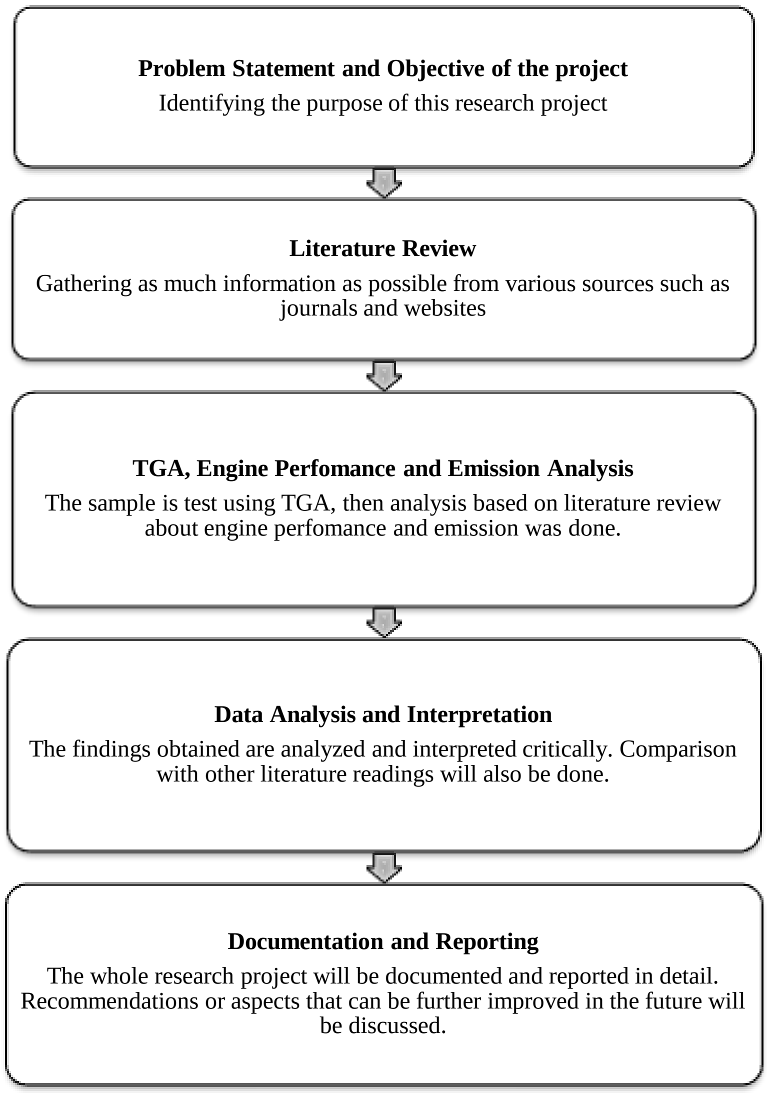
CHAPTER 3: METHODOLOGY

RESEARCH METHODOLOGY

The methodologies for conducting this research analysis project are divided into four categories;

1) Based on past research papers, journal and articles related to this topic, the hypothesis was made as the reference point of the study and research that will be done.
2) Testing and analysis the biodiesel with fossil diesel blend 20% and 10% at different percentage exposed to the isothermal heating with heating rate of 10°C/min using TGA.
3) Engine performance analysis based on past research in order to compare the performance of the engine that fueled by JCB Blends compare to fossil diesel.
4) Emission analysis based on past research in order to compare the emission produced by all the samples.

PROJECT FLOW



STUDY PLAN (GANTT CHART)

No	Study Plan	Number of Week															
			1	2	3	4	5	6	7	MID SEMESTER BREAK	8	9	10	11	12	13	14
1	Preparation	P															
		A															
2	Lab process	P															
		A															
3	Submission of progress report	P															
		A									●						
4	Research analysis	P															
		A															
5	Poster Presentation Preparation	P															
		A															
6	Poster Presentation	P															
		A													●		
7	Consultation and enhancing the project	P															
		A															
8	Dissertation and Technical Report	P															
		A															●
9	Final Presentation	P															
		A															●

● Key Milestone

Plan Process

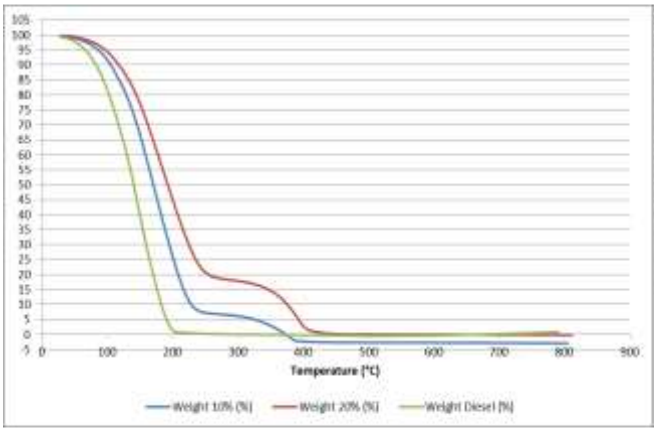
Actual Process

CHAPTER 4: RESULT AND DISCUSSION

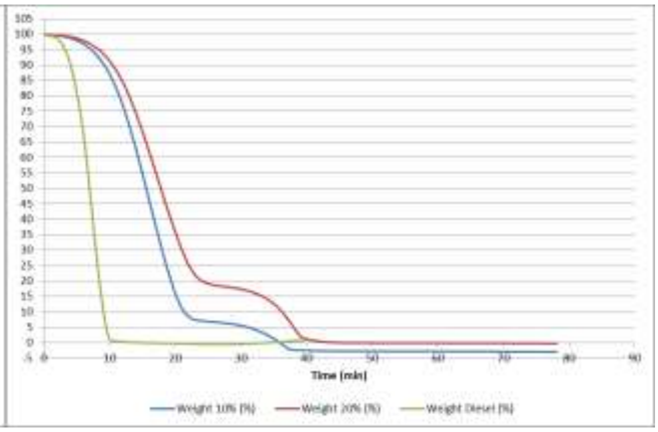
Thermogravimetric analysis (TGA)

Thermogravic analysis is a technique where the mass of the substance is moniterd against the fuction of temperature or time when the samples exposed to a cotrolled temperature program in a controlled atmosphere. Upon the heating process, the weight of the material will be increases or decreases. [1]

Thermal Characterization by Thermogravimetric Analysis (TGA)



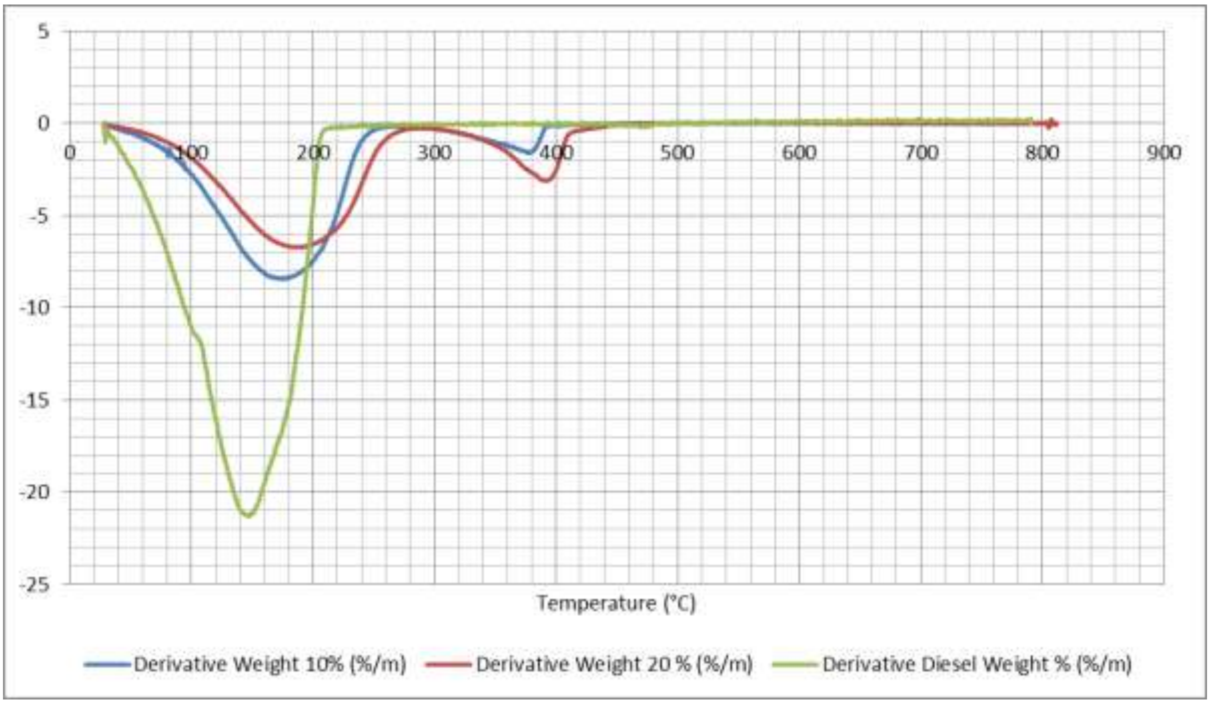
Graph 1: Fuel weight in percent against the temperature in degree Celsius.



Graph 2: Fuel weight percentage against the time in minute.

From the graph 1 and 2, as for the diesel, the graph shows that it is single step graph type while the other two samples shows double step graph. The step for 10% and 20% JCB blends with fossil diesel samples shows that it is corresponding to number of percent of the JCB added to the fuel. It can be seen that for 10% JCB blends, once the weight percent reach 10% the graph change and the step produced. Same goes with the 20% JCB blends samples, the step start to produce when the samples weight percentage reach 20%. This is happened because the different composition and density of JCB with fossil diesel causing it started to burn at separated temperature rather than together with the fossil diesel.

Graph 1 show the different between fossil diesels, 10% JCB blends with fossil diesel and 20% JCB blends with fossil diesel temperature taken in order to reach 0 % weight percentage. For fossil diesel, it need 200°C to reach 0% weight, while for 10% JCB blends with fossil diesel, it need about 390°C to reach 0% weight and for 20% JCB blends with fossil diesel, it need about 430°C to reach 0% weight. As the percentage of JCB blends with fossil diesel increase, the temperature to reach the 0% weight percentage also increased. This is happened because the vaporization of the sample decreased as the percentage of the JCB in the blends increased. Time taken to decrease the samples weight percentage also affected by the percentage number of JCB blends as per shown in the graph 2. It took almost 40 minutes for both 10% and 20% JCB blends with fossil diesel rather than 10 minutes for normal fossil diesel. This is happened because JCB took longer time to combust rather than fossil diesel due to its high flash point than fossil diesel.



Graph 3: 1st Derivative of Weight Lost against the temperature.

Graph 3 shows the information about 1st derivative peak temperature which indicates the point of greatest rate of change on the weight loss curve. It can be seen that the 1st derivative peak temperature for diesel is occurs at about 150^{o}C while for both JCB blends have 2 peak temperatures. For 10% JCB blends the highest peak occurs at 170^{o}C and 380^{o}C for the low peak while for 20% JCB blends the highest peak occurs at 190^{o}C and 390^{o}C for the low peak. There are different between these three samples highest peak temperature, however the different is not very much as it is only about 6.25% changes between 10% JCB blends compare to the fossil diesel and 12.5% for 20% JCB blends compare to the fossil diesel. It can be said that JCB blends with fossil diesel thermal characterization is significant with the fossil diesel.

Engine performance and emission analysis

Based on B.S. Chauhan et al (2012), the engine performance and emission research done by using Kirloskar made engine that have 1 cylinder, air cooled and direct injection. The specification of the engine as per shown in the table 3 below. [1]

Make	Kirloskar
Model	DAF 10
Rated brake power (bhp/kW)	10/7.4
Rated speed (rpm)	1500
Number of cylinder	One
Bore × Stroke (mm)	102 × 116
Compression ratio	17.5:1
Cooling system	Air Cooled (Radial Cooled)
Lubrication system	SAE 30/SAE 40, Forced feed
Cubic capacity	0.78 Lit
Injection pressure (bar)	200–205

Table 3 : Kirloskar Diesel Engine Specification[1]

The experiment was done by using 5%, 10%, 20%, 30% and 100% of JCB blends with fossil diesel and the comparison was made with the fossil diesel fuel.[1] As for M. Mofijur et al (2013), the engine performance and emission research was carried out by using YANMAR TF 120-M Diesel engine with the specification details as per shown In the table 4 below.[29]

Engine type	4 Stroke DI diesel engine
Number of cylinders	One
Aspiration	Natural aspiration
Cylinder bore × stroke (mm)	92 × 96
Displacement (L)	0.638
Compression ratio	17.7
Maximum engine speed (rpm)	2400
Maximum power (kW)	7.7
Injection timing (deg.)	bTDC 17.0
Injection pressure (kg/cm^2)	200
Power take – off position	Flywheel side
Cooling system	Radiator cooling

Table 4 : YANMAR TF 120-M engine specification table.[29]

The testing was carried out by using 3 samples which are fossil diesel, 20% JCB blends with diesel, and 10% JCB blends with fossil diesel.[29]

Engine performance

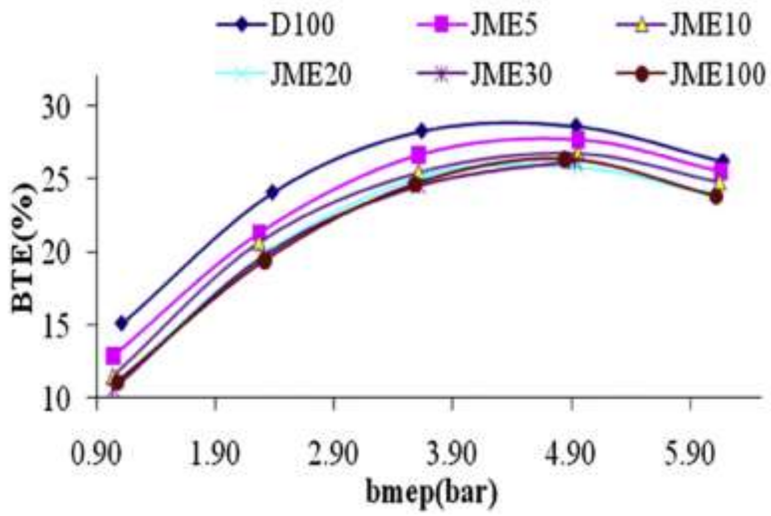


Fig. 2. Variation of brake thermal efficiency with brake mean effective pressure. [1]

As per shown in the Fig 2, Brake thermal efficiency of the JCB and its blend lower than diesel fuel on the entire range. This is happened because JCB and its blends have lower calorific value than diesel fuel.[1]

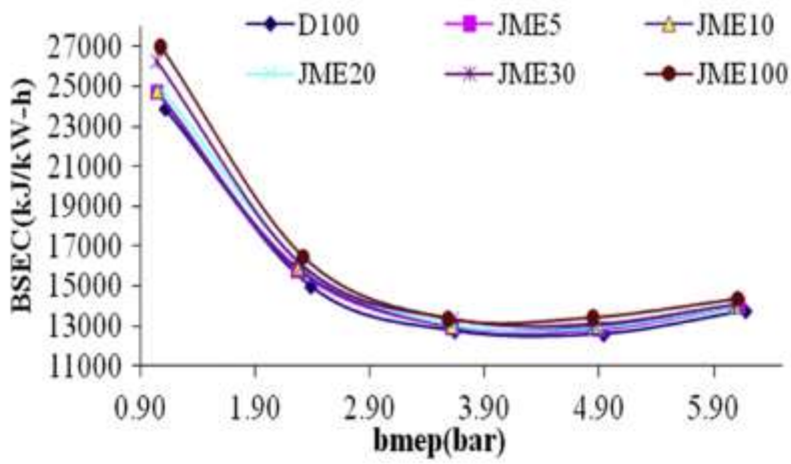


Fig. 3. Variation of brake specific energy consumption with brake mean effective pressure.[1]

In Fig 3. The brake specific energy consumption of the JCB and its blends is higher than fossil diesel due to the high density and low calorific value of the fuel. [1]

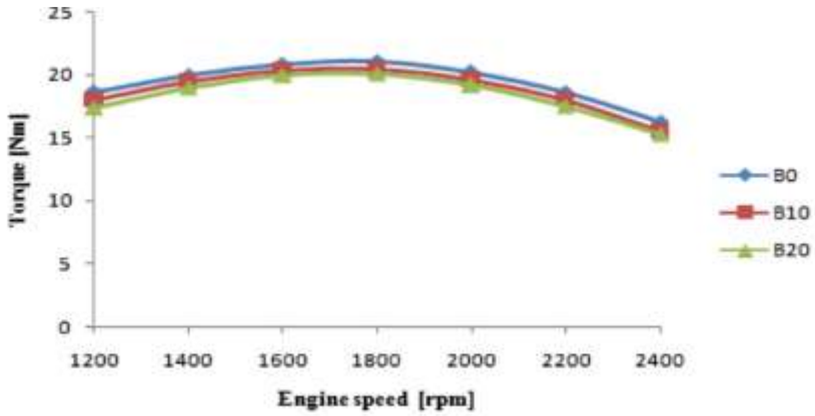


Fig 4 : Torque to speed characteristics[29]

As for M. Mofijur et al (2013) research done on engine performance run on JCB blends, it shows that in the fig 4, fossil diesel torque always higher compare to the JCB blends. The reduction of torque when using JCB blends as fuel happened because of the higher fuel viscosity and lower calorific value of the JCB. [29]

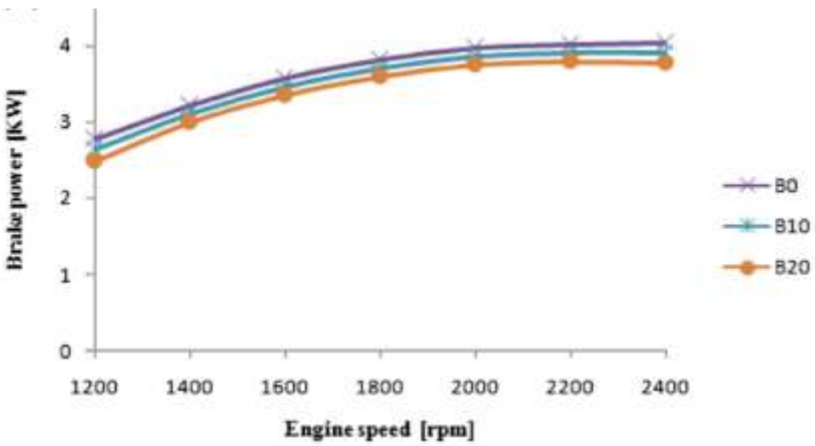


Fig 5: Brake power to speed characteristics [29]

Same things happened to the brake power. Fig 5 shows that both JCB blends have lower overall brake power than the fossil diesel results from lower calorific value and higher viscosity of JCB. [29]

Eventhough the results from both B.S Chauhan et al (2012) and M. Mofijur et al (2013) shows the reduction of performance when using JCB blends as a fuel, however, it can be seen that the overall percent of reduction of the performance is small and not more than 12%. It can be said that actually JCB blends have similarity with the fossil diesel. [1 , 29]

Emission

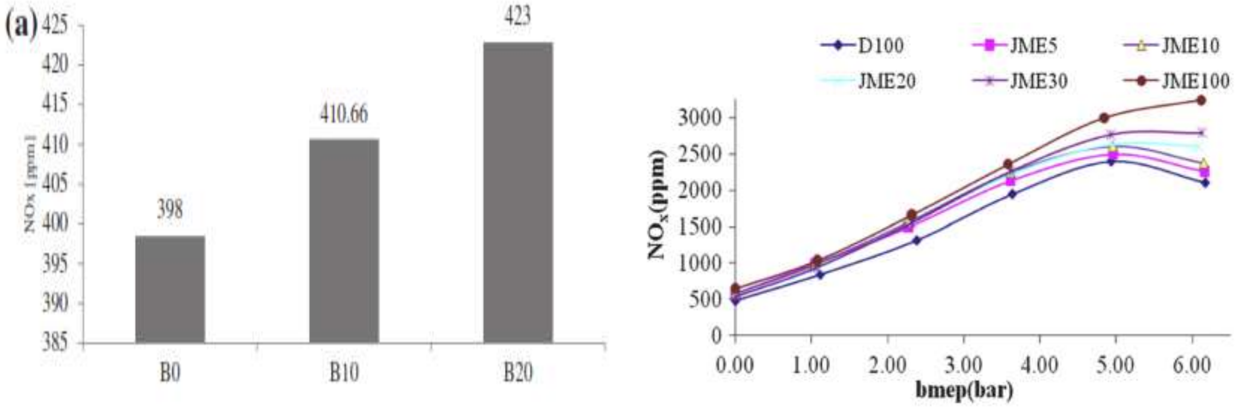


Fig 6 : Both result from B.S Chauhan et al(2012) and M. Mofijur et al(2013) on NOx production.[1,29]

Both chart and figure in figure 6 shows that the JCB blends have higher NOx emission than fossil diesel fuel. NOx emission is related to higher peak combustion temperature where the fuel with higher heat release rate in the premix combustion phase and lower heat release rate in late combustion phase will increase NOx emission. [1 , 29]

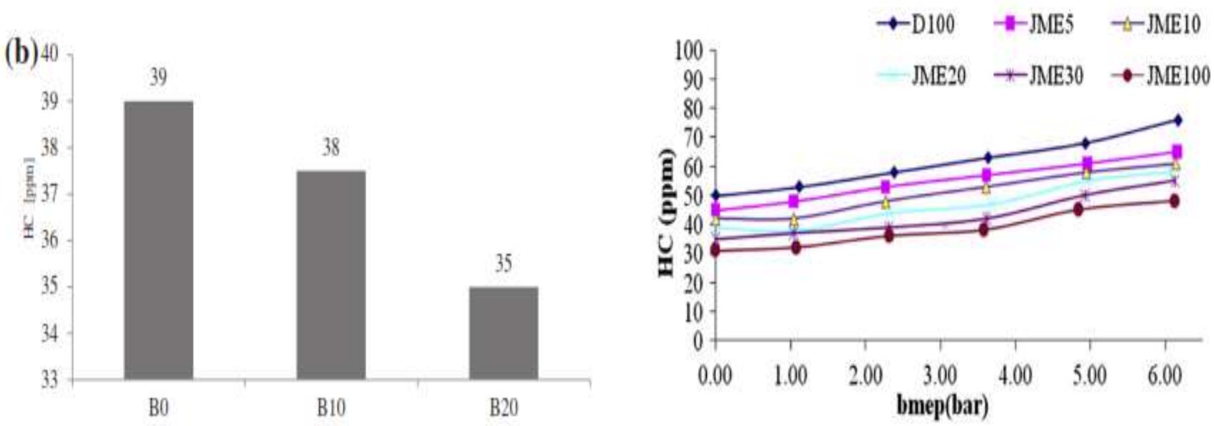


Fig 7 : Both result from B.S Chauhan et al(2012) and M. Mofijur et al(2013) on HC production.[1,29]

From Fig 7, it shows that the unburnt hydrocarbon from the JCB blends is lower than fossil diesel. The higher oxygen content in the JCB helps to complete the combustion and reduced the unburnt hydrocarbon. [1 , 29]

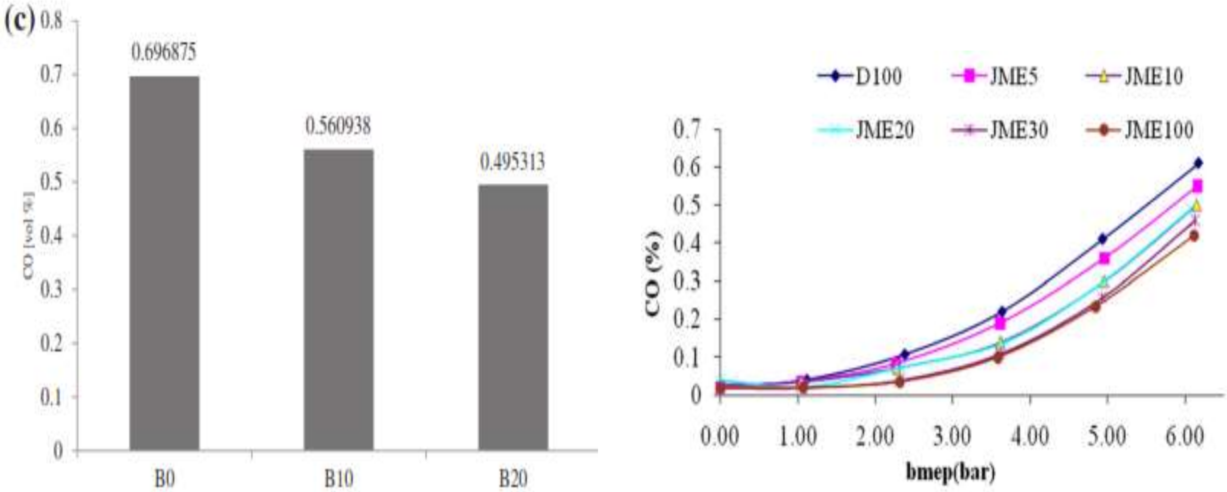


Fig 8 : Both result from B.S Chauhan et al(2012) and M. Mofijur et al(2013) on CO production.[1 , 29]

It can be seen that in Fig 8 the CO emission from JCB blends is less than fossil diesel. CO is formed during the combustion process when there is insufficient oxygen to fully burn all the carbon into Carbon dioxide. In this case, JCB have higher oxygen than fossil diesel thus helping it to complete the combustion and reducing carbon monoxide. [1 , 29]

CONCLUSION

In conclusion, this study is focusing in the study to analyses Jatropha Curcas Biodiesel blend with fossil diesel thermal characterization, engine performance and emission analysis compare to fossil diesel in order to justify either JCB blends can be utilized as new source of fuel. This research is important in order to investigate and determine that the biodiesel is worth as the substitution of fossil diesel in the future. Based on the result and discussion, it can be said that the thermal characterization of the JCB blends is similar to the fossil diesel. While, the engine performance analysis shows that the JCB blends shows comparable performance to the fossil diesel. NOx in the JCB is much higher than fossil diesel however the CO and HC emission reduced compare to the fossil diesel. It can be conclude that JCB could be a good substitute fuel for diesel engine in the near future.

For future recommendations, the study of the cheapest way to produce this biodiesel must be done so that the cost of the biodiesel can compete with the fossil diesel. Cost is the most important criteria before this biodiesel can be utilized in a large scale. Furthermore, future analysis and research on this matter should be done to improve the advantages and goodness of this biodiesel to make it more accepted by the market.

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