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HETEROGENEOUS TRANSESTERIFICATION OF *JATROPHA* SEED OIL: EFFECT OF MOLAR RATIO OF METHANOL TO OIL ON THE METHYL ESTER YIELD

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ABSTRACT
Transeterification is an equilibrium reaction which takes place in three consecutive steps. The reaction is usually affected by variables such as molar ratio, temperature, catalyst type and catalyst amount, reaction time etc. Excess alcohol could be used to shift equilibrium to favour the forward reaction. The effect of molar ratio variation on the transesterification of *Jatropha* seed oil with methanol using calcium oxide catalyst was determined using a gas chromatography with flame ionization detector. Percentage yield of methyl esters produced at one hour each with a molar ratio of 10:1 and 12:1 were 97.75 and 99.96, respectively, while that with a molar ratio of 6:1 was 87.25%. The properties of *Jatropha* biodiesel produced were analysed and were found to satisfy the ASTM D6751.Biodiesel produced from *Jatropha* seed oil has the potential to mitigate climate change and solve environmental pollution crisis because it does not emit excessive harmful gases when it burns in diesel engine as in non-renewable fossil fuels.
Keywords: Transesterification, biodiesel, *Jatropha*,, gas chromatography, calcium oxide, climate change.

INTRODUCTION
The world is confronted with twin crises of fossil fuel depletion and environmental degradation [1]. The use of non-renewable fossil fuel is contributing immensely to global warming leading to climate change and all its catastrophes. Fatty acid methyl esters (FAME) collectively known as biodiesel obtained from renewable vegetable oils such as *Jatropha curcas* seed oil is an alternative fuel for diesel engines [2] . Biodiesel is an environmentally viable fuel [3]. It is biodegradable and does not contribute to global warming. The major benefit of its use as fuel is the reduction in net carbon dioxide emission since all the carbon dioxide emitted were captured during the growing phase of the plant from which the biofuel was made[4] . The use of biodiesel also reduces emission of carbon monoxide and other pollutants such as Sulphur IV oxide and unburned hydrocarbons by 20 to 40% [5].
By transesterification reaction with methanol, *Jatropha curcas* seed oil can be converted into biodiesel [6]. Transesterification is the most effective way to reduce the viscosity of vegetable oils and to make them fit for use in present diesel engines without any modifications[7][8]. Transesterification is an equilibrium reaction and one of the most important variables affecting the reaction is molar ratio of alcohol to oil [9]. Stoichometrically, transesterification reaction involves three moles of alcohol to one mole of triglyceride to produce three moles of fatty acid alkyl esters and one mole of glycerol[10][11]. Excess alcohol or increase molar ratio of alcohol to oil could be used to shift equilibrium to favour the forward reaction (Le Charteleir Principle). Other reaction variables which affects the reaction includes catalyst type and amount, free fatty acid of oil, temperature, reaction time, mixing intensity as well as oil type[12][13] .
In this paper, the effect of variation of molar ratio of methanol to oil on biodiesel yield from *Jatropha* oil transesterification using calcium oxide as catalyst was investigated.

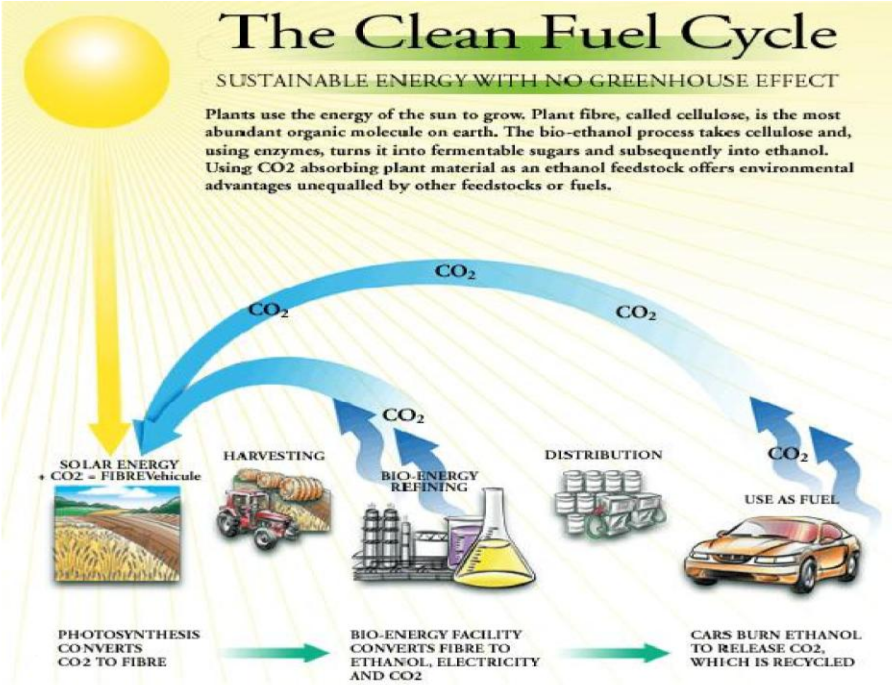

Figure 1: The Clean Fuel Cycle (Das, 2008)

MATERIALS AND METHODS

Material Used for Experiment

Materials used for the experimental work includes *Jatropha curcas* seed oil extracted from fresh *Jatropha* seeds (Figure 1a and 1b) by mechanical method using hydraulic press, methanol of high grade (HPLC grade) and calcium oxide (fluka) both purchased from Sigma Aldrich company Germany, Hot plate with a magnetic stirrer, an improvised reactor (500ml beaker), gas chromatography with flame ionization detector, cotton wool, mercury thermometer.

Experimental Method

50g of *Jatropha* curcas seed oil were weighed into four different 500ml beakers (improvised reactors) namely beaker A,B,C, and D. Each of these was heated to a temperature of 70 to 100^{O}C for 10 minutes to eliminate any moisture present in the oil. The dried oil was allowed to cool to room temperature or about 30^{O}C. The beakers containing the oil each were placed on hot plates set at temperatures of 65^{O}C while stirring at 450 to 500rpm. A mixture of methanol and 1% (0.5g) calcium oxide catalyst by weight of oil was added to each to the beakers, and transesterification took place for 60 minutes. The amount of methanol added to beaker A, B,,C and D were equivalent of molar ratio 6:1, 8:1, 10:1 and 12:1 methanol to oil. After transesterfying for 60 minutes, samples were withdrawn from each beaker and taken for gas chromatographic analysis to determine percentage methyl ester yield (biodiesel yield) in each of the sample. The free fatty acid of the oil used was 1.4% while the average molecular weight is 939g/mole. Figure 3 shows the transesterification reaction equation.

Figure.2a: ***Jatropha curcas*** **seeds**

Figure 2b: ***Jatropha curcas*** **plant with fruits**

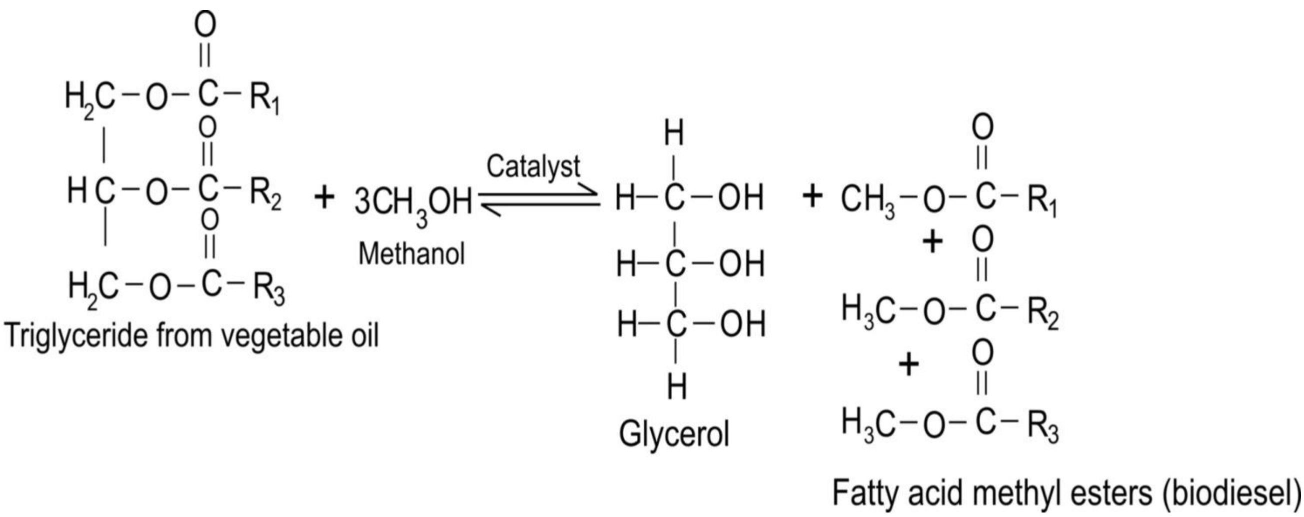

Figure 3: The transesterification reaction equation.

RESULTS AND DISCUSSION

The results of the analysis are shown in Table 1, while the chart of molar ratio effect is shown in Figure 4.

Table 1: Percentage yield of methyl ester

	1% Calcium Oxide			
Molar ratio	6:1	8:1	10:1	12:1
Methyl ester yield	87.249	96.54	97.75	99.96

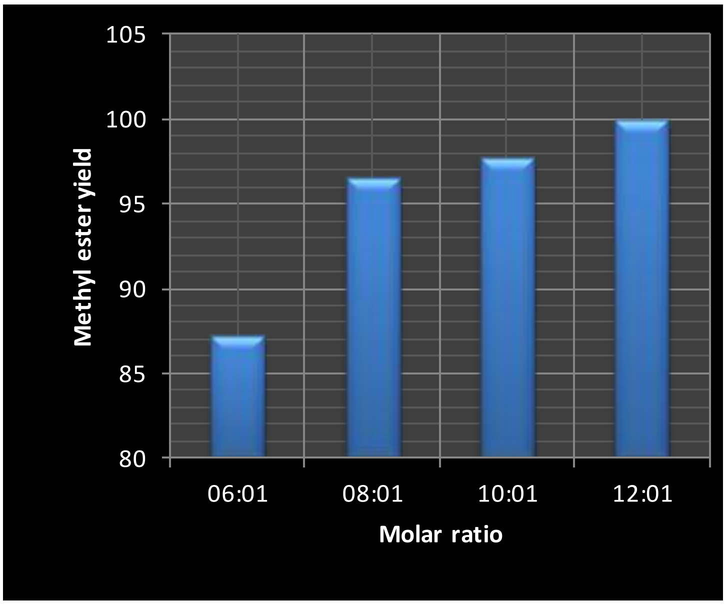

Figure 4: Effect of methanol to oil molar ratio on methyl ester yield using 1% Calcium Oxide at 65^{0}C.

From the results it could be observed that increase molar ratio increases methyl ester yield. For calcium oxide catalyst, there was a consistent increase in biodiesel yield from molar ratio of 6:1 to that of 12:1. The reason for this could be that calcium oxide being a heterogeneous catalyst (solid catalyst) requires more methanol for increase biodiesel yield because of interfacial surface reaction. The mechanism of the solid catalysed reaction is such that requires increase surface of catalyst pores which reacts with the methanol available before reacting with the oil to form products. Increase catalyst surface and more methanol to react with would therefore increase reaction rate and product yield. Therefore for calcium oxide catalyst, as shown by the result, a molar ratio of 10:1 or 12:1 could be recommended for biodiesel production from this oil. Biodiesel yield of over 96% or 97.75% and 99.96% obtained with a molar ratio of 10:1 and 12:1 respectively are indications of completion of reaction[10][9]. The fuel properties of the oil are shown in Table 2.

Table 2: *Jatropha* biodiesel fuel Properties.

Parameter	***Jatropha* biodiesel @65^{o}C, 1% CaO, molar ratio of methanol to oil 8:1**
Pour Point, ^{o}C	9
Flash Point, ^{O}C	192
Cloud Point, ^{O}C	12
Kinematic Viscosity, mm^2/s	4.86
Calorific Value	42.22
Cetane number	48.94
Specific Gravity	0.893
Acid number	0.47

The fuel properties of the biodiesel produced satisfies the ASTM D6751. A flash point of 192 shows that the fuel is very safe and can be transported from place to place without any problem [7].

CONCLUSION

Increase molar ratio of methanol to oil increases yield of biodiesel production from *Jatropha curcas* oil. For calcium oxide catalyst a molar ratio of 10:1, 12:1 or even 8:1 are recommended for the desired conversion. When using calcium oxide a lower molar ratio of 6:1 would require increase reaction time and temperature to achieve the desired yield. The properties of biodiesel produced satisfied the ASTM D6751.

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