Transesterification of *Jatropha curcas* Seed Oil: Reaction Parameters

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ABSTRACT

This study was carried out to determine the reaction parameters of the fatty acid methyl ester (FAME) and yield produced from *Jatropha curcas* (*J. curcas*) oil by alkali transesterification. Optimum reaction parameters were observed at 1:6 w/w methanol to oil ratio, 0.5% w/w NaOH to oil molar ratio, 400 rpm agitation speed and 60 ^{0}C with resulted in a yield of 99% crude biodiesel and 97.71% FAME.

Keywords: Biodiesel, Jatropha curcas, Transesterification, Reaction parameters.

INTRODUCTION

The search for alternatives to petroleum-based fuels has led to the development of fuels from various sources, including renewable feedstocks such as fats and oils. Biodiesel fuel, which consists of simple alkyl esters of fatty acids, has got growing interest due to diminishing petroleum reserves and environmental regulations (Knothe, 2010; Sirappareddy *et al*., 2008; Li *et al*., 2008; Nicolas, 2009; Murugesan *et al*., 2009).

Recently, approximately 85% of commercially produced vegetable fats and oils are used for edible purposes, only about (6-7%) are used as biodiesel fuel. It is predicted that the demand for edible fats and oils will increase along with the growing world population. Utilizing inedible oils such as *J. curcas* oil for biodiesel production has contributed for industrial satisfaction (Ichihashi *et al*., .2011; Patil and Deng, 2009; Koh and Ghazi, 2011; Erhan, 2005; Kurki *et al*., 2006; Azam *et al*., 2005; Charlene *et al*., 2004).

J. curcas is a multipurpose plant with many attributes and considerable potential. Various parts of the Jatropha plant have found many useful applications; the oil extracted from the seed can be utilized as a biodiesel feedstock and in soap production (Rao *et al*., 2009; Satheesh *et al*., 2009).

The stoichiometry of the transesterification reaction requires three moles of alcohol per moles of triglyceride to yield three moles of fatty ester and one mole of glycerol. Lower molar ratios of alcohol to oil require more reaction time. However, an excess amount of alcohol was always required to shift the reaction into product side (Srivastava and Prasad, 2000; Bojan and Durairaj, 2012).

The amount of catalyst required depends on the amount of FFA present in the oil; higher FFA content of the oil requires more alkali to neutralize the FFA; this leads to soap formation, and the separation of the product becomes difficult, leading to decrease in the biodiesel yield (Ma and Hanna, 1999; Akbar *et al*., 2009). This work is aimed at the study of the reaction parameters of alkali transesterification of *J. curcas* oil using one-step transesterification.

MATERIALS AND METHODS

J. curcas seed was obtained from Western Sudan (Abu Karshola) and the *J. curcas* oil was extracted mechanically in a bench scale expeller (OEKO TEC- IBG MONFORTS, Type CA 59 G, 2006, Machine No. 20 201550- Germany). Alkali base catalyzed transesterification was carried out in a multi-reactor unit (three hot plates each equipped with a magnetic stirrer and temperature controller) using ten grams of dried *J. curcas* oil. The effect of methanol to oil ratio: different methanol to oil molar ratios (3:1, 6:1 and 9:1) were used with different times (15, 30, 45, 60, 75 and 90 minutes) at 0.5% NaOH, 60 ^{0}C and 400 rpm. After the reaction was completed the mixture was centrifuged; two layers were observed, the excess amount of methanol was evaporated, then the top layer of methyl ester was separated, and the percent of crude biodiesel (FAME and yield) was determined. The effect of catalyst to oil ratio: different catalysts to oil ratios (0.25, 0.5 and 0.75% NaOH) were used with different times (15, 30, 45, 60, 75 and 90 minutes) at 6:1 methanol to oil molar ratio, 60 ^{0}C and agitation at 400 rpm. The effect of temperature: different temperatures (50, 60 and 70 ^{0}C) were used with different times (15, 30, 45, 60, 75 and 90 minutes) at 6:1 methanol to oil molar ratio and 0.5% NaOH and 400 rpm. The fatty acid composition of the methyl ester of *J. curcas* was determined using GC/MS with auto-sampler (Agilent Technologies 7890A gas chromatograph equipped with 5975C mass spectrometer) under the following conditions: column: DB wax 122–7032 (length: 30 m, film thickness: 0.25 and an internal diameter: 0.25 mm), carrier gas: Helium, flow rate: 1 ml/min, column temp.: 50 ^{0}C; runtime: 35 min, injection volume: 1μL.

RESULTS AND DISCUSSION

Characterization of *J. curcas* seed oil has been discussed in the previous study (Abdelrahman *et al*., 2017). Figures (1) and (2) show the effect of methanol to oil molar ratio at different reaction times on the FAME% and biodiesel yield%, respectively. FAME and biodiesel yield is increased with increasing methanol to oil molar ratio, according to the stoichiometry of the transesterification reaction. The optimum FAME and biodiesel yield was observed with 6:1 methanol to oil molar ratio at 60 minutes. However, at 9:1 methanol to oil molar ratio, approximately similar FAME and biodiesel yield is obtained after 45 minutes, but, alcohol recovery cost was increased without increasing the yield.

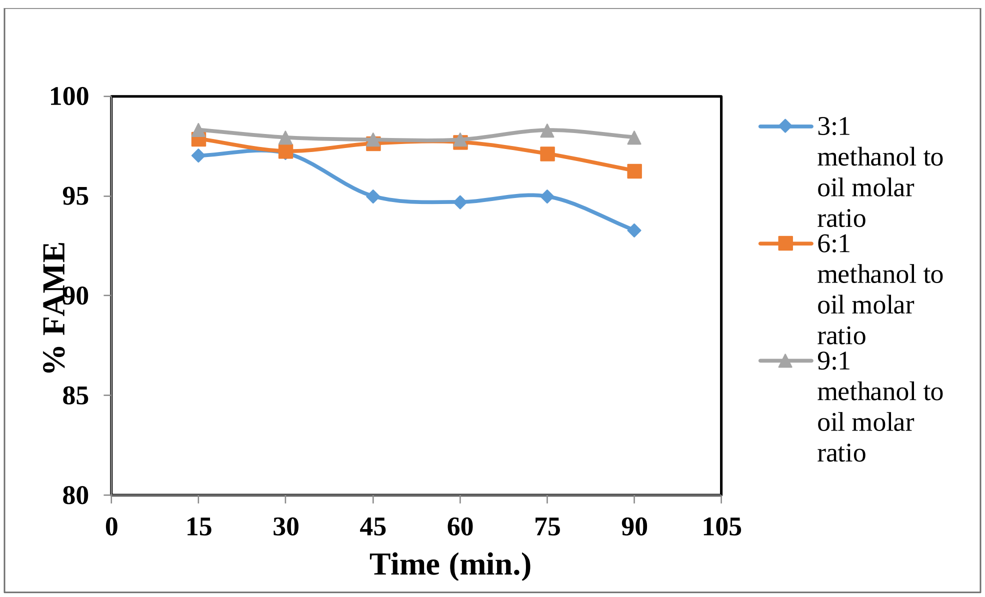

Figure (1): Time Course of the Effect of Methanol to Oil Molar Ratio on FAME from *J. curcas* oil at 0.5% NaOH, 400 rpm and 60 ^{0}C.

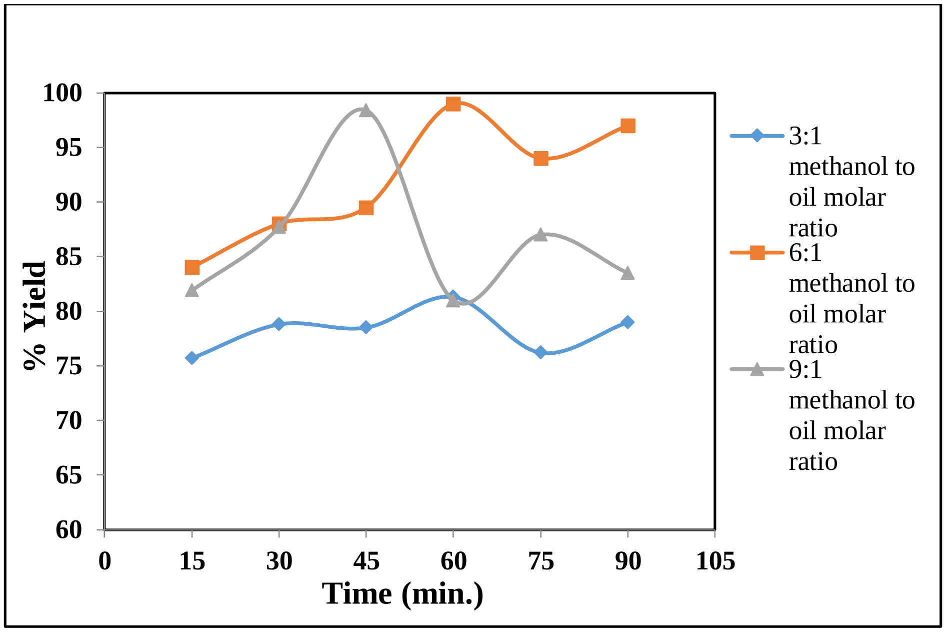

Figure (2): Time Course of the Effect of Methanol to Oil Molar Ratio on the Biodiesel Yield from *J. curcas* oil at 0.5% NaOH, 400 and 60 ^{0}C.

Figures (3) and (4) show the effect of catalyst (NaOH) to oil ratio at different times on the FAME% and biodiesel yield%, respectively. Optimum biodiesel yield and FAME are obtained with 0.5% NaOH (w/w) after 60 minutes. At 0.25% NaOH the separation of FAME produced from glycerin is difficult, whereas, low biodiesel yield is obtained at 0.75% NaOH (w/w).
Figures (5) and (6) show the effect of temperature with time on the FAME% and biodiesel yield respectively, at 6:1 methanol to oil molar ratio and 0.5 NaOH (w/w). The high biodiesel yield and FAME is obtained at 60 ^{0}C with 60 minute reaction time.

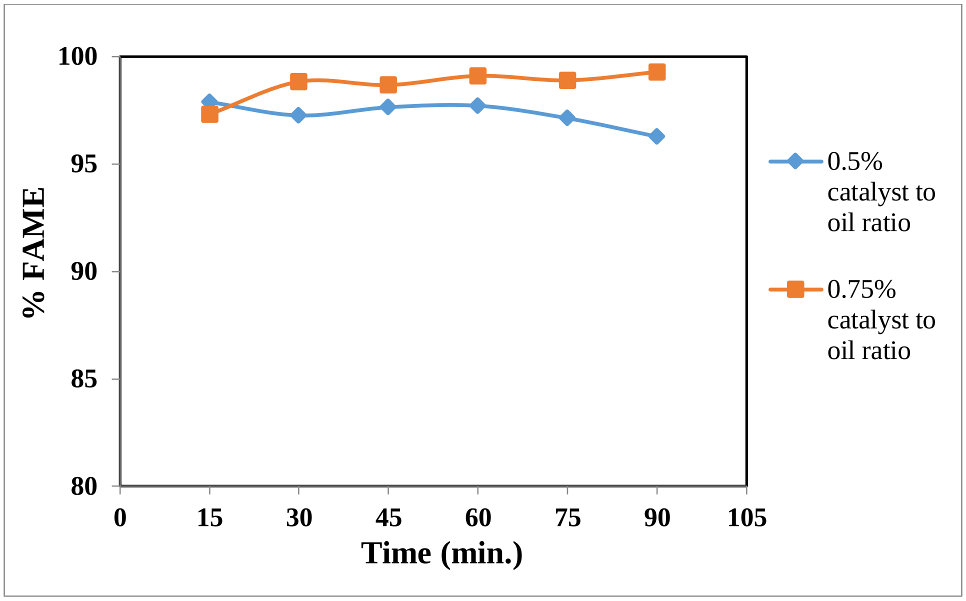

Figure (3): Time Course of the Effect of NaOH on FAME from *J. curcas* oil at 6:1 Methanol to Oil Molar Ratio, 400 rpm and 60 ^{0}C.

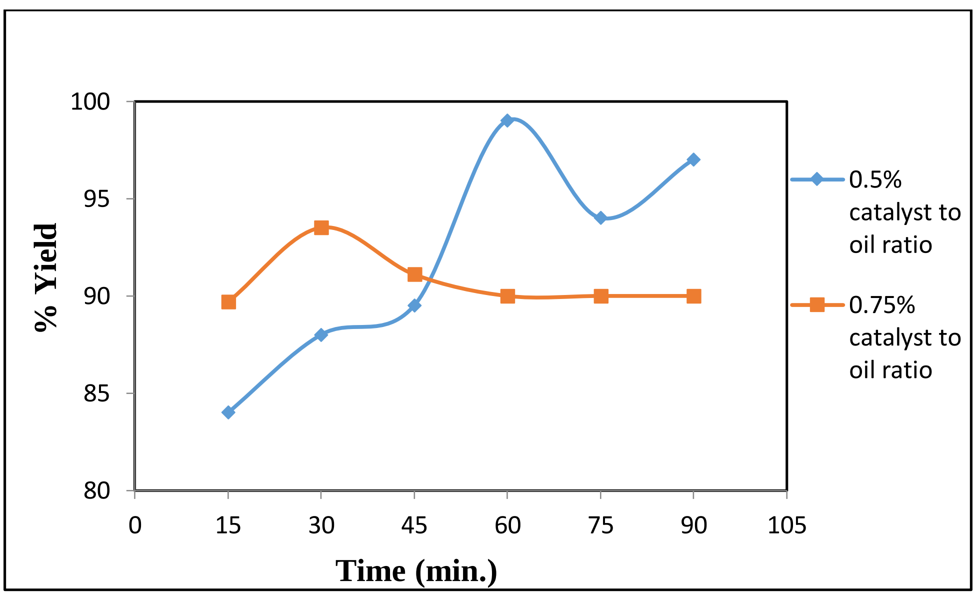

Figure (4): Time Course of the Effect of Catalyst to Oil Ratio on the Biodiesel Yield from *J. curcas* oil at 6:1 Methanol to Oil Molar Ratio, 400 rpm and 60 ^{0}C

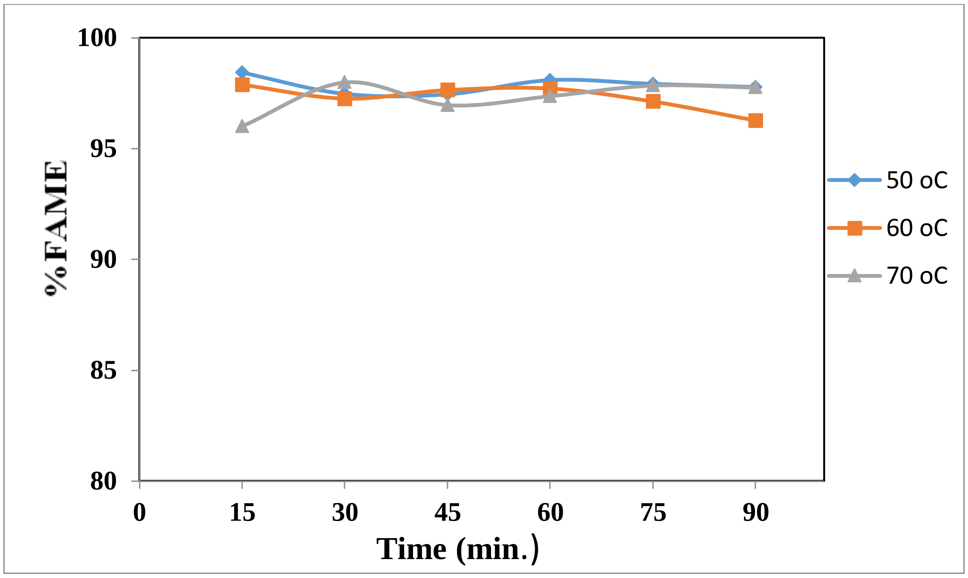

Figure (5): Time Course of the Effect of Temperature on FAME of *J. curcas* oil at 6:1 Methanol to Oil Molar Ratio, 400 rpm and 0.5 % NaOH.

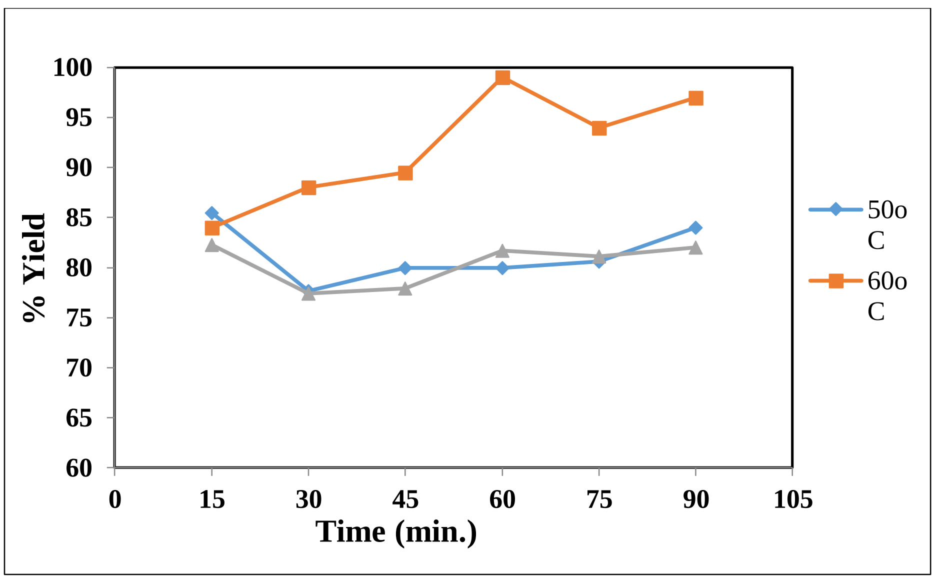

Figure (6): Time Course of the Effect of Temperature on the Biodiesel Yield from *J. curcas* Oil at 6:1 Methanol to Oil Molar Ratio, 400 rpm and 0.5 % NaOH

CONCLUSIONS

The effect of reaction parameters of biodiesel production from *J. curcas* oil has been investigated. The optimum result was obtained at 1:6 w/w methanol to oil ratio, 0.5 % NaOH (w/w) to oil ratio, 400 rpm agitation speed and 60 ^{0}C with a yield of 99% and 97.71% FAME.

ACKNOWLEDGMENTS

This work was conducted under the financial support of the National Oilseed Processing Research Institute (NOPRI) - University of Gezira. We also wish to gratefully acknowledge International Islamic University Malaysia (IIUM) and the University of Malaya- Centre for Ionic Liquids (UMCiL) for their support and permission to conduct this research at their laboratories.

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أسترة زيت بذور الجاتروفا كركاس: معاملات التفاعل

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الملخص

تهدف هذه الدراسة إلى تعيين معاملات تفاعل الأستر الميثيلي ونسبة الوقود المنتج من زيت بذور الجاتروفا كركاس عن طريق الأسترة الالكيلية. وجد أن الظروف المثلى هي نسبة الميثانول إلى الزيت 1:6(w/w)، 0.5% (w/w) هيدروكسيد الصوديوم، 60 درجة مئوية، 400 دورة في الدقيقة, لمدة 60 دقيقة، حيث تم إنتاج (99%) من خام الوقود الحيوي بنسبة (97.71%) من الإستر الميثيلي.