Faculty of Engineering

Production, Optimization and Performance Analysis of Jatropha Biodiesel using Nano CaO Catalyst Synthesized from *Polymesoda erosa* Seashells

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Doctor of Philosophy
2018

UNIVERSITI MALAYSIA SARAWAK

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Production, Optimization and Performance Analysis of Jatropha Biodiesel using Nano CaO Catalyst Synthesized from *Polymesoda erosa* Seashells

Amaranadha Reddy. Manchuri

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Mechanical and Manufacturing)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2018

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Amaranadha Reddy. Manchuri

Date:

DEDICATION

With high esteem this humble work is dedicated to

My parents' Sri. Krishna Reddy and Smt. Rukminamma who nurtured me.

My brother Sri. Praveen Kumar Reddy who enshrined me.

Loving Smt. Jyoshna, Smt. Spandana, Pawan Krishna Reddy and Abhi Ram Reddy who vitalized my intuition.

Sages Sri. Subramanyam Arikatla and Sri. Narayanan Kulathuramaiyer who fortified absolute virtues in me.

-o0o-

ACKNOWLEDGEMENT

I offer salutations to the Supreme Being goddess 'Ādi Parāshakti', divine pure eternal consciousness. Mother, all the time You empowered me to pursue my passions.

I would like to express my sincere gratitude to my supervisor Associate Professor Dr. Abu Saleh Ahmed for his continuous support in my Ph.D. I could not have imagined having a better supervisor for my study. Besides, I would like to thank my co-supervisors Professor Dr. Sinin Hamdan, Dr. Md Rezaur Rahman and Dr. Md Saiful Islam, for their insightful scientific discussions and reinforcement. My sincere thanks also goes to the technical staff and fellow researchers for their indispensable support in experimental investigations.

I would greatly acknowledge UNIMAS, for awarding graduate Scholarship, Zamalah Siswazah UNIMAS award 2015 for the period February-August 2015. I would like to express my highest gratitude towards Ministry of Higher Education (MOHE), Malaysia for awarding prestigious Malaysian International Scholarship, MIS-2015; KPT.B.600-4/1/12 (60) since September 2015. MOHE has fully funded my tuition fees and allowances. Also, my sincere thanks to UNIMAS for sanctioning an internal grant, *Dana Pelajar*, PhD (DPP) F02(DPP45)/1260/2015/60.

Last but not the least, I would like to thank all my family members and well-wishers for their everlasting socio spiritual support throughout this thesis.

Thank you all for being part of my life.

ABSTRACT

In sustainable biodiesel production, both catalyst and feedstock are considered as essential features. Various heterogeneous catalysts are often used to produce biodiesel from non-edible crude oils. In this research, nano calcium oxide (CaO) heterogeneous catalyst was synthesized from indigenous aquatic seashells, *Polymesoda erosa*, through calcination–hydration–dehydration technique. The nano CaO catalyst spectral and structural characteristics were evaluated utilizing spectrographic techniques that include Fourier transform infrared (FT-IR) spectroscopy, transmission electron microscope (TEM), X-ray diffraction (XRD) and Brunauer-Emmett-Teller (BET). A nano CaO with a surface area of 90.61 m^2/g in spherical or rod-shapes with diameters of 66.2nm and 548.7nm measured. The nano CaO catalysis efficiency was investigated in a two-step transesterification of triglycerides from crude Jatropha oil (CJO) as Jatropha biodiesel (JB). A JB yield of 98.54 % was reported at optimal parametric conditions i.e., 0.02:1 (w/w) catalyst concentration, 133.1 min reaction time and 5.15:1 mol. of methanol to the pre-treated oil. An average of 95.8% JB yield was obtained from the catalyst reusability and leaching study up to the sixth cycle. The fatty acid composition (FAC) of a feedstock influences biodiesel physicochemical properties. The impact of FAC on biodiesel produced using CJO originated from the east and west Malaysian regions was investigated. The physicochemical fuel properties of biodiesel and blends were investigated according to ASTM D6751/ EN 14214 standards. The investigations revealed that the FAC of biodiesel can influence physicochemical properties of the JB due to variant degrees of saturated and unsaturated fatty acid levels. A mathematical model, response surface methodology based on central composite design, coupled with desirability approach was utilized to predict the engine performance and emissions. The engine operating parameters that include engine speed (1700 rpm – 2100

rpm), using JB - PD fuel blends of (B5 – B25) and torque (28 N.m – 36 N.m) were utilized as input parameters. At a collective desirability of 0.969, both engine performance and exhaust gas emissions were resulted as optimal. The engine speed of 1900 rpm, JB – PD fuel blend of B13 and torque of 33 N.m were obtained as optimal parameters. Hence, this research recommends use of B13 biodiesel blends.

Keywords: Biodiesel; transesterification; Jatropha; heterogeneous catalyst; nano catalyst; fatty acid composition; fuel properties; engine performance; exhaust emissions; optimization.

***Kajian ke atas Pengeluaran, Pengoptimuman dan Prestasi Biodiesel Jatropha Melalui Sintesis Pemangkin Kalsium Oksida (CaO) Nano daripada Kulit Kerang* Polymesoda erosa**

ABSTRAK

Bagi kemampanan pengeluaran biodiesel, pemangkin dan bahan mentah dianggap sebagai ciri yang penting. Pelbagai pemangkin heterogen sering digunakan bagi menghasilkan biodiesel daripada minyak mentah bukan makanan. Dalam kajian ini, pemangkin heterogen nano kalsium oksida (CaO) nano telah disintesis daripada kerang akuatik asli iaitu Polymesoda erosa, *melalui teknik penalaan-penghidratan-penyahhidratan. Ciri-ciri spektral dan struktur pemangkin CaO nano dinilai dengan menggunakan teknik spektroskopi yang merangkumi Inframerah (FT-IR), Mikroskop Transmisi Elektron (TEM), Sinar Pembelauan-X (XRD) serta teknik Brunauer-Emmett-Teller (BET). CaO nano dengan luas permukaan 90.61 m^2/g dalam bentuk sfera atau rod dengan diameter 66.2nm dan 548.7nm telah diukur. Kecekapan katalitik CaO diuji dalam dua fasa trans-esterifikasi trigliserida dari Minyak Jatropha Mentah (CJO) atau disebut sebagai Biodiesel Jatropha (JB). Penghasilan JB mentah sebanyak 98.54% dilaporkan pada keadaan parametrik optimum iaitu 0.02: 1 (w/w) untuk kepekatan pemangkin, 133.1 min. untuk masa tindak balas dan 5.15: 1 mol untuk nisbah metanol kepada minyak sebelum dirawat. Hasil purata sebanyak 95.8% JB mentah telah diperolehi daripada pemangkin yang dikitar-semula, diikuti dengan pengalihan pemangkin sehingga kitaran ke-enam. Komposisi asid lemak (FAC) dari bahan mentah akan mempengaruhi sifat fizikokimia biodiesel. Kesan FAC terhadap biodiesel yang dihasilkan menggunakan CJO yang berasal dari kawasan timur dan barat Malaysia telah diuji. Ciri-ciri bahan bakar fizikokimia biodiesel dan campuran telah dikaji mengikut piawaian ASTM D6751 / EN 14214. Hasil kajian menunjukkan bahawa FAC biodiesel boleh mempengaruhi sifat fizikokimia JB kerana kepelbagaian suhu asid*

lemak tepu dan tidak tepu. Model matematik, tindakbalas metodologi permukaan berdasarkan rekabentuk komposit berpusat, beserta dengan pendekatan 'desirability' telah digunakan untuk meramalkan prestasi enjin dan pelepasan. Parameter operasi enjin termasuk kelajuan enjin (1700 rpm - 2100 rpm), dengan menggunakan campuran bahan api JB - PD (B5 - B25) dan 'tork' (28 N.m - 36 N.m) digunakan sebagai parameter input. Secara kolektif, pada nilai 'desirability' 0.969, kedua-dua prestasi enjin dan pelepasan gas ekzos yang dihasilkan adalah optimum. Juga pada kelajuan enjin setinggi 1900 rpm, campuran bahan api JB - PD B13 dan tork 33 N.m diperolehi sebagai parameter optimum. Justeru, kajian ini telah mengesyorkan penggunaan biodiesel B13.

Kata kunci: *biodiesel; transesterifikasi; Jatropha; pemangkin heterogen; pemangkm nano; komposisi asid lemak; sifat bahan api; prestasi enjin; pelepasan ekzos; pengoptimuman.*

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LIST OF ABBREVIATIONS

AAS	Atomic absorption spectrometer
ANN	Artificial neural networks
ANOVA	Analysis of variance
ASTM	American Society for Testing and Materials
AV	Acid value
B1.3	BD 1.3% + PD 98.7%
B2	BD 2% + PD 98%
B5	(BD 5% + PD 95%)/ (JB 5% + PD 95%)
B7	BD 7% + PD 93%
B8	BD 8% + PD 92%
B10	(BD 10% + PD 90%) / (JB 10% + PD 90%)
B13	JB 13% + PD 87%
B15	JB 15% + PD 85%
B20	(BD 20% + PD 80%)/ (JB 20% + PD 80%)
B25	JB 25% + PD 75%
B30	(BD 30% + PD 70%)/ (JB 30% + PD 70%)
B100	(JB 100% + PD 0%)/ Pure biodiesel
BD	Biodiesel
BET	Brunauer-Emmett-Teller
BJH	Barrett-Joyner-Halenda
BP	Brake power
BSFC	Brake specific fuel consumption