PRODUCTION OF BIODIESEL FROM JATROPHA OIL BY USING MICROWAVE IRRADIATION

AHMED BAKHEIT AHMED ABD ELHAMEED

UNIVERSITI TEKNOLOGI MALAYSIA

PRODUCTION OF BIODIESEL FROM JATROPHA OIL BY USING MICROWAVE IRRADIATION

AHMED BAKHEIT AHMED ABD ELHAMEED

A thesis submitted in fulfilment of the
requirement for the award of the degree of
Master of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2013

To my beloved father and mother

Bakheit Ahmed, Nawal Babeker

my brother and sisters..

and to all my friends

ACKNOWLEDGEMENT

First of all, I would like to say Alhamdulillah, for giving me the strength, patience and health to go through all obstacles in order to complete this research.

The special thank goes to my helpful supervisor, Professor Dr. Ir. Farid Nasir Bin Hj. Ani for his supervision, valuable and critical ideas, comments and guidance throughout my research.

My appreciation extends to Nor Syarizan Mat Nor and all laboratory staffs in thermodynamic laboratory and chemical laboratory for helping me in this project.

Last but not least, I would like to express my love and many thanks to my parents, family and friends, who have supported, assisted and motivated me throughout this research.

ABSTRACT

Environmental issues, the growing demand for energy, political concerns, increasing crude oil prices and the medium term depletion of petroleum created the need for the development of vegetable oils as alternative fuels. Vegetable oil based fuels (bio fuels) are promising alternative fuels for diesel engines because of their environmental and strategic advantages. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources. Chemically biodiesel is monoalkyl esters of long chain fatty acids derived from renewable feed stock like vegetable oils and animal fats. The costs of feedstock and production process are two important factors which are particularly against large-scale biodiesel production. *Jatropha curcas* oil (JCO) is considered a future feedstock for biodiesel production because it is easily grown in harsh environments and is a non-edible crop that is not in demand as a food source. Microwave irradiation is one of the good methods to reduce the reaction time and get the higher yield; however, heterogeneous transesterification using a solid catalyst rather than a liquid acid or base catalyst is a more environmentally responsible way to utilize crude Jatropha oil for biodiesel production. The use of a heterogeneous catalyst also avoids neutralization and washing steps, thereby leading to a simpler and more efficient process. This project presents optimize three critical reaction parameters including catalyst concentration, microwave exit power and reaction time from the transesterification of used jatropha curcas oil (JCO) by using microwave irradiation in an attempt to reduce the production cost of biodiesel. To arrest the reaction, similar quantities of methanol to oil molar ratio (6:1) and calcium oxide as the catalyst were used. The results showed that the best yield percentage (96%) was obtained using 300W microwave exit power, 8 %(wt) CaO and 7 min. From the results obtained it was clear that free acid methyl ester (FAME) was within the standards of biodiesel and diesel fuel.

ABSTRAK

Isu alam sekitar, permintaan yang semakin meningkat untuk tenaga, kebimbangan politik, peningkatan harga minyak mentah dan kekurangan jangka sederhana petroleum mewujudkan keperluan bagi pembangunan minyak sayuran sebagai bahan api alternatif, bahan api berasaskan Minyak sayuran (bahan bakar bio) menjanjikan bahan api alternatif bagi diesel enjin kerana kelebihan alam sekitar dan strategik, Biodiesel semakin lebih dan lebih penting sebagai bahan api yang menarik kerana bahan api semakin berkurangan sumber fosil. Kimia biodiesel adalah ester monoalkyl rantaian panjang asid lemak yang diperolehi daripada stok suapan boleh diperbaharui seperti minyak sayuran dan lemak haiwan. Minyak Jatropha curcas (JCO) dianggap bahan mentah masa depan bagi pengeluaran biodiesel kerana ia mudah ditanam dalam persekitaran yang sukar tumbuh dan adalah tanaman yang tidak boleh dimakan yang tidak berada dalam permintaan sebagai sumber makanan. Penggunaan mangkin heterogen juga mengelakkan langkah peneutralan dan membasuh, sekali gus membawa kepada proses yang mudah dan lebih cekap. Projek ini membentangkan dan mengoptimumkan tiga parameter kritikal reaksi termasuk kepekatan pemangkin, kuasa gelombang mikro keluar dan reaksi masa dari transesterification digunakan jatropha curcas minyak (JCO) dengan menggunakan penyinaran gelombang mikro dalam usaha untuk mengurangkan kos pengeluaran biodiesel. Untuk reaksi kuantiti yang sama dengan metanol kepada nisbah minyak molar (06:01) dan kalsium oksida sebagai pemangkin telah digunakan. Keputusan menunjukkan bahawa hasil peratusan terbaik (96%) telah diperolehi dengan menggunakan kuasa gelombang mikro dengan keluaran 300W, 8% (wt) CaO dan 7 min. Daripada keputusan yang diperolehi, ia adalah jelas bahawa asid metil ester (FAME) adalah bebas dalam piawaian biodiesel dan diesel.

TABLE OF CONTENTS

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	American Standard of Testing Material
FAME	Fatty Acid Methyl Ester
FFA	Free Fatty Acid
GC	Gas Chromatography
CaO	calcium oxide
ME	Methyl Ester
NaOH	Sodium Hydroxide
Sec	Seconds
JCO	Jatropha Curcas Oil
CJO	Crude Jatropha Oil

CHAPTER 1

INTRODUCTION

1.1 Introduction

When Rudolf Diesel designed an engine to run on peanut oil in 1894, he was convinced that it would have a great future and even went on to predict that biofuels would play a significant role in the future. The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in the course of time as important as petroleum and the coat tar products of the present time. He stated little did he know that it would take so long for the world of technology to catch-up with his vision of motor fuel. Biofuel (Biodiesel and Bioethanol) will become a vital part of our energy supply in the near future. Being derivates of renewable resources, they provide the opportunity for us to become less dependent on crude oil. Furthermore, the introduction of bio fuels into the motor fuel market will be the most immediate and most efficient way to meet the obligations of the “KYOTO Protocol”, which is the United Nations framework convention on climate change -in order to reduce greenhouse gas emissions. For example, The “EU Bio fuels Regulation” intends to raise the market usage of bio fuels from 2% in 2005 to a remarkable 5.75% in 2010 in the transport fuel market. This is equivalent to a market potential of approximately 14 million tons of biofuels by 2010. The construction of large scale production units will be inevitably necessary. In the US the production is projected to reach 5.6 billion gallons of Bioethanol by 2008 and 1.0 billion gallons of Biodiesel in the same period.

Biodiesel production is worthy of continued study and optimization of production procedures because of its environmentally beneficial attributes and its renewable nature. Non-edible vegetable oils such as Jatropha oil, produced by seed-bearing shrubs, can provide an alternative and do not have competing food uses. However, these oils are characterized by their high free fatty acid contents. Using the conventional transesterification technique for the production of biodiesel is well established. In this study an alternative energy stimulant, ‘‘microwave irradiation’’, will be used for the production of the alternative energy source, biodiesel. The optimum parametric conditions obtained from the conventional technique were applied using microwave irradiation in order to compare the systems.

Then as it can be seen in the previous paragraphs, the vegetable oils have a high potential to be used in diesel engines even without any processing and only with some simple modification of diesel engine. Previous researchers showed that the main difference between the fatty acids is in the length of their carbon chain and also in the number of double bonds. Then the best way to overcome these problems and make their combustion properties close to those petroleum fuels is some simple modifications, Transesterification, micro-emulsion and pyrolysis are three different ways to modify the vegetable oil and prepare it as a fuel to be used in a type of diesel engine. Transesterification is introduced as the best well-established way to produce an alternative and safe fuel from vegetable oil to replace the petroleum based fuels.

1.2 Background of Study

The first concept of using vegetable oil as a fuel was developed by Dr. Rudolf Diesel later back to 1895, when the first diesel engine to run on vegetable oil. Diesel later demonstrated his engine and received the 'Grand Prix' at the World Fair in Paris, France in 1900. This engine stood as an example of Diesel's vision because it was powered by peanut oil as bio fuel though not strictly biodiesel, since it not was transesterified. Biodiesel was introduced in South Africa to power heavy-duty vehicle before World War II. During the 1920s diesel engine manufacturers altered to utilize the lower viscosity of the fossil fuel (petro diesel) rather than vegetable oil, and biomass fuel.

In 1980s, the revival of biodiesel production started with farm cooperative and the first industrial-scale plant opened with capacity in excess of 10,000 m^3 per year in the 1991 in Austria. In 1990s, France launched the local production of biodiesel fuel (known locally as diester) obtained by transesterification of rapeseed. Recently, environmental and economic concerns have renewed the interest in biodiesel throughout the world, especially in Europe, where it has been used for 20 years.

Biodiesel (fatty acid alkyl esters) is an alternative diesel fuel derived from the reaction of vegetable oils or lipids and alcohol with or without the presence of a catalyst. Despite the invention of the vegetable oil fuelled engine by Rudolf Diesel dated back in the 1900s, full exploration of vegetable oil based fuel such as biodiesel only came into light in the 1980s as a result of renewed interest in renewable energy sources for reducing greenhouse gas (GHG) emissions, and alleviating the depletion of fossil fuel reserves. Since then, biodiesel has slowly penetrated the market in Europe, especially in Germany and France, as a blend to petro diesel. Commercially, these blends are named as B5, B20 or B100 to represent the volume percentage of biodiesel component in the blend with petro diesel as 5, 20 and 100 vol. %, respectively. Currently, many countries around the world have explored and commercially used biodiesel blends for their vehicles such as US, Japan, Brazil, India, and so on. Esterification and transesterification reactions are currently the most favoured reaction pathways to produce biodiesel. Any type of feedstock that contains free fatty acids and/or triglycerides such as vegetable oils, waste oils, animal fats, and waste greases can be converted into biodiesel. However, the final products must meet stringent quality requirements before it can be accepted as biodiesel (EN14214 for European standard; ASTM D6751 for US). The fuel properties of B5, B20, B100 and No. 2 Diesel, according to the standards, are well established in the literature. A number of processing technologies for the production of biodiesel have been reported as the feedstock conversion that depends on the type of feedstock used (N. Yusuf, 2012)

Jatropha is a genus of approximately 175 succulent plants, shrubs and trees from the family Euphorbiaceae. Jatropha is native to Central America and has become naturalized in many tropical and subtropical areas, including Asia, Africa, and North America. (Abebe K, 2011) Originating in the Caribbean, Jatropha was spread as a valuable hedge plant to Africa and Asia by Portuguese traders. The mature small trees bear separate male and female flowers, and do not grow very tall. Normally, it grows between three and five meters in height, but can attain a height of up to eight or ten meters under favourable conditions. Jatropha yield varies depending on the variety (species) of the plant that is used for cultivation. The extract from its seeds, Jatropha oil, is processed to obtain bio fuel and bio diesel. The yield of oil can be influenced by several factors; such as; soil, Organic fertilizers, rainfall, climate, processing etc, (we can see the effect of every one of this aspect later). A combination of all these conditions, along with consideration of the plant’s genetic constitution, influences the yields. In spite of the fact that the Jatropha yield can vary considerably according to such factors, it is possible to estimate optimum figures for the yield of oil. An estimated yield of 12000 kg of seed per hectare from irrigated plantations and 4000 kg of seed from rain fed plantations can be expected from 5th year onwards. The quantity of oil extracted per hectare can be as high as 2.7 tons. The harvest from this degree of sowing can be as considerable as 78 tons (El Diwani G, 2009).

1.3 Statement of Problem

Currently, diesel powered vehicles represent about one third of the vehicles sold in Europe and the United States. Worldwide diesel fuel consumption, as the amount of available petroleum decreases, the need for alternative technologies that can prolong the use of liquid fuels and mitigate a forthcoming shortage of transportation fuels increases, there are currently two global biomass-based liquid transportation fuels that have the potential to replace gasoline and diesel fuel: bioethanol and biodiesel. It is assumed that biodiesel will be used as a fossil diesel replacement and that bioethanol will replace gasoline.

Over the past decade (2000–2010), biodiesel production has increased to an unprecedented level, fuelled mainly by increases in oil prices, high demand from emerging countries, speculation, and efforts to combat climate change. Figure 1.1 and 1.2 illustrates how world biodiesel production increased from 9 million tons in 2007 to 12.6 million tons in 2012, which is an increase of 300% over five years. It is estimated that biodiesel could replace approximately 10% of diesel fuel consumption in Europe and 5% of Southeast Asia’s total fuel demand. Biodiesel demand increased from less than 200 million liters in 2000 to about 251 million liters in 2012 and will surpass 350 million liters in 2020. Th is steep increase in world demand for biodiesel is due to the obligation of nations to diversify energy supply sources and energy security policies because of the Kyoto Protocol and/ or national objectives. There are, therefore, strong export opportunities for countries that can produce biodiesel. Increasing biodiesel consumption will require an optimized production process characterized by high production capacity, simplified operations, high yields, and a lack of special chemical requirements and waste streams. (Harumi Veny, 2010)

A global market survey observes three key trends in the jatropha feedstock market. The first trend is the expansion of commercial-scale jatropha production from India, Africa, Southeast Asia , and Latin America. The second trend is the participation by governments and major energy concerns in the cultivation and production of jatropha. The third key trend is that jatropha-based projects are being developed as dual-purpose entities, both as government programs and as a solution to rising global bio fuels demands.

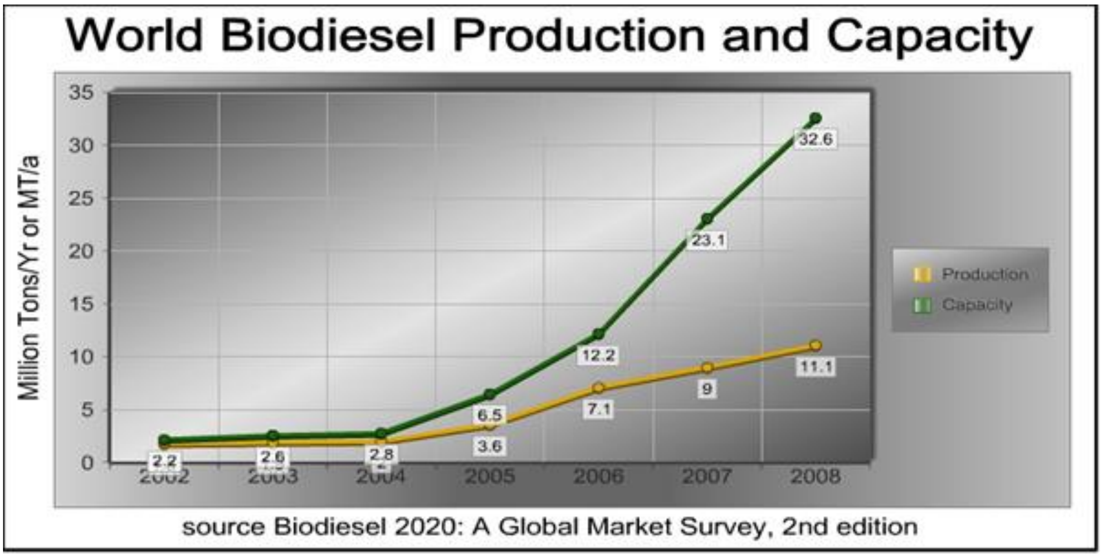

Fig 1.1 biodiesel production and demand in 2020

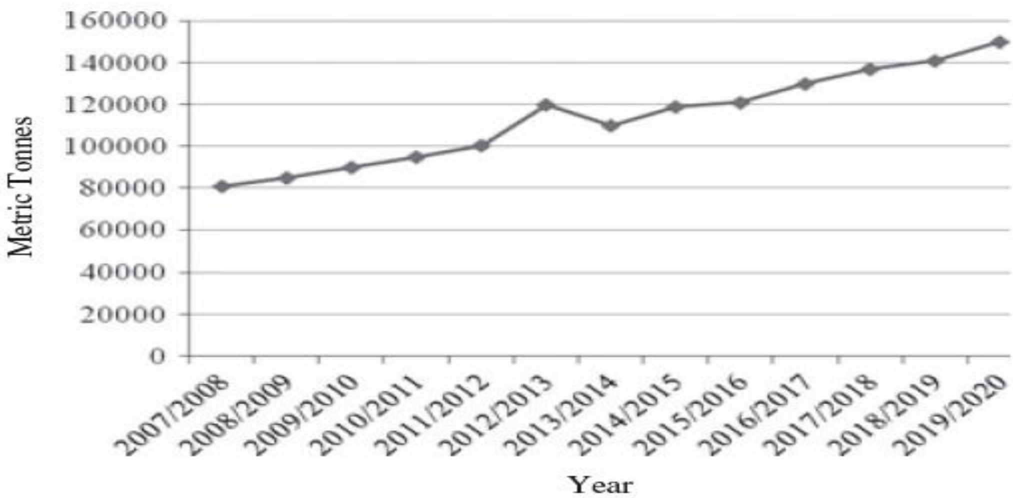

Fig 1.2 Annual diesel consumption

1.4 Objectives of the Study

The objectives of this research are:

i) To produce biodiesel from jatropha oil by using microwave irradiation using heterogeneous catalyst.

ii) To investigate the effect of some critical parameters that will affect the yield of transesterification.

iii) To compare the yield of the biodiesel production and characteristics of produced biodiesel with the petro diesel.

1.5 Scope of the Study

The scopes of this project will include:

i. Conducting literature survey on the various researches on producing biodiesel from Jatropha Curcas.

ii. Setting up the apparatus to convert the jatropha oil to biodiesel and also the equipment needed for oil characterization.

iii. Extract oil from Jatropha seeds, conversion to biodiesel and characterizing the Jatropha oil and the biodiesel produced.

iv. Comparing the test results obtained with conventional diesel.

.

1.6 Project's Flow chart:

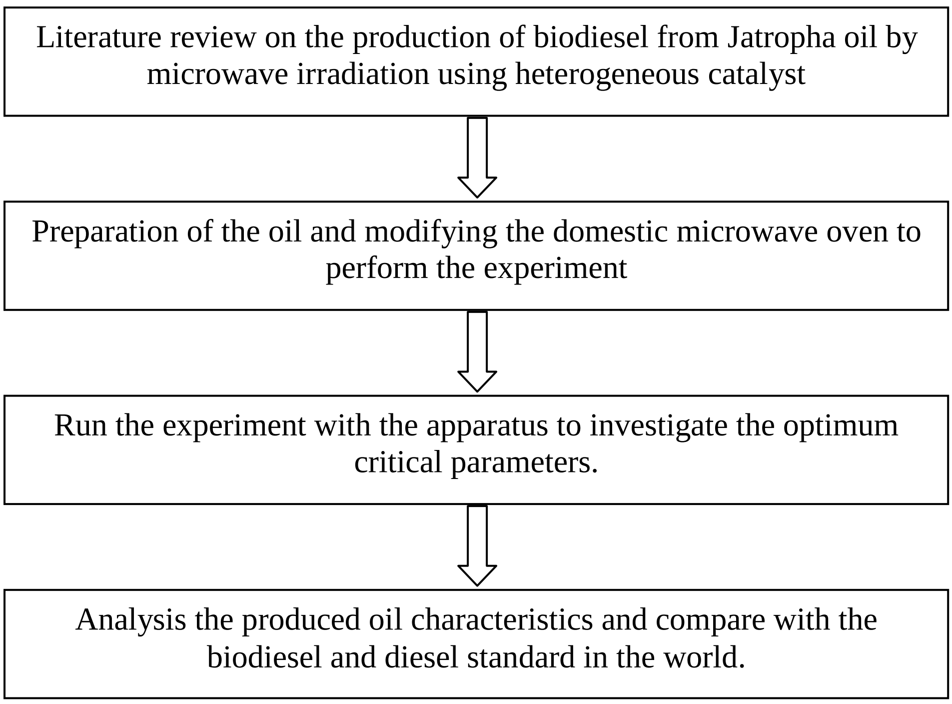

Figure 1.3 Research flowchart

REFERENCES

Abebe K. Endalew, Yohannes Kiros, Rolando Zanzi (2011). Heterogeneous catalysis for biodiesel production from Jatropha curcas oil (JCO), A.K. Endalew et al. / Energy 36 2693-2700

Aminul Islam, Yun Hin Taufiq-Yap, Chi-Ming Chu, and Eng-Seng Chan (2012). Pogaku Ravindra, Review Studies on design of heterogeneous catalysts for biodiesel production, Process Safety and Environmental Protection

Amish P. Vyas, N. Subrahmanyam, Payal A. Patel (2009). Production of biodiesel through transesterification of Jatropha oil using KNO3/Al2O3 solid catalyst, A.P. Vyas et al. / Fuel 88, 625–628

El Diwani G. N. K. Attia, S. I. Hawash (2009). Development and evaluation of biodiesel fuel and by-products from jatropha oil.

Grisel Corro a, Nallely Tellez, Edgar Ayala, Alma Marinez-Ayala (2010). Two-step biodiesel production from Jatropha curcas crude oil using SiO2 HF solid catalyst for FFA esterification step, G. Corro et al. / Fuel 89, 2815–2821

Hawash S., G.El Diwani, E.Abdel Kader (2011). Optimization of Biodiesel Production from Jatropha Oil By Heterogeneous Base Catalysed Transesterification, S.Hawash et al. / International Journal of Engineering Science and Technology (IJEST).

Jonathan Beckerlegge , Simon Robinson (2011)Jatropha In Africa – Economic Potential Bio Diesel Fuels Inc.

Jidon Janaun, and Naoko Ellis (2010). Perspectives on biodiesel as a sustainable fuel. Janaun, N. Ellis / Renewable and Sustainable Energy Reviews 14 - 1312–1320

Joana M. Dias a, Maria C.M. Alvim-Ferraz , Manuel F. Almeida, José D. Méndez Díaz b, Manuel Sánchez Polo, José Rivera Utrilla , (2011). Selection of heterogeneous catalysts for biodiesel production from animal fat, J.M. Dias et al. / Fuel 94 (2012) 418–425

John Sheeha, Vince Camobreco, James Duffield, Michael Graboski, Housein Shapouri (1998). An Overview of Biodiesel and Petroleum Diesel Life Cycles, U.S. Department of Agriculture and, U.S. Department of Energy

Kaida Khalid, Azyan Hazwani Jabar, Ionel Valeriu Grozescu and Mahmod Narenji (2009). Microwave Application for the Detection of Biodiesel-Glycerine and Biodiesel-Water Interfaces in the Biodiesel Production, 978-1-4244-5335-1/09/$26.00 ©2009 IEEE

Kapilan.N, (2012). Production of Biodiesel from Vegetable Oil Using Microware Irradiation, Acta Polytechnica Vol. 52 No. 1/2012.

Khemthong P, Luadthong,C, Nualpaeng .W, Changsuwan,P , Tongprem.N, Viriya-empikul.K, Faungnawakij, (2012). Industrial eggshell wastes as the heterogeneous catalysts for microwave-assisted biodiesel production, Catalysis Today.

Nik N.A.N Yusuf, and Siti K. Kamarudin and Zahira Yaakob (2012). Overview on the production of biodiesel from Jatropha curcas L. by using heterogenous catalysts. Biofuels Bioprod. Bioref; 6:319–334.

Peng-Lim Boey, Gaanty Pragas Maniama,, Shafida Abd Hamid (2011). Review: Performance of calcium oxide as a heterogeneous catalyst in biodiesel production, Boey et al. / Chemical Engineering Journal 168 - 15–22

Pranab K. Barua (2011). Biodiesel from Seeds of Jatropha Found in Assam, India, International Journal of Energy, Information and Communications Vol, Issue1.

Refaat.A,A, El Sheltawy; Sadek, (2008). Optimum reaction time, performance and exhaust emissions of biodieselmproduced by microwave irradiation. Int. J. Environ. Sci. Tech., 5 (3), 315-322

Singh Chouhan A.P., Sarma (2011). Modern heterogeneous catalysts for biodiesel production: A comprehensive review, A.P.S. Chouhan, A.K. Sarma / Renewable and Sustainable Energy Reviews 15, 4378– 4399

Srinivasan S.P., .Malliga and .Nirmalraj (2009). A Fuzzy logic based decision support system to forecast the yield of Jatropha in cultivable wastelands, 978-1-4244-3672-9/09/$25.00 ©2009 IEEE.

Sulaiman Al-Zuhair (2007). Production of biodiesel: possibilities and challenges, Society of Chemical Industry and John Wiley & Sons, Ltd | *Biofuels, Bioprod. Bioref.* **1**:57–66 (2007); DOI: 10.1002/bbb

Suliana Abu Bakar, suzana Yusup, Murni Melati, Armanda T.Quitian, Mitsuru Sasaki, Motonobu, Yoshimitsu Uemura (2012). Microwave assisted acid catalyzed esterification of high FFA crude Jatropha oil for biodiesel production.

Surbhi Semwal , Ajay K. Arora , Rajendra P. Badoni , Deepak K. Tuli (2011). Review: Biodiesel production using heterogeneous catalysts, S. Semwal et al. / Bioresource Technology 102, 2151–216.

Tarek Abdel-Hamid, (2009) Growing Jatropha in Dry, Desert Climatic Condition (experience in Egypt, Libya, Sudan, and Syria). Production of Biodiesel from Jatropha Curcas oil by using Pilot Biodiesel Plant, Bulk Agro (India) Pvt. Ltd

Taufiq-Yap Y.H, Lee, Hussein.M.Z. , Yunus C (2010). Calcium-based mixed oxide catalysts for methanolysis of Jatropha curcas oil to biodiesel, bio mass and bio energy 35 (2011) 827e834.

Taufiq-Yap Y.H. et al. (2011). Effect of stoichiometric composition .Ca–Mg mixed oxide catalyst, / Chemical Engineering Journal 178 342– 347

Taufiq,Yapa Y.H., Leea, Yunus,. Juan.J.C (2011). Transesterification of non-edible Jatropha curcas oil to biodiesel using binary.

Tint Tint Kywe, Mya Mya.O. (2009). Production of Biodiesel from Jatropha Oil (Jatropha curcas) in Pilot Plant, proceedings of world academy of science, engineering and technology volume 38 February 2009 ISSN: 2070-3740

Van Gerpen J., Shanks, and Pruszko, (2004), Biodiesel Production Technology, National Renewable Energy Laboratory 1617 Cole Boulevard, Golden, Colorado 80401-3393 303-275-3000

Viriya-empikul N., P. Krasae, B. Puttasawat, B. Yoosuk, N. Chollacoop, K. Faungnawakij (2010). Short Communication: Waste shells of mollusk and egg as biodiesel production catalysts, Bio resource Technology 101, 3765–3767

Wilson Parawira (2010). Review: Biodiesel production from Jatropha curcas, Scientific Research and Essays Vol. 5(14), pp. 1796-1808.

Woulandakoye. O, buhari. B.y, bashir.a, Sama, abdulrazaq.a (2011). Biodiesel production from jatropha curcas oil: a nigerian perpective

Xin Deng, Zhen Fang, Yun-hu Liu, Chang-Liu Yu, (2011). Production of biodiesel from Jatropha oil catalyzed by nanosized solid basic catalyst, X. Deng et al. / Energy 36, 777e784

Yaakob Z., I.S.Sukarman, S.K.Kamarudin, S.R.S.Abdullah, F.Mohamed (2012). Production of Biodiesel from Jatropha Curcas by Microwave Irradiation, 2nd WSEAS/IASME International Conference on renewable energy sources (res'08).

Yogesh Sharma, Bhaskar Singh, John Korstad (2011). Review article Latest developments on application of heterogenous basic catalysts for an efficient and eco friendly synthesis of biodiesel, Y.C. Fuel 90 1309–1324

Yuka Tomomatsu and Brent Swallow (2007). Jatropha curcas biodiesel production in Kenya, World Agroforestry Centre, Working Paper 54.