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SYNTHESIS AND CHARACTERIZATION OF EGUSI MELON METHYL ESTER AS DIESEL FUEL SUBSTITUTE

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By

GIWA SOLOMON OLANREWAJU

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATED TO

God Almighty, the Alpha and Omega of life. Also, to my beloved father Late Chief D. A. Giwa who thoughtfully laid the foundation of sound and quality education, and unknowingly sowed the seed of greatness.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

SYNTHESIS AND CHARACTERIZATION OF EGUSI MELON METHYL ESTER AS DIESEL FUEL SUBSTITUTE

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Chairman: Associate Professor Ir. Nor Mariah Adam, PhD

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Biodiesel is a monoalkyl esters of vegetable oils (VOs), animal fats and waste oil widely accepted as substitute for fossil-derived diesel fuel. It is a renewable and sustainable energy source that is environmentally friendly. Food-fuel strain of conventional VOs has renewed research interest in exploring 350 alternative oil-bearing crops that can be harnessed as diesel fuel substitute, but with less than 100 investigated. *Colocynthis citrullus Lanatus*, 'egusi', has been studied for the first time as a potential biodiesel feedstock. Crude oil from the seeds have been characterized and transesterified using methanol in the presence of sodium methoxide as catalyst. The design of experiment for the optimization of the reaction conditions was conducted using response surface methodology (RSM). A three-level-three-factors face centered central composite design was employed. Catalyst amount (0.25 - 1.8% wt.), reaction temperature (45 – 65 °C) and oil-methanol molar ratio (4 – 10) were studied as important factors influencing the reaction. Fuel properties of egusi melon methyl ester (EMME) were determined in

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accordance to ASTM D 6751 and EN 14214 standard test methods. The fatty acid profile of EMME was analyzed using gas chromatograph. Also, rheological behaviors of EMME and its blends (B2, B5, B10) in relation to viscosity were studied.

The amount of catalyst and reaction temperature was the most significant ($P < 0.0001$) factors affecting the yield of EMME. Multiple regression analysis was used to develop an empirical mathematical model for predicting methyl ester yield of EMME. The optimum reaction conditions obtained from the model for EMME synthesis were 1:6.54 oil-to-methanol molar ratio, 1.22% catalyst amounts, and 65 ˚C reaction temperature resulting in a yield of 84.01%. Under experimental conditions, methyl esters yield of 84.46 ± 0.075% was obtained on an average with the optimal values. This yield value is well within the range predicted by the model. RSM was found to be a suitable technique for optimizing the transesterification of egusi melon seed oil. The quality and fuel properties of EMME determined were found to satisfy prescribed ASTM (D 6751) and EN 14214 specifications. The viscosity behavior of EMME and its blends with diesel fuel (pseudoplastic and Newtonian in nature) was found to agree with those of other biodiesels reported in literature.

From this present study, it was discovered that fuel properties and fatty ester profile of egusi melon biodiesel resemble those of sunflower, soybean and safflower. The kinematic viscosity (KV) of EMME was found to be 3.51 mm^2/s (at 40 °C), a value remarkably lower than most biodiesels (above 4.0 mm^2/s at 40 °C) reported. In addition, its cloud point is relatively low compared to soybean, rapeseed and sunflower biodiesels. Comparisons of egusi melon biodiesel with Malaysian palm biodiesel were satisfactory with the former offering better cloud point and significantly lower KV than the latter. In this work, the probable potential of *Colocynthis citrullus* L. seed oil for biodiesel production is clearly presented.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SINTESIS DAN PENGGAMBARAN SIFAT ESTER MINYAK EGUSI MELON SEBAGAI PENGGANTI KEPADA MINYAK DIESEL

Oleh

GIWA, SOLOMON OLANREWAJU

Disember 2009

Pengerusi: Profesor Madya Ir. Nor Mariah Adam, PhD

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Biodiesel merupakan monoalkyl ester minyak sayuan (VOs), lemak haiwan dan minyak sisa diterima pakai secara meluas sebagai bahan ganti bahanapi diesel terbitan fosil. Ia adalah punca tenaga bolehdiperbaharui dan berterusan (sustainable) yang mesra alam. Strain makanan-bahanapi VO biasa telah mencetus penyelidikan untuk menerokai 350 tanaman alternatif yang mampu diguna sebagai alternatif gantian diesel, tetapi hanya 100 sahaja yang telah diselidik. *Colocynthis citrillus lanatus* 'egusi' telah pertama kalinya dikaji sebagai bahan gantian diesel yang berpotensi. Minyak mentah dari biji benih telah dicirikan dan ditransesterifikasi menggunakan methanol dengan sodium methoxide sebagai pemangkin. Rekabentuk eksperimen untuk pengoptimuman keadaan tindakbalas telah dijalankan dengan kaedah tindakbalas permukaan (RSM). Rekabentuk komposit permukaan tengah berfaktorkan tiga aras telah digunakan. Amaun pemangkin (0.25 - 1.8% berat), suhu tindakbalas (45 - 65 °C) dan nisbah minyak-methanol (4 - 10)

telah dikaji sebagai faktor penting yang mempengaruhi tindakbalas. Sifat bahanapi minyak egusi melon methyl ester (EMME) telah ditentukan mengikut kaedah standard ASTM D 6751 dan EN 14214. Profil asid lemak EMME telah diuji menggunakan gas kromatograf. Pelakuan reologi EMME dan campuran (B2, B5, B10) berkaitan kelikatan juga telah dikaji.

Amaun pemangkin dan suhu tindakbalas adalah faktor paling signifikan ($P < 0.0001$) mempengaruhi hasil EMME. Analisis pelbagai regresi telah digunakan untuk membangun model empirical matematik untuk meramal hasil EMME. Keadaan optimum tindakbalas yang didapati dari model sintesis EMME adalah 1:6.54 nisbah molar minyak:methanol, 1.22% amaun pemangkin dan suhu tindakbalas 65 °C mengeluarkan hasil sebanyak 84.01%. Dalam keadaan eksperimen, methyl ester menghasilkan 84.46 ± 0.075% secara purata dengan nilai optimum. Nilai hasil ini adalah dalam julat ramalan model. RSM merupakan kaedah yang sesuai untuk pengoptimuman transesterifikasi minyak melon egusi. Kualiti dan sifat bahanapi EMME memenuhi kehendak ASTM (D 6751) dan EN 14214. Kelakuan kelikatan EMME dan campuranya adalah hamper menyerupai biodiesel lain yang dilaporkan dalam literature.

Dalam kajian ini, sifat bahanapi dan profil lemak ester minyak egusi melon menyerupai minyak bunga matahari, kacang soya ban safflower. Kelikatan kinematic (KV) EMME didapati jauh lebih rendah daripada kebayakan biodiesel lain. Tambahan pula titik kabus EMME adalah lebih rendah berbanding biodiesel kacang soya, rapeseed dan bunga

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matahari. Perbandingan minyak melon egusi dengan minyak sawit adalah memuaskan dengan EMME mempunyai titik kabus yang lebih bagus dan nilai KV jauh lebih rendah dari minyak sawit. Dalam kajian ini, potensi Colocynthis citrullus Lanatus sebagai biodiesel adah cerah.

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I certify that a Thesis Examination Committee has met on 4th December 2009 to conduct the final examination of Giwa Solomon Olanrewaju on his thesis entitled "Synthesis and Characterization of Egusi Melon Methyl Ester As Diesel Fuel Substitute" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science degree.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institution.

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TABLE OF CONTENTS

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LIST OF TABLES

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LIST OF FIGURES

Figure **Page**

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
CaO	Calcium Oxide
CCD	Central Composite Design
CCRD	Central Composite Rotatable Design
CEMSO	Crude Egusi Melon Seed Oil
CN	Cetane Number
CO	Carbon Monoxide
COST	Changed One Separate Factor at a Time
CO_2	Carbon Dioxide
CP	Cloud Point
D2	No. 2 Diesel
DG	Diglyceride
EMA	Engine Manufacturers Association
EMME	Egusi Melon Methyl Ester
EN 14214	European Standard
EU	European Union
FA	Fatty Acid
FFA	Free Fatty Acid
FID	Flame Ionization Detection
GC	Gas Chromatography
GL	Glycerol
H_2O	Water

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H_2SO_4	Sulphuric Acid
HHV	Higher Heating Value
HPLC	High Performance Liquid Chromatography
KOH	Potassium Hydroxide
KV	Kinematic Viscosity
MeOH	Methanol
MG	Monoglyceride
MgO	Magnesium Oxide
MPa	mega Pascal (Pressure)
MPOB	Malaysian Palm Oil Board
$NaOCH_2CH_3$	Sodium Ethoxide
$NaOCH_3$	Sodium Methoxide
NaOH	Sodium Hydroxide
PORIM	Palm Oil Research Institute Malaysia
PP	Pour Point
RSM	Response Surface Methodology
SCM	Supercritical Methanol
SiO_2	Silicon Dioxide
SO_2	Sulpur Dioxide
TG	Triglyceride
VO	Vegetable Oil
vol	volume
wt	weight

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g	gram
rpm	revolution per minute
s^{-1}	shear rate
Pa	pascal (shear stress)
Pas	viscosity (dynamic)
min	minutes
mol	mole
max	maximum
K	kelvin (temperature)
h	hour
cSt	centistokes
ml	millilitre
ppm	part per million
µl	microlitre

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy has been an indispensable and important issue of world concern. Major energy supply have been from fossil sources; petroleum, coal and gas. The scarcity of traditional fossil fuels, growing emissions of combustion-generated pollutants, and their increasing costs will make biomass sources more attractive (Sensoz *et al.*, 2000). Petroleum-based fuels have limited reserves concentrated in certain regions of the world and these sources are on the verge of declining off their peak production. The fossil fuel resources are depleting day by day. Known petroleum reserves are scarce and have made renewable energy sources more attractive, especially in very near future. Transportation and energy generation is reported to consume an estimated 90% of petroleum fuels (Crabbe *et al.*, 2001 and Demirbas, 2007).

Biodiesel refers to a diesel-equivalent processed fuel derived from biological sources which makes it a renewable form of energy. Biodiesel fuels are attracting increasing attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines. Biodiesel, as an alternative fuel for internal combustion engines, is defined as a mixture of monoalkyl esters of long chain fatty acids (FAME) derived from a renewable lipid feedstock, such as vegetable oil, animal fat and waste oil. Biodiesel

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typically comprises alkyl fatty acid (chain length C_{14} - C_{22}) esters of short-chain alcohols, primarily; methanol or ethanol. Biodiesel is the best candidate for diesel fuels in diesel engines. An alternative fuel to petrodiesel is expected to be technically feasible, economically competitive, environmentally acceptable, and easily available (Pinto *et al*., 2005).

Biodiesel can offer benefits including reduction of greenhouse gas emissions, regional development and social structure, especially to developing countries (Demirbas and Demirbas, 2007). Biodiesel improve the lubrication properties of diesel fuel and also reduce long term engine wear in diesel engines when used as blend. It is a good lubricant which is about 66% better than petrodiesel (Demirbas, 2009). Recently, biodiesel fuels have received significant attention both as a possible renewable alternative fuel and as an additive to existing petroleum-derived fuels. Besides an additional fuel supply, biodiesel presents several advantages when compared to existing fossil-based fuel. Numerous researchers have shown that exhaust particulate matter, unburned hydrocarbons, carbon monoxide, and sulfur levels are all significantly reduced when using biodiesel fuels (Graboski and McCormick, 1998; Murugesan *et al*., 2009). Research in this field has also shown increase in the levels of oxides of nitrogen, primarily as a result of advanced injection timing with biodiesel. Considerable research has been undertaken to understand the performance characteristics of biodiesel fuels as well as the production methods (Chang and Gerpen, 1997; Shahid and Jamal, 2007). Additional advantage of biodiesel is that it can be distributed using today's infrastructure, and its use and production are on rapid increase. Biodiesel raw materials

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are basically from three sources; vegetable oils (VOs), animal fats, and waste oils. VOs of rapeseed, canola, soybean, sunflower and palm have been investigated (Ma and Hanna, 1999) and used for biodiesel production both on small and large scales in different countries of the world. Other oil-bearing crops, especially the non edible ones (jatropha, neem oil, castor oil) have also been studied (Murugesan *et al*., 2009; Meher *et al*., 2006a; Demirbas, 2009).

There are various other biodiesel sources: almond, andiroba (*Carapa guianensis*), babassu (*Orbignia sp.*), barley, camelina (*Camelina sativa*),coconut, copra, cumaru (*Dipteryx odorata*), *Cynara cardunculus*, fish oil, groundnut, *Jatropha curcas*, karanja (*Pongamia glabra*), laurel, *Lesquerella fendleri*, *Madhuca indica*, microalgae (*Chlorella vulgaris*), oat, piqui (*Caryocar sp.*), poppy seed, rice, rubber seed, sesame, sorghum, tobacco seed, and wheat (Pinto *et al*., 2005).

Because it has similar properties to petroleum diesel fuel, biodiesel can be used alone (known as B100) or mixed in any proportion with petroleum diesel fuel. Biodiesel has slightly less energy content and a higher cetane number than the average diesel fuel. When biodiesel is blended with conventional diesel in proportions of 20% or less, any difference in engine performance is nearly imperceptible (Anonymous, 2001). Malaysia biodiesel policy also encourages the use of 5% palm biodiesel blend with diesel to reduce emission related environmental problem and over-dependence on fossil fuel due to declining petroleum reserves.

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1.2 Problem Statement

Conventional oils (soybean, palm, sunflower, rapeseed oils etc.) mostly used for food purposes have been recently used as fuel (biodiesel) due to the rekindled interest in alternative fuel for diesel (Balat and Balat, 2008; Demirbas, 2007). In spite of this, biodiesel production from these oils has progressively strained food uses, price, production and availability of these oils (Rashid *et al*., 2008a). In addition, this has precipitated a demand-driven competition between food and non-food uses of these VOs at the expense of their relatively constant supply. Consequently, this has ignited the search for additional regional biodiesel raw material. The increasing need of biorenewable energy sources to substitute petroleum-derived diesel has driven research for other oil crops to meet biodiesel production needs without strain to food uses of VOs.

Various oils have been in used different countries as raw materials for biodiesel production owing to their availability. Soybean oil is commonly used in United States and rapeseed oil is used in many European countries for biodiesel production, whereas, coconut oil and palm oils are used in Malaysia and Indonesia for biodiesel production (Ghadge and Raheman, 2005; Srivastava and Verma, 2008; Sarin *et al*., 2007; Demirbas, 2006).

With over 350 oil crops identified (Demirbas, 2007; 2009; Balat and Balat, 2008) and their availability in different geographical locations (Pinto *et al*., 2005), there is the need

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to explore these oil-bearing crops' potential as biodiesel feedstock apart from the conventional VOs. Low quality underused raw materials have been reported used for biodiesel production (Pinto *et al*., 2005). Moreso, recent studies showed the investigation of lesser known, under-utilized and neglected oil crops in various parts of the world as potential feedstocks for biodiesel production. Schinas *et al*. (2009), Kansedo *et al*. (2009), Rashid *et al*. (2008a), Hosamani *et al*. (2009), Yang *et al*. (2009), Chapagain *et al*. (2009) and Li *et al*. (2009) investigated pumpkin (*Cucurbita pepo L*), sea mango (*Cerbera odollam*), *moringa oleifera* oil, *michelia champaca* and *garcinia indica* seed oils, *idesia polycarpa var. vestita* fruit oil, desert date (*Balanites aegyptiaca*) and *eruca sativa gars* vegetable oil, respectively and reported their potential as biodiesel fuels. Also, Schinas *et al*. (2009) studied pumpkin melon oil, first of curcubit family to be investigated for its biodiesel potential and found its fuel properties in good agreement with European (EN 14214) biodiesel standard.

Cucurbitaceae is a large plant family which consists of nearly 100 genera and 750 species (Ng, 1993). This plant family is known for its enormous genetic diversity and wide range adaptation which includes tropical and subtropical regions, arid deserts and temperate locations (Achu *et al*., 2006). Seeds of cucurbits are sources of oil and protein (Ng, 1993, Achu *et al*., 2005) and contain about 50% oil with up to 35% proteins (Achu *et al*., 2005) and are cultivated and consumed for these reasons world over. Egusi melon belongs to the species of the genus *Citrullus* of cucurbitaceae family, which usually consist of a large number of varieties that are generally known as melons (Mabaleha *et al*., 2007). Egusi melon is among the 300 species of melon found in tropical Africa (Ntui *et al*., 2009). It is cultivated for its seeds, which are rich in oil (53%) and protein (28%)

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(Ntui *et al*., 2009). It is cultivated in regions of Middle East, West Africa, especially, Nigeria, Ghana, Togo, Benin and Cameroon for the foods in the seeds and as a crop interplanted with maize, cassava and yam (Uruakpa and Aluko, 2004). In Nigeria only, ''egusi'' is cultivated over an area of 361,000 ha with a production figure of 347,000 tonnes (seeds) in 2002 (Federal Ministry of Agriculture and Rural Development, 2005) with harvest period of three to four months. It is used both as local condiment and soup thickener and the industrial scale production of the oil yet to be utilized despite the huge potential (Uruakpa and Aluko, 2004). The crude oil from the seed was investigated as potential feedstock for biodiesel production.

1.3 Purpose and Objectives

The main purpose of this work was to investigate egusi melon oil as a potential fuel substitute for petrodiesel. Biodiesel is a regional issue of energy security since the raw materials used in various countries have to do with its availability in those countries in question. Egusi melon was chosen for this study due to its high oil content (52% based on preliminary work conducted), less food use, availability (in region where it is cultivated), less competition for food use and commercial VO production potential yet to be harnessed. Response surface methodology (RSM) was used to design the experiment in order to optimize selected reaction variables. The three most important variables (reaction temperature, catalyst amount and molar ratio of oil to methanol) affecting the yield of esters during transeseterification process were selected for investigation. The optimum conditions for the transesterification of egusi seed oil to produce egusi melon

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biodiesel were determined based on the yield of egusi melon methyl ester (EMME). The quality and selected key fuel properties of EMME as fossil-diesel fuel substitute were measured in accordance with biodiesel standards. In addition, the rheological behavior of EMME and its blends with diesel fuel was investigated. The specific objectives of this study were as follows;

1. To synthesize egusi melon methyl ester (EMME) and optimize the reaction variables.
2. To characterize EMME and study its rheological behavior including its blends with diesel fuel.

1.4 Scope and Limitation

The scope of this research focuses on the investigation of a new, lesser-known and under-utilized oil crop of curcubit family called ‘egusi’ melon (*Colocynthis citrullus* L.) as fuel substitute for petrodiesel. This entails the transesterification of crude egusi melon seed oil using methanol and sodium methoxide ($NaOCH_3$) as alcohol and catalyst, respectively. The choice of $NaOCH_3$ as catalyst over NaOH and KOH was informed by the high yield of EMME during preliminary study. Important transesterification reaction variables (reaction temperature, catalyst amount and oil/methanol molar ratio) were optimized. The characterization of the raw oil and the resulting methyl ester and the rheological study on the methyl ester product (including its blend with diesel fuel) were carried out.

REFERENCES

Achu, M. B. Fokou, E. Tchiegang, C. Fotso, M., and Tchouanguep, F. M. (2005). Nutritive value of some cucurbitaceae oilseeds from different regions in Cameroon . *Afr. J. Biotechnol*. 11, 1329-1334.

Achu, M. B. Fokou, E. Tchiegang, C. Fotso, M., and Tchouanguep, F. M. (2006). Chemical characteristics and fatty acid composition of cucurbitaceae oils from Cameroon . http://dx.doi.org/10.1051/IUFoST:20060026. Accessed on 29 March 2009.

Adjaye, J. D. Katikaneni, S. P. R., and Bakhsi, N. N. (1995). Catalytic conversion of canola oil to fuels and chemicals over various cracking catalysts. *Can. J. Chem. Eng.* 73, 484-97.

Akoh, C. C., and Nwosu, C.V. (1992). Fatty acid composition of melon seed oil lipids and phospholipids. *J. Am. Oil Chem. Soc.* 69, 314-316.

Alcantara, R. Amores, J. Canoira, L. Fidalgo, E. Franco, M. J., and Navarro, A. (2000). Catalytic production of biodiesel from soy-bean oil, used frying oil and tallow. *Biomass Bioenergy* 18, 515-527.

Al-Khalifa A. S. (1996). Physicochemical characteristics, fatty acid composition and lipoxygenase activity of crude pumpkin and melon seeds. *J. Agric. Food Chem*. 44, 964-966.

Allen, C. A. W. Watts, K. C. Ackman, R. G., and Pegg, M. J. (1999). Predicting the viscosity of biodiesel fuels from their fatty acid ester composition. *Fuel* 78, 1319-26.

Al-Widyan, M., and Al-Shyoukh, A. (2002). Experimental evaluation of the transesterification of waste palm oil into biodiesel. *Bioresourc. Technol*. 85, 253-256.

Anonymous. (2001). Association of Equipment Manufacturer “The new Diesel Fuels: They are in your future for non road equipment”. Provided as a service by Association of Equipment Manufacturer. http://www.aem.org/Technical/PDF/diesel-fuels-rpt.pdf. Accessed on 12 August 2009.

Antolin, G. Tinaut, F. Briceno, Y. Castano, V. Perez, C., and Ramirez, A. (2002). Optimisation of biodiesel production by sunflower oil transesterification. *Bioresourc. Technol*. 83, 111-114.

© COPYRIGHT UPM

Bajpai, D., and Tyagi, V. K. (2006). Biodiesel: Source, production, composition, properties and its benefits. *J. Oleo Sci*. 55,487-502.

Balat, M., and Balat, H. (2008). A critical review of biodiesel as vehicular fuel. *Energy Convers. Mgmt*. 49, 2727-2741.

Balat, M. (2005). Biodiesel from vegetable oils via transesterification in supercritical ethanol. *Energy Edu. Sci. Technol*. 16, 45-52.

Balat, M. (2006). Fuel characteristics and the use of biodiesel as a transportation fuel. *Energy Sourc*. 28, 855–64.

Balat, M. (2007). Production of biodiesel from vegetable oils: a survey. *Energy Sour*. 29, 895-913.

Bautista, L. F. Vicente, G. Rodrı´guez, R., and Pacheco, M. (2009). Optimisation of FAME production from waste cooking oil for biodiesel use. *Biomass Bioenergy* doi:10.1016/j.biombioe.2009.01.009.

Bhatia, S. Twaiq, F. A., and Zabidi, N. A. M. (1999). Catalytic conversion of palm oil to hydrocarbons: Performance of various zeolite catalysts. *Ind. Eng. Chem. Res*. 38, 3230-7.

Boocock, D. S. Konar , V., and M. S. Buligan. (1998). Fast formation of high-purity methyl esters from vegetable oils. *J. Am. Oil Chem. Soc*. 75, 1167-1171.

Canacki, M., and Gerpen, J. V. (1999). Biodiesel production via acid catalysis. *Trans Am. Soc. Agric. Eng*. 42, 1203-10.

Canakci, M., and Gerpen, J. V. (2001). Biodiesel production from oils and fats with high free fatty acids. *Trans. ASAE* 44, 1429-1436.

Canakci, M., and Gerpen, J. V. (2003). A pilot plant to produce biodiesel from high free fatty acid feedstocks. *Trans. ASAE* 46, 945-55.

Candeia, R. A. Freitas, J. C. O. Souza, M. A. F. Conceio, M. M., Santos , I. M. G. Soledade, L. E. B., and Souza, A. G. (2007). Thermal and rheological behavior of diesel and methanol biodiesel blends. *J. Therm. Anal. Cal*. 87, 653-656.

Candeia, R. A. Silva, M. C. D. Filho, J. R. C. Brasilino, M. G. A. Bicudo, T. C. Santos, I. M. G., and Souza, A. G. (2009). Influence of soybean biodiesel content on basic properties of biodiesel–diesel blends. *Fuel* 88, 738-743.

Chang, D. Y. Z., and Gerpen, J. H. V. (1997). Fuel properties and engine performance for biodiesel prepared from modified feedstocks. *SAE Paper* 971684, 1997.

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Chapagain, B. P. Yehoshua, Y., and Wiesman, Z. (2009). Desert date (*balanites aegypytiaca*) as an arid sustainable bioresource for biodiesel. *Bioresourc. Technol*. 100, 1221-1226.

Chongkhong, S. Tongurai, C. Chetpattananondh, and P. Bunyakan, C. (2007). Biodiesel production by esterification of palm fatty acid distillate. *Biomass Bioenergy* 31, 563-568.

Chung, K. H. Kim, J., and Lee, K. Y. (2009). Biodiesel production by transesterification of duck tallow with methanol on alkali catalysts. *Biomass Bioenergy* 33, 155-158.

Clark, S. Wagner, L. Schrock, and M. Piennaar, P. (1984). Methyl and ethyl soybean esters as renewable fuels for diesel engines. *J. Am. Oil Chem. Soc*. 61, 1632-1638.

Conceicao, M. M. Candeia, R. A. Dantas, H. J. Soledade, L. E. B. Jr., V. J. F., and Souza, A. G. (2005). Rheological behavior of castor oil biodiesel. *Energy Fuels* 19, 2185-2188.

Conceicão, M. M. Candeia, R. A. Silva, F. C. Bezerra, A. F. Jr., V. J. F., and Souza, A. G. (2007). Thermoanalytical characterization of castor oil biodiesel. *Renew. Sustain. Energy Rev.* 11, 964-975.

Crabbe, E. Hipolito, N. C. Kobayashi, G. Sonomoto, K., and Ishizaki, A. (2001). Biodiesel production from crude palm oil and evaluation of butanol extraction and fuel properties. *Process Biochem*. 37, 65-71.

Dandik, L., and Aksoy, H. A. (1998). Pyrolysis of used sunflower oil in the presence of sodium carbonate by using fractionating pyrolysis reactor. *Fuel Proc.Technol*. 57, 81-92.

Darnoko, D., and Cheryan, M. (2002). Kinetics of palm oil transesterification in a batch reactor. *J. Am. Oil Chem. Soc*. 77, 1263-7.

Demirbas, A., and Demirbas, I. (2007). Importance of rural bioenergy for developing countries. *Energy Convers. Mgmt*. 48, 2386-98.

Demirbas, A. (2002). Biodiesel from vegetable oils via transesterification in supercritical methanol. *Energy Convers. Mgmt*. 43, 2349-56.

Demirbas, A. (2003). Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. *Energy Convers. Mgmt*. 44, 2093-109.

Demirbas A. (2005). Biodiesel production from vegetable oils via catalytic and noncatalytic supercritical methanol transesterification methods. *Prog. Energy Combus. Sci*. 31, 466-87.

Demirbas, A. (2006).Biodiesel production via non-catalytic SCF method and biodiesel fuel characteristics. *Energy Convers. Mgmt*. 47, 2271-82.

Demirbas, A. (2007a). Importance of biodiesel as transportation fuel. *Energy Policy* 35 4661-4670.

Demirbas, A. (2007b). Biodiesel from sunflower oil in supercritical methanol with calcium oxide. *Energy Convers. Mgmt*. 48, 937-41.

Demirbas, A. (2008). Relationships derived from physical properties of vegetable oil and biodiesel fuels. *Fuel* 87, 1743-1748.

Demirbas, A. (2009). Progress and recent trends in bidiesel fuels. *Energy Convers. Mgmt*. 50, 14-34.

Demirbas, D., and Karslıoglu, S. (2007). Biodiesel production facilities from vegetable oils and animal fats. *Energy Sour*. 29, 133-41.

Diasakou, M. Louloudi, A., and Papayannakos, N. (1998). Kinetics of the non-catalytic transesterification of soybean oil. *Fuel* 77, 1297-1302.

Divakar, S., and Manohar, B. (2007). Use of lipases in the industrial production of esters. Polaina, MacCabe, A. P. (eds.), Industrial Enzymes, 283-300. *Springer*.

Domingos, A. K. Saad, E. B. Wilhelm, H. M., and Ramos, L. P. (2008). Optimization of the ethanolysis of *Raphanus sati*Vus (L. Var.) crude oil applying the response surface methodology. *Bioresour. Technol*. 99, 1837-1845.

Dufey, A. (2006). Biofuels production, trade and sustainable development: emerging issues. Environment report, International Institute for Environment and Development (IIED), London, UK, November 22, 2006. <www.iied.org/pubs>.

El-Diwani, G. Attia, N. K., and Hawash, S. I. (2009). Development and evaluation of biodiesel fuel and by-products from jatropha oil. *Int. J. Environ. Sci. Tech*. 6, 219-224.

Encinar, J. M. Gonzalez, J. F. Rodriguez, J. J., and Tejedor, A. (2002). Biodiesel fuels from vegetable oils: transesterification of *Cynara cardunculus* L. oils with ethanol. *Energy Fuel* 16, 443-50.

© COPYRIGHT UPM

Engler, C. R. Johnson, L. A. Lepori, W. A., and Yarbrough, C. M. (1983). Effects of processing and chemical characteristics of plant oils on performance of an indirect-injection diesel engine. *J. Am. Oil Chem. Soc*. 60, 1592-1596.

Federal Ministry of Agriculture and Rural Development. Agrucultural outlook in Nigeria . (2005) A paper presented at the Nigeria National Crop Outlook Conference, Kano State , Nigeria , 26th - 27th May, 2005. Accessed 26 July, 2009.

Ferella, F. Mazziotti, D. Celso, G. De Michelis, I. Stanisci, V., and Vegliò, F. (2009). Optimization of the transesterification reaction in biodiesel production. *Fuel* doi:10.1016/j.fuel.2009.01.025.

Fernando, S. Karra , P. Hernandez, R., and Jha, S. K. (2007). Effect of incompletely converted soybean oil on biodiesel quality. *Energy* 32, 844-851.

Foon, C. S. May, C. Y. Liang, Y. C. Ngan, M. A., and Basiron, Y. (2005). Palm biodiesel: Gearing towards Malaysian biodiesel Standards. *MPOB*, 2005. Accessed: January 13, 2009.

Freedman, B. Pryde, E., and Mounts, T. (1984). Variables affecting the yields of fatty esters from transesterified vegetable oils. *J. Am. Oil Chem. Soc*. 61, 1638-1643.

Fukuda, H. Kondo, A., and Noda, H. (2001). Biodiesel fuel production by transesterification of oils. *J. Biosci. Bioengrg*. 92, 405-416.

Ghadge, S. V., and Raheman H. (2005). Biodiesel production from mahua (*Madhuca indica*) oil having high free fatty acids. *Biomass Bioenergy* 28, 601-5.

Ghadge, S., and Raheman, H. (2006). Process optimization for biodiesel production from mahua (*madhuca indica*) oil using response surface methodology. *Bioresourc. Technol*. 97, 379-384.

Ghazi, A. T. I. M. Resul, M. F. M. G. Yunus, R., and Yaw, T. C. S. (2008). Preliminary design of oscillatory flow biodiesel reactor for continuous biodiesel production from jatropha triglycerides. *J. Engrg. Sci. Technol*. 3, 138-145.

Goering, C. E., and Fry, B. (1984). Engine durability screening test of a diesel oil/soy oil/alcohol microemulsion fuel. *J. Am. Oil Chem. Soc*. 61, 1627-1632.

Goodrum, J. W. (2002). Volatility and boiling points of biodiesel from vegetable oils and tallow. *Biomass Bioenergy* 22, 205-11.

Goodrum, J. W. Geller, D. P., and Adams, T. T. (2003). Rheological characterization of animal fats and their mixtures with #2 fuel oil. *Biomass Bioenergy* 24, 249-256.

© COPYRIGHT UPM

Graboski, M. S., and McCormick, R. L. (1998). Combustion of fat and vegetable oil derive fuels in diesel engines. *Prog. Energy Comust. Sci*. 24, 125-164.

Granados, M. L. Poves, M. D. Z. Alonso, D. M. Mariscal, R. Galisteo, F. C., and Tost, R. M. (2007). Biodiesel from sunflower oil by using activated calcium oxide. *Appl. Catal B. Environ.* 73, 317-26.

Gryglewiez, S. (1999). Rapeseed oil methyl esters preparation using heterogeneous catalyst. *Bioresourc. Technol*. 70, 249-253.

Guerreiro, L. Castanheiro, J. E. Fonseca, I. M. Martin-Aranda, R. M. Ramos, A. M. J., and Vital, J. (2006). Transesterification of soybean oil over sulfonic acid functionalized polymeric membranes. *Catal. Today* 118, 166-71.

Gupta, P. K. Kumar, R. Panesar, P. S., and Thapar, V. K. (2007). Parametric studies on bio-diesel prepared from rice bran oil. *Agric Eng Int*: CIGR EJ 2007; IX (April) [Manuscript EE 06 007].

Haas, M. J., and Scott, K. M. (1996). Diesel fuel as a solvent for the lipase-catalyzed alcoholysis of triglycerides and phosphatidylcholine. *J. Am. Oil Chem. Soc*. 73, 1497-1504.

Hameed, B. H. Lai, L. F., and Chin, L. H. (2009). Production of biodiesel from palm oil (Elaeis guineensis) using heterogeneous catalyst: An optimized process. *Fuel Process. Technol.* 90, 606-610.

Hosamani, K. M. Hiremath, V. B., and Keri, R. S. (2009). Renewable energy sources from *Michelia champaca* and *Garcinia indica* seed oils: A rich source of oil. *Biomass Bioenergy* 33, 267-270.

Isigigur, A. Karaosmonoglu, F., and Aksoy, H. A. (1994). Methyl ester from safflower seed oil of Turkish origin as a biofuel for diesel engines. *Appl. Biochem. Biotechnol*. 46, 103-12.

Iso, M. Chen, B. Eguchi, M. Kudo, T., and Shrestha, S. (2001). Production of biodiesel fuel from triglycerides and alcohol using immobilized lipase. *J. Molec. Catal. B. Enzym.* 16, 53-8.

Jeong, G. T. Yang, H. S., and Park, D. H. (2009). Optimization of transesterification of animal fat ester using response surface methodology. *Bioresourc. Technol*. 100, 25-30.

Jeong, G. T., and Park, D. H. (2009). Optimization of biodiesel production from castor oil using response surface methodology. *Appl. Biochem. Biotechnol.* 156, 431-441.

© COPYRIGHT UPM

Joshi, R. M., and Pegg, M. J. (2007). Flow properties of biodiesel fuel blends at low temperatures. *Fuel* 86, 143-51.

Kalam, M., and Masjuki, H. (2002). Biodiesel from palmoil - an analysis of its properties and potential. *Biomass Bioenergy* 23, 471-479.

Kamel, B. S. Dawson, H., and Kakuda, Y. (1995). Characteristics and composition of melon and grape seed oils and cakes. *J. Am. Oil Chem. Soc.* 62, 881-883.

Kansedo, J. Lee, K. T., and Bhatia, S. (2009). *Cerbera odollam* (sea mango) oil as a promising non-edible feedstock for biodiesel production. *Fuel* 88, 1148-1150.

Karmee, S. K., and Chadha, A. (2005). Preparation of biodiesel from crude oil of *Pongamia pinnata*. *Bioresourc. Technol.* 96, 1425-1429.

Katikaneni, S. P. R. Adjaye, J. D., and Bakhshi, N. N. (1995). Catalytic conversion of canola oil to fuels and chemicals over various cracking catalysts. *Can. J. Chem. Eng.* 73, 484-97.

Kerschbaum, S., and Rinke, G. (2004). Measurement of the temperature dependent viscosity of biodiesel fuels. *Fuel* 83, 287-91.

Kim, H. J. Kang, B. S. Kim, M. J. Park, Y. M. Kim, D. K., and Lee, J. S. (2004). Transesterification of vegetable oil to biodiesel using heterogeneous base catalyst. *Catal. Today* 95, 315-20.

Knothe, G. Historical perspectives on vegetable oil-based fuels. (2001). Vol. 12, *Inform*.

Knothe, G. (2005). Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters. *Fuel Process. Technol.* 86, 1059-1070.

Knothe, G. (2006). Analyzing biodiesel: standards and other methods. *J. Am. Oil Chem. Soc.* 83, 823-33.

Köse, O. Tuter, M., and Aksoy, H. (2002). Immobilized Candida ntarctica lipase-catalyzed alcoholysis of cotton seed oil in a solvent-free medium. *Bioresourc. Technol.* 83, 125-129.

Kusdiana, D., and Saka, S. (2001). Kinetics of transesterification in rapeseed oil to biodiesel fuels as treated in supercritical methanol. *Fuel* 80, 693-8.

Kusdiana, D., and Saka, S. (2004). Effects of water on biodiesel fuel production bysupercritical methanol treatment. *Bioresourc. Technol.* 91, 289-95.

Lang, X. Dalai, A. K. Bakhshi, N. N. Reaney, M. J., and Hertz, P. B. (2001). Preparation and characterization of bio-diesels from various bio-oils. *Bioresour. Technol.* 80, 53-63.

Leung, D. (2001). Development of a clean biodiesl fuel in Hong Kong using recycled oil. *Water, Air, and Soil Pollution* 130, 277-282.

Leung, D., and Guo, Y. (2006). Transesterification of neat and used frying oil: optimization for biodiesel production. *Fuel process. Technol*. 87, 883-890.

Li, S. Wang , Y. Dong, S. Chen, Y. Cao, F. Chai, F., and Wang, X. (2009). Biodiesel production from *Eruca Sativa Gars* vegetable oil and motor, emissions properties. *Renew. Energy* 34, 1871-1876.

Lima, D. G. Soares, V. C. D. Ribeiro, E. B. Carvalho, D. A. Cardoso, E. C. V., and Rassi, F. C. (2003). Diesel-like fuel obtained by pyrolysis of vegetable oils. *J. Anal. Appl. Pyrol*. 71, 987-96.

Lotero, E. Goodwin, J. G. Jr., B. D. A. Suwannakarn, K. Liu, Y., and Lopez, D. E. (2006). *The Catalysis of Biodiesel Synthesis*. In J. Spivey (Ed.), *Catalysis* (pp. 41-83). London : Royal Society of Chemistry.

Ma, F., and Hanna, M. A. (1999). Biodiesel production: a review. *Bioresourc. Technol*. 70, 1-15.

Ma, F. Clements, L. D., and Hanna, M. A. (1999). The effect of mixing on transesterification of beef tallow. *Bioresourc. Technol*. 69, 289-93.

Mabaleha, M. B. Mitei, Y. C., and Yeboah, S. O. (2007). A comparative study of the properties of selected melon seed oils as potential candidates for development into commercial edible vegetable oil. *J. Am. Oil Chem. Soc.* 84, 31-36.

Madras, G. Kolluru, C., and Kumar, R. (2004). Synthesis of biodiesel in supercritical fluids. *Fuel* 83, 2029-33.

May, C. Y. (2004). Transesterification of palm oil: effect of reaction parameters. *J. oil palm research* 16, 1-11.

Mbaraka, I., and Shanks B. (2006). Conversion of oils and fats using advanced mesoporous heterogeneous catalysts. *J. Am. Oil Chem. Soc.* 83, 79-91.

Mbaraka, I. McGuire, K., and B. Shanks. (2006). Acidic mesoporous silica for the catalytic conversion of fatty acids in beef tallow. *Ind. Eng. Chem. Res.* 45, 3022-28.

© COPYRIGHT UPM

Meher. L. C. Dharmagadda, S. S., and Naik, S. N. (2006a). Optimization of alkali catalyzed transesterification of *Pongamia pinnata* oil for production of biodiesel. *Bioresourc. Technol*. 97, 1392-7.

Meher. L. C. Sagar, D. V., and Naik, S. N. (2006b). Technical aspects of biodiesel production by transesterification – a review. *Renew. Sustain. Energy Rev*. 10, 248-68.

Meka, P. K. Tripathi, V., and Singh, R. P. (2007). Synthesis of biodiesel fuel from safflower oil using various reaction parameters. *J. Oleo Sci*. 56, 9-12.

Milovanović, M., and Pićurić-Jovanović, K. (2005). Characteristics and composition of melon seed oil**.** *J. Agric. Sci.* 50, 41-49.

Mittelbach, M. (1996). Diesel fuel derived from vegetable oils, vi: specifications and quality control of biodiesel. *Bioresourc. Technol*. 56, 7-11.

Mohan, D. Pittman Jr, C. U., and Steele, P. H. (2006). Pyrolysis of wood/biomass for bio-oil: a critical review. *Energy Fuels* 20, 848-89.

Monteiro, M. R. Ambrozin, A. R. P. Lião, L. M., and Ferreira, A. G. (2008). Critical review on analytical methods for biodiesel characterization. *Talanta* 77, 593-605.

Moore, N. Katz, E. Willner, I., and Tao, G. (1996). Electrocatalytic reduction of organic peroxides in organic solvents by microperoxidase-11 immobilized as a monolayer on a gold electrode. *J. Electroanal. Chem.* 417, 189-192.

Moser, B. R., and Erhan, S. Z. (2008). Branched chain derivatives of alkyl oleates: Tribological, rheological, oxidation, and low temperature properties. Fuel 87, 2253-57.

Moser, B. R. (2009). Biodiesel production, properties, and feedstocks. *In vitro cell dev. Biol. plant* 45, 229-226.

Muniyappa, P. Brammer, S., and Noureddini, H. (1996). Improved conversion of plant oils and animal fats into biodiesel and co-product. *Bioresourc. Technol*. 56, 19-24.

Murugesan, A. Umarani, C. Subramanian, R., and Nedunchezhian, N. (2009). Bio-diesel as an alternative fuel for diesel engines- A review. *Renew. Sustain. Energy Rev*. 13, 653-62.

Nagel, N., and Lemke, P. (1990). Production of methyl fuel from miceoalgea. *Appl. Biochem. Biotechnol.* 24, 355-61.

© COPYRIGHT UPM

Nang, H. L. L. Liang, Y. C. Wei, P. C., and May, C. Y. (2007). Determination of the quality parameters of biodiesel. *MPOB information series*, accessed January 5, 2008.

Ng, T. J. (1993). *New opportunities in the cucurbitaceae.* In: J., Janick and J. E., Simon (Eds.), New Crops (pp. 538-46). New York : Wiley.

Nik, W. B. W. Ani, F. N. Masjuki, H. H., and Giap, S. G. E. (2005). Rheology of bio-edible oils according to several rheological models and its potential as hydraulic fluid. *Ind. Crops Prod*. 22, 249-55.

Noureddini, H. Harkey, D., and Medikonduru, V. (1998). A continuous process for the conversion of vegetable oils into methyl esters of fatty acids. *J. Am. Oil Chem. Soc*. 75, 1775-83.

Noureddini, H., and D. Zhu. (1997). Kinetics of Transesterification of Soybean Oil. *J. Am. Oil Chem. Soc*. 74, 1457-63.

Ntui, V.O. Thirukkumaran, G. Iioka, S., and Mii, M. (2009). Efficient plant regeneration via organogenesis in ‘‘egusi’’ melon (*Colocynthis citrullus* L.). *Scientia Horticulturae* 119, 397-402.

Ozaktas, T. (2000). Compression ignition engine fuel properties of a used sunflower oil - diesel fuel blend. *Energy Sour.* 22, 377-82.

Patil, P. D., and Deng, S. (2009). Optimization of biodiesel production from edible and non-edible vegetable oils. *Fuel* 88, 1302-06.

Phan, A. N., and Phan, T. M. (2008). Biodiesel production from waste cooking oils. *Fuel* 87, 3490-96.

Pinto, A. C. Guarieiro, L. L. N. Rezende , M. J. C. Ribeiro, N. M. Torres, E. A., and Lopes, W. A. (2005). Biodiesel: an overview. *J. Brazil Chem. Soc*. 16, 1313-30.

Pioch, D. Lozano, P. Rasoanantoandro, M. C. Graille, J. Geneste, P., and Guida, A. (1993). Biofuels from catalytic cracking of tropical vegetable oils. *Oleagineux* 48, 289-91.

Pramanik, K. (2003). Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine. *Renewable Energy* 28, 239-248.

Raheman, H., and Phadatare, A. (2004). Diesel engine emissions and performance from blends of karanja methyl ester and diesel fuel. *Biomass Bioenergy* 27(4), 393-97.

© COPYRIGHT UPM

Ramadhas, A. S. Jayaraj, S., and Muraleedharan, C. (2005). Biodiesel production from high FFA rubber seed oil. *Fuel* 84, 335-40.

Ramos, M. J. Fernandez, C. M. Casas, A. Rodriguez, L., and Perez. A. (2009). Influence of fatty acid composition of raw materials on biodiesel properties. *Bioresour. Technol*. 100, 261-268.

Rashid, U. Answar, F. Moser, B. R., and Knothe, G. (2008a). Moringa oleifera oil: A possible source of biodiesel. *Bioresourc. Technol*. 99, 8175-8179.

Rashid, U., and Anwar, F. (2008b). Production of biodiesel through optimized alkaline-catalyzed transesterification of rapeseed oil. *Fuel* 87, 265-273.

Rashid, U., and Anwar, F. (2008c). Production of biodiesel through base-catalyzed transesterification of safflower oil using an optimized protocol. *Energy Fuels* 22, 1306-1312.

Rashid, U. Anwar, F., and Arif, M. (2009a). Optimization of base catalytic methanolysis of sunflower (*Helianthus annuus*) seed oil for biodiesel production by using response surface methodology. *Ind. Eng. Chem. Res*. 48, 1719-1726.

Rashid, U. Anwar, F. Ansari, T. M. Arif, M., and Ahmad, M. (2009b). Optimization of alkaline transesterification of rice bran oil for biodiesel production using response surface methodology. *J. Chem. Technol. Biotechnol*. 84, 1364-70.

Sadrameli, S. M. Seames, W., and Mann, M. (2008). Prediction of higher heating values for saturated fatty acids from their physical properties. *Fuel* 87, 1776-1780.

Samson, W. Vidrinc, C. D., and Robbins, J. (1985). Chinese tallow seed oil as diesel fuel extenders. *Transactions of the ASAE* 28(5), 1406-09.

Santos , J. C. O. Santos , I. M. G., and Souza, A. G. (2005). Effect of heating and cooling on rheological parameters of edible vegetable oils. *J.Food Engrg*. 67, 401-05.

Sarin, R. Sharma, M. Sinharay, S., and Malhotra, R. K. (2007). Jatropha-palm biodiesel blends: an optimum mix for Asia. *Fuel* 86, 1365-71.

Sastry, G. S. R. Murthy, A. S. R. K, Prasad P. R. Bhuvaneswari, K., and Ravi, P. V. (2006). Identification and determination of bio-diesel in diesel. *Energy Sour*. 28, 1337-42.

Saydut, A. Duz, M. Z. Kaya, C. Kafadar, A. B., and Hamamci, C. (2008). Transesterified sesame (*Sesamum indicum* L.) seed oil as a biodiesel fuel. *Bioresourc. Technol*. 99, 6656-60.

© COPYRIGHT UPM

Schinas, P. Karavalakis, G. Davaris, C. Anastopoulos, G. Karonis, D. Zannikos, F. Stournas, S., and Lois, E. (2009). Pumpkin (*cucurbita pepo* L.) seed oil as an alternative feedstock for the production of biodiesel in Greece. *Biomass Bioenergy* 33, 44-49.

Schlick, M. L. Hanna, M. A., and Schinstock, J. L. (1988). Soybean and sunflower oil performance in a diesel-engine. *Transactions of the ASAE* 31, 1345-1349.

Schuchardt, U. Sercheli, R., and Vargas, R. M. (1998). Transesterification of vegetable oils: a review. *J. Brazil Chem. Soc*. 9, 199-210.

Schwab, A. W. Bagby, M. O., and Freedman, B. (1987). Preparation and properties of diesel fuels from vegetable oils. *Fuel* 66, 1372-1378.

Sensoz, S. Angin, D., and Yorgun, S. (2000). Influence of particle size on the pyrolysis of rapeseed (*Brassica napus* L.): fuel properties of bio-oil. *Biomass Bioenergy* 19, 271-9.

Shahid, E. M., and Younis, J. (2007). A review of biodiesel as vehicular fuel. *Sustain Renew. Energy Rev*. 12, 2484-94.

Sharma, Y.C. Singh, B., and Upadhyay, S. N. (2008). Advancements in development and characterization of biodiesel: A review. *Fuel* 87, 2355-73.

Sharma, Y. C., and Singh, B. (2008). Development of biodiesel from karanja, a tree found in rural India. *Fuel* 67, 1740-2.

Shay, E. G. (1993). Diesel fuel from vegetable oils: status and opportunities. *Biomass Bioenergy* 4, 227-42.

Srivastava, A., and Prasad, R. (2000). Triglycerides-based diesel fuels. *Renew. Sustain. Energy Rev*. 4, 111-33.

Srivastava, P. K., and Verma, M. (2008). Methyl ester of karanja oil as an alternative renewable source energy. *Fuel* 87, 1673-7.

Stavarache, C. Vinatoru, M. Nishimura, R., and Maed, Y. (2005). Fatty acids methyl esters from vegetable oil by means of ultrasonic energy. *Ultrason. Sonochem*. 12, 367-72.

Strayer, R. C. Blake, J. A., and Craig, W. K. (1983). Canola and high erucic rapeseed oil as substitutes for diesel fuel: Preliminary tests. *J. Am. Oil Chem. Soc*. 60, 1587-92.

© COPYRIGHT UPM

Tangsathitkulchai, C. Sittichaitaweekul, Y. and Tangsathitkulchai M. Temperature. (2004). Effect on the viscosities of palm oil and coconut oil blended with diesel oil. *J. Am. Oil Chem. Soc*. 81, 401-05.

Tat, M. E., and Gerpen, J. H. V. (1999). The kinematic viscosity of biodiesel and its blends with diesel fuel. *J. Am. Oil Chem. Soc*. 76, 1511-13.

Tate, R. E. Watts, K. C. Allen, C. A. W., and Wilkie, K. I. (2006a). The densities of three biodiesel fuels at temperatures up to 300 °C. *Fuel* 85, 1004-09.

Tate, R. E. Watts, K. C. Allen, C. A. W., and Wilkie, K. I. (2006b). The viscosities of three biodiesel fuels at temperatures up to 300 °C. *Fuel* 85, 1010-15.

Tippayawong, N. Wongsiriamnuay, T., and Jompakdee, W. (2002). Performance and emissions of a small agricultural diesel engine fueled with 100% vegetable oil: effects of fuel type and elevated inlet temperature. *Asian J. Energy Environ*. 3, 139-58.

Tiwari, A. K. Kumar, A., and Raheman, H. (2007). Biodiesel production from jatropha oil (*Jatropha curcas*) with high free fatty acids: an optimized process. *Biomass Bioenergy* 31, 569-75.

Tomasevic, A. V., and Siler-Marinkovic, S. S. (2003). Methanolysis of used frying oil. *Fuel Process. Tech*. 81, 1-6.

Uruakpa, F. O., and Aluko, R. E. (2004). Heat-induced gelation of whole egusi (*Colocynthis citrullus* L.) seeds. *Food Chem*. 87, 349-54.

Usta, N. (2005). Use of tobacco seed oil methyl ester in a turbocharged indirect injection diesel engine. *Biomass and Bioenergy* 28, 77-86.

Vicente, G, Coteron, A. Martinez, M., and Aracil, J. (1998). Application of the factorial design of experiments and response surface methodology to optimize biodiesel production. *Ind. Crops Prod*. 8, 29-35.

Vicente, G. Martínez, M., and Aracil, J. (2005). Optimization of *Brassica carinata* oil methanolysis for biodiesel production. *J. Am. Oil Chem. Soc*. 82, 899-904.

Vicente, G. Martínez, M., and Aracil J. (2007). Optimisation of integrated biodiesel production. Part I. A study of the biodiesel purity and yield. *Bioresourc. Technol*. 98, 1724-33.

Wu, W. H. Foglia, T. A. Marmer, W. N., and Phillips, J. G. (1999). Optimizing production of ethyl esters of grease using 95% ethanol by response surface methodology. *J. Am. Oil Chem. Soc*. 76, 517-21.

© COPYRIGHT UPM

Yahya, Azmi, and Marley, S. J. (1994). Physical and chemical characterization of methyl soyoil and methyl tallow esters as CI engine fuels. *Biomass Bioenergy* 6, 321-28.

Yang, F. Su, Y. Li, X. Zhang, Q., and Sun, R. (2009). Preparation of biodiesel from *Idesia polycarpa* var. *vestita* fruit oil. *Ind. Crops Prod*. 29, 622-28.

Yuan, X. Liu, J. Zeng, G. Shi, J. Tong, J., and Huang, G. (2008). Optimization of conversion of waste rapeseed oil with high FFA to biodiesel using response surface methodology. *Renew. Energy* 33, 1678-84.

Zhou, W. Konar, S., and Boocock, D. (2003). Ethyl esters from the single-phase base-catalyzed ethanolysis of vegetable oils. *J. Am. Oil Chem. Soc*. 80(4), 367-71.

Ziejewski, M. Kaufman, K. R. Schwab, A. W., and Pryde, E. H. (1984). Diesel engine evaluation of a nonionic sunflower oil-aqueous ethanol microemulsion. *J. Am. Oil Chem. Soc*. 61, 1620-6.

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