UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF JATROPHA FRUIT SHELLING MACHINE FOR KERNEL RECOVERY IN BIODIESEL PRODUCTION

LIM BO YUAN

FK 2016 3

DEVELOPMENT OF *JATROPHA* FRUIT SHELLING MACHINE FOR KERNEL RECOVERY IN BIODIESEL PRODUCTION

By

LIM BO YUAN

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

March 2016

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

DEVELOPMENT OF *JATROPHA* FRUIT SHELLING MACHINE FOR KERNEL RECOVERY IN BIODIESEL PRODUCTION

By

LIM BO YUAN

March 2016

Chairman : Associate Professor Rosnah Shamsudin, PhD
Faculty : Engineering

Most of available shelling machines remove outer shells of Jatropha fruits to produce seeds, without removing husks (outer coating of seeds). The presence of the husks will affect oil yield and quality during oil extraction process in biodiesel production. Therefore, the project has developed a Multistage Jatropha Fruit Shelling Machine which is capable to produce oil-rich kernels (nucleus) by removing both of shells and husks from Jatropha fruits. The developed machine consists of two cracking units with screw-type rollers (rollers with male threads) and three separators (two blowers and a vibratory sieve). The designed screw-type rollers were found to be able to reduce breakage of kernels and kernel loss during separation process through blower. During performance evaluation, the roller clearance, blower air speeds and Jatropha fruits' moisture content were found could significantly affect the machine performance. Based on the findings, the machine could remove 99.45 % of shells and 52.84 % of husks while controlling the kernel loss at 5.24 %. Further, the study has carried out Computational Fluid Dynamics (CFD) multiphase modeling of separation process through blower to understand dynamic behaviour of Jatropha fruits' particles under airstreams. For the modeling, Dense Discrete Phase model (DDPM) under Eulerian framework in ANSYS Fluent software was selected to define particle injections following Rosin Rammler particle size distribution. The shape of particles was identified using Matlab Image Region Analyzer and the calculated aspect ratio, 0.625 was used to define non-spherical drag law. The numerical results show that the particles tend to flow in such a way to follow the direction of diverted air flow and vortices in separator duct with slope end design. The phenomena have a tendency to cause particle momentum loss especially for heavier kernel particles, causing the kernel particles to drop in the separator and leading to lower kernel loss during separation process. Furthermore, a scaling factor was developed based on dimensional analysis. The developed scaling factor suggests that the air airflow rate should be controlled to keep air velocity to be a constant parameter in order to ensure similar working condition in scale-up unit. In fact, the research project has successfully developed a more efficient shelling machine for kernel recovery and provided validated numerical model and scaling factor as better insights for making decision during development of future commercial unit that benefits Jatropha biodiesel industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PEMBANGUNAN MESIN PEMBUANGAN KULIT BUAH *JATROPHA* UNTUK MENGHASILKAN INTI YANG DIGUNAKAN DALAM INDUSTRI BIODIESEL

Oleh

LIM BO YUAN

Mac 2016

Pengerusi : Profesor Madya Rosnah Shamsudin, PhD
Fakulti : Kejuruteraan

Kulit buah-buahan Jatropha boleh dibuang dengan menggunakan mesin tetapi kebanyakan mesin tidak dapat membuang sekam (lapisan luar benih). Kandungan sekam boleh memberi kesan negatif pada hasil dan kualiti minyak semasa proses pengekstrakan minyak dalam industri biodiesel. Oleh itu, projek ini telah membangunkan sebuah mesin (*Multistage Jatropha Fruit Shelling Machine*) yang dapat membuang kedua-dua kulit luar dan sekam daripada buah-buahan Jatropha untuk menghasilkan inti Jatropha (nukleus yang berminyak). Mesin yang berikut melibatkan dua peringkat peretakan yang disiapkan dengan roda yang mempunyai benang skru dan tiga peringkat pengasingan (dua peniup dan satu ayak bergetar). Roda yang tersebut dapat mengurangkan pecahan inti dan mengurangkan kehilangan inti semasa proses pengasingan yang menggunakan angin. Selepas eksperimen, didapati bahawa jarak antara roda, kelajuan udara peniup dan kandungan air buah Jatropha dapat menjejaskan pretasi mesin tersebut. Mesin itu didapati boleh membuang kulit luar sebanyak 99.45 % dan sekam sebanyak 52.84 % manakala kehilangan inti hanya 5.24 %. Selain itu, proses pengasingan antara sekam dan inti dalam peniup telah disimulasikan dengan menggunakan *Computational Fluid Dynamics (CFD) multiphase modeling* daripada *ANSYS Fluent. Dense Discrete Phase Model* (DDPM) daripada rangka kerja *Eulerian* dan taburan saiz zarah-zarah daripada cara *Rosin Rammler* telah dipilih untuk menubuhkan suntikan zarah-zarah ke dalam aliran udara yang disimulasikan. Bentuk zarah-zarah telah dikenal pasti dengan menggunakan *Image Region Analyzer* daripada *Matlab*. 0.625 yang dikira sebagai nisbah aspek telah digunakan untuk menentukan *non-spherical drag law*. Selepas kajian, didapati bahawa arah aliran zarah-zarah telah dijejaskan oleh pengalihan arah aliran udara dan vorteks yang terbentuk dalam salur yang direka. Ini menyebabkan kehilangan momentum zarah-zarah inti Jatropha. Maka, fenomena tersebut berpontensi untuk mengurangkan kehilangan inti Jatropha semasa proses pengasingan. Di samping itu, faktor skala juga telah dibangunkan berdasarkan cara analisis dimensi. Analisis itu menunjukkan bahawa halaju udara tidak boleh diubahkan semasa pembesaran model manakala kadar aliran udara perlu ditukar dengan mengikuti luas keratan rentas salur udara untuk memastikan keadaan yang sama dalam mesin yang lebih besar. Secara keseluruhan, projek telah berjaya membangunkan mesin pembuangan kulit Jatropha yang berkesan dan menyediakan model berangka dan faktor skala yang berguna untuk pembanguan mesin yang berkapasiti lebih tinggi pada masa hadapan.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to Assoc. Prof. Dr. Rosnah Shamsudin, the Chairman of the Supervisory Committee for her constant encouragement, tireless guidance and giving me the space to develop my ideas. Her generosity and countless support cannot be over emphasized.

Further, I express my greatest gratitude to Prof. Dr. Robiah Yunus and Assoc. Prof. Ir. Dr. B. T. Hang Tuah Baharudin, members of the Advisory Committee for their invaluable advice at various stages of the research. Their tolerance and patient throughout the whole study are very much appreciated. My sincere thanks also go to Dr. Azhari Muhammad Syam for his help and advice during the research. I also wish to extend my gratitude to the Ministry of Higher Education, Malaysia and Universiti Putra Malaysia (UPM), for the financial support.

Appreciation goes to my family and my wife, Christine Kan Pui Fun for their love and spiritual support. Last but not least, I would like to express my utmost gratitude to the entire technical staff and research fellows of the Department of Process and Food Engineering, for their help that led to the smooth run of the research.

I certify that a Thesis Examination Committee has met on 31 March 2016 to conduct the final examination of Lim Bo Yuan on his thesis entitled "Development of *Jatropha* Fruit Shelling Machine for Kernel Recovery in Biodiesel Production" 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 Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Mohd Shamsul bin Anuar, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Chin Nyuk Ling, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Noriznan bin Mokhtar, PhD, -Ing.
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Lilik Soetiarso, PhD, M.Eng.
Professor Ir.
Gadjah Mada University
Indonesia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 25 May 2016

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Rosnah Shamsudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Robiah Yunus, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

B.T. Hang Tuah Baharudin, PhD
Associate Professor, Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: __________________

Name and Matric No.: Lim Bo Yuan, GS33632

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________

Name of Chairman of Supervisory Committee: Associate Professor Rosnah Shamsudin,

Signature: ______________________

Name of Member of Supervisory Committee: Professor Robiah Yunus,

Signature: ______________________

Name of Member of Supervisory Committee: Associate Professor, Ir. B.T. Hang Tuah Baharudin,

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CFD	Computational Fluid Dynamics
DDPM	Dense Discrete Phase Model
DEM	Discrete Element Method
EU	European Union
FEA	Finite Element Analysis
KTGF	Kinetic Theory of Granular Flow

CHAPTER 1

INTRODUCTION

1.1 Background

Natural gas, coal and crude oil are fossil fuels which have been widely used for many purposes such as vehicle power and electricity and heat generation. However, the fossil fuels are in danger of exhaustion resulting from overuse of fossil fuels for the country development. Unstable supplies and price fluctuations of fossil fuels in market can also have an effect on the economies of developing countries. Further, the usage of coal, natural gas and crude oil together was reported to be more than 80 % of the total world energy consumption in 2013 (BP, 2014). Meanwhile, the energy demand for the world was estimated to grow again by 37 % from 2013 to 2035 (BP, 2015). Further, the statistics indicate that the fossil fuels keep to be primary resources in order to fulfil current energy demand.

The high dependency on energy and the fossil fuel depletion have drawn attention towards developing sustainable solution. For this reason, biodiesel has been proposed to be one of alternative resources. In fact, the biodiesel, which is similar to conventional diesel, has been reported as a promising replacement for diesel (Atadashi et al., 2010). Biodiesel is basically derived from animal fats or vegetable oil (Mehla, 2007). Biodiesel can be used in a compression ignition engine and no major engine modification is required with up to 20 % (B20) of biodiesel blends (Kumar and Sharma, 2008). Further, the biodiesel has advantage over conventional diesel as it produces less particulate matter, carbon monoxide, carbon dioxide and sulphur dioxide (Pandey et al., 2012). Therefore, the biodiesel blends will directly reduce environmental impact. In addition, the current world trend shows the fossil fuel based diesel is being slowly superseded by biodiesel.

Different countries use different vegetable oils for biodiesel production. The United States, which is an edible oil exporter, uses soybean as the raw material (Ong et al., 2011). Meanwhile, the European countries mostly use rapeseed oil for biodiesel production (Ong et al., 2011). In tropical countries (e.g. Malaysia), the palm oil or coconut oil is basically used for the purpose. On the other hand, India uses non-edible oils (e.g. Jatropha, Karanja and Simarouba) to produce biodiesel since the India is trying to reduce its dependency on edible oils (Ong et al., 2011). Further, the biodiesel can be a feasible and prospective fuel if it can compete economically with fossil fuels, be readily available and be technically viable (Srivastave and Prasad, 2000). In fact, the cost of biodiesel production can be reduced by using a less expensive source such as inedible oil, animal fat, waste food oil or the by-products of refining vegetable oils (Veljkovic et al., 2006).

As mentioned, the plant sources including rapeseed oil, soybean oil, coconut oil and palm oil are currently being used for biodiesel production. Most of the feedstock are edible and the plants require a large growing space. Overuse of food based crops in the industry will potentially result in a food crisis problem. For this issue, inedible vegetable oil can be a more suitable choice. In fact, food security issue is always being considered during feedstock selection in any bioenergy development. Ideally, cultivation of feedstock for biodiesel production should not likely to compromise future demands in terms of food supply (BEFS, 2010). Therefore, with no disturbance of food supply and displacement of food based crops, the focus has been shifted from first generation edible feedstocks to *Jatropha curcas L.* as energy crop of choice (Acthen et al., 2007; Hanny and Shisuko, 2008; Moser et al., 2010; Kalam et al., 2012). Meanwhile, the Jatropha has been widely accepted due to high adaption of Jatropha trees to poor soil or waste land (Silitonga et al., 2011). Moreover, Jatropha is a perennial crop with deeper root system enabling it to effectively retain water and nutrients (Heller, 1996; Gübitz et al., 1999; Eijck et al., 2014). Therefore, the plant requirement for water and nutrients is lower. Further, the cultivation of Jatropha can also help reclaiming waste land, controlling erosion and stimulating rural development (Francis et al., 2005; Ogunwole et al., 2008; Silitonga et al., 2011).

1.1.1 Preparation of Jatropha Feedstock for Biodiesel Production

The cultivation of trees, fruit harvesting, harvested fruit pretreatment, oil extraction, oil purification and biodiesel production are basically the activities involved in Jatropha biodiesel production (Koh and Ghazi, 2011; Kalam et al., 2012). Production on a large scale basis is needed to cope with energy source depletion issue. Meanwhile, large amount of Jatropha seeds are required for the production to meet energy demand. Further, the harvested mature fruits need to be cleaned to remove foreign matter and dried prior to a shelling process. The shelling process is a produciton activity carried out to remove and separate outer shells of fruits in order to recover Jatropha seeds prior to oil extraction process. As part of pretreatment process it is an important step due to a fact that the outer shells, which do not contain any oil, can prevent oil from leaving oil-rich kernels and also tend to absorb the oil during the extraction process. A previous report stated that oil yield during oil extraction process could be higher with decorticated seeds when compared to whole fruits (Kumar & Sharma, 2011). In addition, shell content can lead to high pressing pressures and energy loss in the oil expeller (Zheng et al., 2005).

Figure 1.1. The composition and oil yield of Jatropha fruits, shells, seeds, husks and kernels (Reinhardt et al., 2008; Pandey et al., 2012; Kalam, et al., 2012)

The shelling process can be carried out manually or mechanically (FACT, 2010). The usual manual method uses a hard material to break the fruits. After that, the detached shells are removed directly by using fingers (Achten et al., 2008). The process is labour intensive with low output rates. A manual process worker can only remove shells from 50 kg of dried fruits per day which is a relatively low rate as compared a rate of 100 kg hr^{-1} achieved by a motorised machine (FACT, 2010; Wang et al., 2011). Further, labour shortages and labour costs are the major concerns as the labours are required at all stages with a series of activities including fruit collection, drying and shelling during seed production stage (Wang et al., 2011). Replacing labour by machine can ensure low production costs and improve sustainability of biodiesel feedstock in the industry.

A shelling machine normally comprises a dehulling/shelling unit and a separation unit. The principle of shelling is to break, loosen and open Jatropha fruits by applying adequate impulsive, compression or shearing force in order to detach fruits' shells from the fruits. According to literatures, Jatropha shells can be detached using different means such as cylindrical rollers, rotating shearing blades or a horizontal rotating cylinder (FACT, 2010; Pradhan et al., 2010; Shamsudin et al., 2010). After that, the detached shells need to be separated and discharged prior to oil extraction process. The separation process can be easily completed using a sieve or mesh that matches size of the seed. However, a zero shell content cannot be achieved because of some of the shells are similar in size to seeds and thus they can pass through the mesh along with the seeds. Therefore, blower is commonly added and used to further improve cleanness level of Jatropha seed.

1.2 Problem Statement

At present, shelling process has gained renewed interest not only due to labour and mechanisation issues, but also due to some negative impacts of seeds' coating, commonly called husks. The researchers have actually extended the study to investigate possibility to further remove the husks from the Jatropha seeds for kernel recovery. The husks are thin and brittle seeds' coating. Besides that, the husks do not contain oil and can obstruct oil extraction from oil-rich kernels inside the seeds. This was proven by some past reports revealing a reduction of husk content could actually improve oil yield (Shukla, 2006; Wim et al., 2007; Amoah, 2012). In order to eliminate the barrier, the whole seeds have to be cracked and the husks has to be removed from kernels. The other report stated that fibre content decreased with lower husk content (Greyt et al., 2007). Therefore, the reduction of husks can also reduce fibre content and thus reducing wear and tear of the press during extraction process. However, it is important to understand that zero husk content is not encouraged since an adequate pressing pressure from husk content is still required in an oil expeller to speed up oil extraction from kernels (FACT, 2010).

On the other hand, quality of biodiesel production is highly depended on Jatropha crude oil quality (Hynd and Smith, 2004; Uriarte, 2010). In fact, the husk content tends to affect colour of crude oil and form sediment in extracted crude oil. Therefore, the husk content has a tendency to reduce efficiency of crude oil purification process during biodiesel production as well as affecting commercial value of final biodiesel product. In addition, kernels with low husk content will require less solvent during oil extraction through solvent extraction method. Therefore, achieving removal of husk can also lower production cost.

However, the removal of husks is yet to be a common practice due to not much commercial technology available to directly recover the Jatropha kernels from whole fruits on a large scale basis. Currently, all commercially available machines are basically designed to recover whole seeds from fruits without removing the husks (FACT, 2010; Pradhan et al., 2010; Shamsudin et al., 2010). In fact, an additional seed cleaning system or device is required for further removing the husks from seeds. This will lead to a higher capital cost. Further, very few seed dehulling system can be found, indicating that the technology development is still at an emerging stage. The Jatropha seed dehulling system in India and China occupied a large production space since the system consists of a few individual machines, including grading machine, feeding elevator, seed shelling machine, sorting machine and air classifier (He, 2014; Goldin, 2014). As a result, the system is costly and not suitable for small scale industry. On the other hand, a shelling drum on a fixed concave was used to remove the husks from Jatropha seeds in Ghana and Sudan (Amoah, 2012; Kheiralla et al., 2015). Both approaches were reported to be quite successful but the percentage of kernel loss has not been analysed. This is an important parameter which cannot be ignored since it decides profit of production operation especially when the production is carried out on a large scale.

Most of the machines are basically developed for a purpose of detaching and separating shells to produce whole seeds without dehulling seeds. This is due to the difficulty in dehulling seeds mechanically without crushing kernels which are inside the seeds. The crushed kernels are not desirable since the kernels in broken form are irregular in sizes and tend to have masses similar to the masses of husk particles, leading to high difficulty in separating between kernels and husks mechanically. In fact, the shape of a Jatropha seed is oblong and each seed has fragile kernel. Besides that, the wall (husk) of the seed is hard and thicker around the edges of the seed (Mehla, 2007). Therefore, the breakage of kernel can be prevented only at a condition where the force on the seed is selective and applied only to the wall (husk) of the seed.

1.3 Objectives

Keeping the above arguments in mind, the study focused on the development of a viable machine to produce shell-free kernels with low husk content for better oil yield and oil quality. An efficient system was required to process a mixture of kernels, shells and husks with variable size, mass and shape. To achieve this, a novel design which is screw-type rollers (rollers with male threads on surface) has been developed and included in a newly developed Multistage Jatropha Fruit Shelling Machine. Meanwhile, the separation unit must be properly designed based on the differences in these properties. Furthermore, the design of the machine must consider both cost and size since high operational and maintenance costs could put the economic viability of production system at risk. On the other hand, none of the previous researches related to shelling machine considers modeling and simulation study of separation unit namely blower system. Thus, the potential for improvement in the efficiency of the blower system to reduce kernel loss has not been properly investigated. In summary, the project main goal was to develop a Jatropha fruit shelling machine which is capable of producing Jatropha kernels directly from the whole fruits so that higher oil yield and better oil quality can be achieved in Jatropha biodiesel production. The machine must be able to remove outer shells and husks while maintaining low kernel loss during the process. Furthermore, the study covered a multiphase modeling of air-solid flow using Computational Fluid Dynamics (CFD) tool which has never been done before for Jatropha kernels production. The numerical modeling has also made possible the development and validation of a scaling factor, enabling scaling up of prototype unit to commercial scale unit in the future.

The specific objectives targeted to achieve the project goals are summarised as below:

a. To develop a Jatropha shelling machine with cracking units coming complete with screw-type rollers and blower separators to produce Jatropha kernels directly from whole fruits.

b. To carry out performance evaluation of developed shelling methods and machine to identify optimal process conditions, including roller clearance, blower air speed and fruits' moisture content, for cracking unit and separator of the machine.

c. To perform a Computational Fluid Dynamics (CFD) multiphase modeling describing dynamic behaviour of Jatropha fruits' particles under airstream during separation process through blower.

d. To develop and validate an appropriate scaling factor through dimensional analysis and numerical modeling respectively for use in achieving similar working condition for scale-up unit.

REFERENCES

Achten, W. M. J., Mathhijs, E., Verchot, L., Singh, V. P., Aerts, R. and Muys, B. (2007). Jatropha biodiesel fueling sustainability. *Biofuels, Bioprodoucts and Biorefining*, 1: 283-291.

Achten, W. M. J., Verchot, L., Franken, Y. J., Mathijs, E., Singh, V. P., Aerts, R. and Muys, B. (2008). Jatropha bio-diesel production and use. *Biomass and Bioenergy*, 32: 1063-1084.

Achten W. (2010). *Sustainability Evaluation of Biodiesel from Jatropha Curcas L. A Life Cycle Oriented Study*. PhD Thesis, Katholieke Universiteit Leuven.

Adewumi, B. A. (2008). Proceedings from Food Processing Automation Conference '08: *2D Modeling of Grain Transport and Separation in the Horizontal Air Stream*. Providence, Rhode Island.

Aguiba, M. M. (2012). *Gov't to Test Jatropha Biodiesel Offered by Company from Malaysia*. Philippines: Manila Bulletin Publishing Corporation. Retrieved from https://thegreenreporter.wordpress.com /2012/03/27/govt-to-test-jatropha-biodiesel-offered-by-company-from-malaysia/

Akubuo, C. O. and Eje, B. E. (2002). Palm kernel and shell separator. *Biosystem Engineering*, 81: 193-199.

Alder, B. J. and Wainwright, T. E. (1960). Studies in molecular dynamics II: Behaviour of a small number of elastic spheres. *The Journal of Chemical Physics*, 33(5): 1439-1451.

Amoah, F. (2012). *Modification and Evaluation of a Groundnut Cracker for Cracking Jatropha Curcas Seeds*. Master Thesis, Kwame Nkrumah University of Science and Technology.

Andersson, B, Andersson, R., Håkansson, L., Mortensen, M., Sudiyo, R. and Wachem, B. V. (2012). *Computational Fluid Dynamics for Engineers*. United Kingdom: University Press, Cambridge.

ANSYS Fluent. (2013a). *ANSYS Fluent 12.0 User's Guide*. United States: ANSYS, Inc.

ANSYS Fluent. (2013b). *ANSYS Fluent 12.0 Theory Guide*. United States: ANSYS, Inc.

Ashes, J. R. and Peck, N. J. (1978). A simple device for dehulling seeds and grain. *Animal Feed Science and Technology*, 3(2): 109-116.

Atadashi, I. M., Aroua, M. K. and Abdul, A. A. (2010). High quality biodiesel and its diesel engine application: a review. *Renewable and Sustainable Energy Reviews*, 14: 1999-2008.

Azam, M.M., Waris, A. and Nahar, N.M. (2005). Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass and Bioenergy*, 29: 293-302.

Badday, A. S., Abdullah, A. Z. and Lee, K. T. (2014). Artificial neural network approach for modeling of ultrasound-assisted transesterification process of crude Jatropha oil catalyzed by heteropolyacid based catalyst. *Chemical Engineering and Processing: Process Intensification*, 75: 31-37.

Bamgboye, A. I. and Adebayo, S. E. (2012). Seed moisture dependent on physical and mechanical properties of Jatropha curcas. *Journal of Agricultural Technology*, 8: 13-26.

Basili, M. and Fontini, F. (2012). Biofuel from Jatropha curcas: Environmental sustainability and option value. *Ecological Economics*, 78: 1-8.

Batchelor, G. K. (1967). *An Introduction to Fluid Dynamics*. England: Cambridge University Press.

Batchelor, G. K. (1988). A new theory of the instability of a uniform fluidized bed. *Journal of Fluid Mechanics*, 193: 75-110.

Beerens, P. (2007). *Screw-pressing of Jatropha seeds for fueling purposes in less developed countries*. Einhoven, The Netherlands: Eindhoven University of Technology. Retrieved from http://jatropha.pro/PDF%20bestanden/AfstudeerverslagPeterBeerens26-08-07[1]%20jatropha%20tanzania.pdf

BEFS. (2010). *Bioenergy and Food Security. The BEFS analytical framework.* Rome: Food and Agriculture Organization of United Nations. Retrieved from http://www.fao.org/docrep/013/i1968e/i1968e.pdf

Bionas. (2014). *Development: Jatropha*. Malaysia: Bionas Sdn. Bhd. Retrieved from http://www.bionas.com.my/Development.html

Bionas. (2015). *Technology & Products: Bio-diesel*. Malaysia: Bionas Sdn. Bhd. Retrieved from http://www.bionas.com.my/Prod.html

Blair, B. (2008). *Nutrition and Feeding of Organic Poultry*. Wallingford: CABI.

Boonkiatpong, K. and Sinthupinyo, S. (2011). Proceedings from International Conference on Information and Electronics Engineering, IPCSIT vol. 6: *Applying Multiple Neural Networks on Large Scale Data*. Singapore.

Borman, G. D., Maltitz, G. P., Tiwari, S. and Scholes, M. C. (2013). Modeling the economic returns to labour for Jatropha cultivation in southern Africa and India at different local fuel prices. *Biomass and Bioenergy*, 59: 70-83.

BP. (2014). *BP Statistical Review of World Energy June 2014*. UK: PB. Retrieved from http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf

BP. (2015). *BP Energy Outlook 2035*. UK: PB. Retrieved from http://www.bp.com/content/dam/bp/pdf/Energy-economics/energy-outlook-2015/Energy_Outlook_2035_booklet.pdf

Buckingham, E. (1914). On physically similar systems; illustrations of the use of dimensional Eqs. *Physical Review*, 4(4): 345–376.

Carlisle. (2003). *Industrical V-belt Drives Desgin Guide*. UK: Power Transmission Product Inc.

Carter, R. M. and Yan, Y. (2005). Measurement of particle shape using digital imaging techniques. *Journal of Physics: Conference Series*, 15: 177-182.

Çengel, Y. A. and Cimbala, J. M. (2006). *Fluid Mechanics. Fundamentals and Applications*. New York: McGraw-Hill.

Chandrakar, B., Jain, A., Roy, S., Gutlapalli, V.R., Saraf, S., Suppahia, A., Verma, A., Tiwari, A., Yadav, M. and Nayarisseri, A. (2013). Molecular modeling of Acetyl-CoA carboxylase (ACC) from Jatropha curcas and virtual screening for identification of inhibitors. *Journal of Pharmacy Research*, 6(9): 913-918.

CGC. (2013). *Official Grain Grading Guide*. Canada: Canadian Grain Commission.

Chapman, S. and Cowling, T. G. (1990). *The Mathematical Theory of Non-Uniform Gases, 3rd edition*. Cambridge England: Cambridge University Press.

Chong J. H. (2009). *Design and Fabrication of Jatropha Curcas L. Fruit Shelling Machine.* Undergraduate Thesis, Universiti Putra Malaysia.

Cloete, S., Johansen, S., Braun, M., Popoff, B. and Amini, S. *Evaluation of a Lagrangian Discrete Phase Modeling Approach for Resolving Cluster Formation in CFB Risers*. Paper presented at the 7th International Conference on Multiphase Flow, ICMF 2010, Tampa, Florida, USA. 30 May - 4 June 2010.

Corino, S., Romero, E. and Mantilla, L. F. (2008). Proceedings from the International Conference on Renewable Energies and Power Quality (ICREPQ'08): *How the Efficiency of Induction Motor is Measured?* Santander.

David, S. (1998). *Producing Bean Seed Handbook One. Handbooks for Small-scale Bean Seed Producers.* Africa: Network on Bean Research, Occasional Publication Series.

Ding, J. and Gidaspow, D. (1990). A bubbling fluidization model using kinetic theory of granular flow. *AIChE Journal*, 36(4): 523-538.

Dunford, N. (2013). *Oil and Oilseed Processing I*. United States: Oklahoma State University.

Eckart, K., Henshaw, P. (2012). Jatropha curcas L. and multifunctional platforms for the development of rural sub-Saharan Africa. *Energy for Sustainable Development*, 16: 303-311.

ECHO. (2006). *Jatropha Curcas Physic Nut*. United States: ECHO Community.

Edrisi, S. A., Dubey, R. K., Tripathi, V., Bakshi, M., Srivastava, P., Jamil, S., Singh, H. B., Singh, N. and Abhilash, P. C. (2015). Jatropha curcas L.: A crucified plant waiting for resurgence. *Renewable and Sustainable Energy Reviews*, 41: 855-862.

EIA. (2013). *Top World Oil Net Importers, 2013*. Washington: U.S. Energy Information Admistration. Retrieved from http://www.eia.gov/countries/index.cfm?topL=imp

Eijck, J. V., Romijn, H., Smeets, E., Bailis, R., Rooijakkers, M., Hooijkaas, N., Verweij, P. and Faaij, A. (2014). Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania. *Biomass and Bioenergy*, 61: 25-45.

Emori, R. I. (1968). "Analytical approach to automobile collisions", *SAE Technical Paper 680016*. Doi: 10.4271/680016

Emori, R. I., Saito, K. and Sekimto, K. (2000). *Scale Models in Engineering (In Japanese: Mokei Jikken no Riron to Ohyou).* Tokyo, Japan: Gihodo Publishing Co.

Euler, L. (1757). General principles concerning the motion of fluids (Principes générauxdu mouvement des fluides). *Mémoires de l'académie des sciences de Berlin*, 11: 274-315.

FACT. (2010). *The Jatropha Handbook. From Cultivation to Application*. The Netherlands: FACT Foundation.

Farran, I. G. and Macmillan, R. H. (1979). Grain-chaff separation in a vertical air stream. *Journal of Agricultural Engineering Research*. 24(1): 115-129.

Francis, G., Edinger, R. and Becker, K. (2005). A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: need, potential and perspectives of Jatropha plantations. *Natural Resources Forum*. 29: 12-24.

Foidl, N., Foidl, G., Sanchez, M., Mittelbach, M. and Hackel, S. (1996). Jatropha curcas L. as a source for the production of biofuel in Nicaragua. *Bioresource Technology*, 58: 77-82.

Gambhir, N. (2010). Jatropha Decorticator. India: Rajkumar Agro Engineers Pvt. Ltd. [Video file]. Retrieved from http://www.youtube.com/watch?v=MA3T4q2gd5Q

Gambhir, N. (2013). Decorticator, Pongamia Decorticator, Jatropha Decorticator 100 to 500kgs/hr Capacity. India: Rajkumar Agro Engineers Pvt. Ltd. [Video file]. Retrieved from http://www.youtube.com/watch?v=BiFUcnXw4tA

Garnayak, D. K., Pradhan, R. C., Naik, S. N. and Bhatnagar, N. (2008). Moisture-dependent physical properties of jatropha seed (Jatropha curcas L.). *Industrial Crops and Products*, 27: 123-129.

GEXSI. (2008). *Gexsi Global Market Study on Jatropha*. London: GEXSI LLP. Retrieved from http://www.jatropha-alliance.org/fileadmin/documents/ GEXSI_Global-Jatropha-Study_FULL-REPORT.pdf

Ghosh, T. (2013). *Modeling of an Air-based Density Separator*. PhD Thesis, Mining Engineering, University of Kentucky. Retrieved from http://uknowledge.uky.edu/mng_etds/7

Gibson, M. M. and Launder, B. E. (1978). Ground effects on pressure fluctuations in the atmospheric boundary layer. *Journal of Fluid Mechanics*, 86: 491-511.

Gidaspow, D., Bezburuah, R. and Ding, J. (1992). Proceedings from the 7th Engineering Foundation Conference on Fluidization: *Hydrodynamics of Circulating Fluidized Beds, Kinetic Theory Approach, Fluidization VII*. 75-82.

Gidaspow, D. (1994). *Multiphase Flow and Fluidization Continuum and Kinetic Theory Descriptions*. Boston, MA: Academic Press.

Goldin. (2014). *Jatropha Seeds Dehulling System for Biodiesel Production*. India: Goldin (India) Equipment Pvt. Ltd. Retrieved from http://www.indiamart.com/goldinequipment/ dehulling-machine.html

Gosain, A. K. (2005). *Modelling Effect of Jatropha on Water Resources of Chhattisgarh*. New Delhi: Indian Institute of Technology Delhy & INRM Consultants Pvt. Ltd.

Goyal, M. C. and Raghuvanshi, G. S. (2011). *Engineering Mechanics, Second Edition*. New Delhi: PHI Learning Private Limited.

Greyt, W. D., Maes, J., Simons, B., Balshaw, C. and Miles, D. *Improved Yield and Biodiesel Quality from Jatropha Curcas by Optimized Seed Processing and Oil Pretreatment*. Paper presented at AOCS International Congress on Biodiesel, Vienna, Austria. 5-7 November 2007.

Grimsby, L. K., Aune, J. B. and Johnsen, F. H. (2012). Human energy requirements in Jatropha oil production for rural electrification in Tanzania. *Energy for Sustainable Development*, 16: 297-302.

Gregg, B. and Billups, G. (2009). *Seed Conditioning Volume 1: Management*. United States: Science Publishers.

Gübitz, G. M., Mittelbach, M. and Trabi, M. (1999). Exploitation of the tropical oil seed plant Jatropha curcas L. *Bioresource Technology*. 67: 73-82.

Haat, J., Opp, P., Jalmahal, Road, A. and Jaipur. *Latest Technologies in Cleaning, Grading & All Kinds of Seeds, Pulses, Spices, Fruit & Vegetable Produce*. Paper presented at the International Exhibition & Conference on Processed Food, India, 29 August-2 September 2007.

Haider, A. and Levenspiel, O. (1989). Drag coefficient and terminal velocity of spherical and nonspherical particles. *Powder Technology*, 58: 63-70.

Hanny, J. B. and Shizuko, H. (2008). Biodiesel production from crude Jatropha curcas L. seed oil with a high content of free fatty acids. *Bioresource Technology*, 99: 1716-1721.

He, M. (2014). *Jatropha Seeds Cleaning, Grading, Shelling and Sorting Machine*. China: Zhengzhou Amisy Trading Co., Ltd.. Retrieved from http://www.alibaba.com/product-gs/672415156/Jatropha_seeds_cleaning_grading_shelling_and.html

Heller, J. (1996). *Physic Nut. Jatropha curcas L. Promoting the Conservation and Use of Underutilized and Neglected Crops*. Rome: Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute.

Henning, R. (2003). *The Jatropha Booklet: A Guide to the Jatropha System and Its Dissemination in Africa*. Germany: baganí GbR.

Henning, R. K. (2005). *Jatropha Curcas L. in Africa*. Germany: Global Facilitation Unit for Underutilized Species.

Herak, D., Kabutey, A., Divisova, M. and Simanjuntak, S. (2013). Mathematical model of mechanical behaviour of Jatropha curcas L. seeds under compression loading. *Biosystems Engineering*, 114(3): 279-288.

Hibbeler, R. C. (2004). *Engineering Mechanics Dynamics Third Edition*. Singapore: Prentice-Hall, Inc.

Hynd, A. and Smith, A. (2004). *Meeting a Pressing Need, Project Appraisal of the Oilseed Ram Press and Approaches to Implementation*. Developing, Design, Dissemination Case Study Series.

Jain, S. and Sharma, M. P. (2010). Prospects of biodiesel from Jatropha in India: A review. *Renewable and Sustainable Energy Reviews*, 14: 763-771.

Jingura, R.M. (2011). Technical options for optimization of production of Jatropha as a biofuel feedstock in arid and semi-arid areas of Zimbabwe. *Biomass and Bioenergy*, 35: 2127-2132.

Kalam, M. A., Ahamed, J. U. and Masjuki, H. H. (2012). Land availability of Jatropha production in Malaysia. *Renewable and Sustainable Energy Reviews*, 16: 3999-4007.

Karaj, S. and Müller, J. (2010). Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha curcas L. *Industrial Crops and Products*, 32: 129-138.

Karaj, S. *Modelling and Design of a Prototype Machine for De-hulling Jatropha Curcas L. Fruit.* Paper presented at Sustainable Provision of Rural Renewable Energy with Focus on Financially Viable Solutions in Developing Countries, University of Hohenheim, German, 4-15 November 2013.

Karaj, Shkelgim, Huaitalla, Mendoza, R., Müller and Joachim. *Physical, Mechanical and Chemical Properties of Jatropha Curcas L. Seeds and Kernels.* Paper presented at Conference on International Agricultural Research for Development, Stuttgart-Hohenheim, Germany. 7-9 October 2008.

Kheiralla, A. F., Tola, E. H., Korsha, A. N. and Eltigani, A. (2015). Development and evaluation of Jatropha seeds shelling machine for biofuel production. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 15(4): 630-639.

King, J. A., He, W., Cuevas, J. A., Freudenberger, M., Ramiaramanana, D. and Graham, I. A. (2009). Potential of Jatropha curcas as a source of renewable oil and animal feed. *Journal of Experimental Botany*, 60: 2897-2905.

Koh, M. Y. and Ghazi, T. I. M. (2011). A review on biodiesel production from Jatropha curcas L. oil. *Renewable and Sustainable Energy Reviews*, 15: 2240-2251.

Kotrba, R. (2013, July 25). Malaysia Expands Biodiesel Program, Looks Beyond 5 Percent Blend. *Biodiesel Magazine* . Retrieved from http://www.biodieselmagazine.com/articles/9239/malaysia-expands-biodiesel-program-looks-beyond-5-percent-blend

Kumar, A. and Sharma, S. (2008). An evaluation of multipurpose oil seed corp for industrial uses (*Jatropha curcas L.*): a review. *Industrial Crops and Produsts*, 28: 1-10.

Kumar, A. and Sharma, S. (2011). Potential non-edible oil resources as biodiesel feedstock: an Indian perspective. *Renewable and Sustainable Energy Reviews*, 15: 1791-1800.

Kuwana, K., Hassan, M. I., Singh, P. K., Saito, K. and Nakagawa, J. (2008). Scale-model experiment and numerical simulation of steel teeming processes. *SME Journal: Materials and Manufacturing Processes*, 23(4): 407-412.

Lapola, D. V., Priess, J. A. and Bondeau, A. (2009). Modeling and land requirements and potential productivity of sugarcane and jatropha in Brazil and India using the LPJmL dynamic global vegetation model. *Biomass and Bioenergy*, 33(8): 1087-1095.

Launder, B. E. and Spalding, D. B. (1972). *Lectures in Mathematical Models of Turbulence*. London, England: Academic Press.

Launder, B. E., Reece, G. J. and Rodi, W. (1975). Progress in the development of a Reynolds-stress turbulence closure. *Journal of Fluid Mechanics*, 68(3): 537-566.

Launder, B. E. (1989). Second-Moment Closure: Present... and Future? *International Journal of Heat and Fluid Flow*, 10(4): 282-300.

Leadshine. (2015). *Motor Torque Calculation*. USA: Leadshine America Inc.

Lebowitz, J. L. (1964). Exact solution of generalized Percus-Yevick Eq. for a mixture of hard spheres. *The Phyical Review*, 133(4A): A895-A899.

Lim, S. and Teong, L. K. (2010). Recent trends, opportunities and challenges of biodiesel in Malaysia: an overview. *Renewable and Sustainable Energy Reviews*, 14: 938–954.

Liu, K., Yang, Q., Ge, Z. and Liu, X. (2012). Simulation of Jatropha curcas L. root in response to water stress based on 3D visualization. *Procedia Engineering*, 28: 403-408.

Lun, C. K. K., Savage, S. B., Jeffrey, D. J. and Chepurniy, N. (1984). Kinetic theories for granular flow: Inelastic particles in couette flow and slightly inelastic particles in a general flow field. *Journal of Fluid Mechanics*, 140: 223-256.

Macmillan, R. H. (2007). *The Mechanics of Fluid-particle Systems with Special Reference to Agriculture.* Australia: University of Melbourne.

Makkar, H. P. S., Francis, G. and Becker, K. (2008). Protein concentrate from Jatropha curcas screw-pressed seed cake and toxic and antinutritional factors in protein concentrate. *Journal of the Science of Food and Agriculture*, 88: 1542-1548.

Maltitz, G. and Borman, G. *Modeling the Economic Sustainability of Jatropha Projects*. Paper presented at 17th EU Biomass Conference, Germany. 29 June-3 July 2009.

Mehla, S. K. (2007). *Biodiesel Production Technologies*. Jaipur, India: Pointer Publishers.

Meriam, J. L. and Kraige, L. G. (2011). *Engineering Mechanics: Statics. 7th edition*. United States: Wiley.

Mofijur, M., Masjuki, H. H., Kalam, M. A., Hazrat, M. A., Liaquat, A. M., Shahabuddin, M. and Varman, M. (2012). Prospects of biodiesel from Jatropha in Malaysia. *Renewable and Sustainable Energy Reviews*, 16: 5007-5020.

Mogaka, V., Ehrensperger, A., Liyama, M., Birtel, M., Heim, E., and Gmuender, S. (2014). Understanding the underlying mechanism of recent Jatropha curcas L. adoption by smallholders in Kenya: a rural livelihood assessment in Bondo, Kibwezi and Kwale districts. *Energy for Sustainable Development*, 18: 9-15.

Moser, B. R., Knothe, G. and Cermak, S. C. (2010). Biodiesel from meadowfoam (Limnanthes alba L.) seed oil: oxidative stability and unusual fatty acid composition. *Energy & Environmental Science*, 3: 318-327.

Motor. (2014). *Determining Electric Motor Load and Efficiency*. United States: U.S. Department of Energy.

Mulugetta, Y. (2009). Evaluation the economics of biodiesel in Africa. *Renewable and Sustainable Energy Reviews*, 13: 1592-1598.

Nahar, K. and Ozores-Hampton, M. (2011). *Jatropha: An Alternative Substitute to Fossil Fuel*. United States: University of Florida IFAS Exension, EDIS. Retrieved from http://edis.ifas.ufl.edu/hs1193

Nivitchanyong, S. *Zero Waste Agriculture for Jatropha Plantation*. Paper presented at the Biomass Asia Workhop, Shah Alam, Malaysia. 20-22 November 2007.

Obedencio, R. V. (2014, August 20). Malaysian Firm to Make Bohol the Philippines' Jatropha Hub. *The Philippine STAR*. Retrieved from http://www.philstar.com/region/2014/08/20/1359643/malaysian-firm-make-bohol-philippines-jatropha-hub

Odira, C. (2011). Mixa Jatropha/peanut Sheller [Video file]. Retrieved from http://www.youtube.com/watch?v=GJA8x9pTJF8

Ogawa, S., Umemura, A. and Oshima, N. (1980). On the Eq. of fully fluidized granular materials. *Journal of Applied Mathematics and Physics (ZAMP)*, 31: 483-493.

Ogunwole, J. O., Chaudhary, D. R., Gosh, A., Daudu, C. K., Chikara, J. and Patolia, S. (2008). Contribution of Jatropha curcas to soil quality improvement in a degraded Indian entisol. *Acta Agriculturae Scandinavica, Section B-Soil & Plant Science*, 58: 245–251.

Ong, H. C., Mahlia, T. M. I., Masjuki, H. H. and Norhasyima, R. S. (2011). Comparison of palm oil, Jatropha curcas and Calophyllum inophyllum for biodiesel: a review. *Renewable and Sustainable Energy Reviews*, 15: 3501-3515.

Openshaw, K. (2000). A review of Jatropha curcas: An oil plant of unfulfilled promise. *Biomass and Bioenergy*, 19: 1-15.

Pandey, V. C., Singh, K., Singh, J. S., Kumar, A., Sing, B. and Singh, R. P. (2012). Jatropha curcas: a potential biofuel plant for sustainable environmental development. *Renewable and Sustainable Energy Reviews*, 16: 2870-2883.

Passalacqua, A. and Fox, R. O. (2009). Proceedings from Seventh International Conference on CFD in the Minerals and Process Industries: *Multiphase CFD for Gas-particle Flows: Beyond the Two-fluid Model*. Melbourne, Australia: CSIRO.

Petrů, M., Novak, O., Herak, D. and Simanjuntak, S. (2012). Finite element method model of the mechanical behaviour of Jatropha curcas L. seed under compression loading. *Biosystems Engineering*, 111(4): 412-421.

Pompelli, M. F., Antunes, W. C., Ferreira, D. T. R. G., Cavalcante, P. G. S., Wanderley-Filho, H. C. L. and Endres, L. (2012). Allometric models for non-destructive leaf-area estimation of Jatropha curcas. *Biomass and Bioenergy*, 36(2012): 77-85.

Popoff, B. and Braun, M. *A Lagrangian Approach to Dense Particulate Flows*. Paper presented at International Conference on Multiphase Flow, Leipzig, Germany. 2007.

Pradhan, R. C., Naik, S. N., Bhatnagar, N. and Vijay, V. K. (2009). Moisture-dependent physical properties of jatropha fruit. *Industrial Crops and Products*, 29: 341-347.

Pradhan, R. C., Naik, S. N., Bhatnagar, N. and Vijay, V. K. (2010). Design, development and testing of hand-operated decorticator for Jatropha fruit. *Applied Energy*, 87: 762-768.

Pradhan, R. C., Mishra, S., Naik, S. N., Bhatnagar, N. and Vijay, V. K. (2011). Oil expression from Jatropha seeds using a screw press expeller. *Biosystems Engineering*, 109: 158-166.

Rawle, A. (2011). *Basic Principles of Particle Size Analysis*. United Kingdom: Malvern Instruments Limited.

Reinhardt, G., Ghosh, P. K. and Becker, K. (2008). *Basic Data for Jatropha Production and Use*. Heidelberg: Institute for Energy and Environmental Research.

Richard, P. T., Edgardo, V. C., Engelbert, K. P. and Jessie, C. E. (2012). Design, fabrication and optimization of Jatropha sheller. *IJOCTA*, 2: 113-127.

Roco, M. C. (1993). *Particulate Two-phase Flow (Butterworth-Heinemann Series in Chemical Engineering)*. Boston: Butterworth-Heinemann.

Saito, K. (2008). *Progress in Scale Modeling*. Netherlands: Springer.

Schmidt, L. (2000). *Guide to Handling of Tropical and Subtropical Forest Seed*. Denmark: Danida Forest Seed Centre.

Shahabuddin, M., Masjuki, H. H. and Kalam, M. A. (2013). Experimental investigation into tribological characteristics of bio-lubricant formulated from jatropha oil. *Procedia Engineering*, 56: 597-606.

Shamsudin, R., Yunus, R., Chong, J. H. and Azhari. *Efficient Jatropha Curcas L. Fruit Shelling Machine for Biodiesel Production*. Paper presented at The World Exhibition on Inventions, Research and New Technologies, Brussels. 18-20 November 2010.

Sharma, V., Pradhan, R. C., Naik, S. N., Bhatnagar, N. and Singh, S. (2013). Evaluation of a centrifugal impaction-type decorticator for shelling tung fruits. *Industrial Crops and Products*, 43: 126-131.

Shih, T. H., Liou, W. W., Shabbir, A., Yang, Z. and Zhu, J. (1995). A new k-ϵ eddy-viscosity model for high Reynolds number turbulent flows - model development and validation. *Computers Fluids*, 24(3): 227-238.

Shukla, A. *Jatropha (Physic Nut) in Research Frame at Pantnagar. In: Singh, B., Swaminathan, R. and Ponraj, V. (eds.).* Paper presented at Biodiesel Conference Towards Energy Independence – Focus on Jatropha, Rashtrapati Nilayam, Bolaram, Hyderabad, India. 9-10 June 2006.

Slater, J. W. (2008). *Tutorial on CFD Verification and Validation*. United States: NASA, Glenn Research Center. Retrieved from http://www.grc.nasa.gov/WWW/wind/valid/tutorial/tutorial.html

Silitonga, A. S., Atabani, A. E., Mahlia, T. M. I., Masjuki, H. H., Irfan, A. B. and Mekhilef, S. (2011). A review on prospect of Jatropha curcas for biodiesel in Indonesia. *Renewable and Sustainable Energy Reviews*, 15: 3733-3756.

Siqueira, V. C., Resende, O. and Chaves, T. H. (2013). Mathematical modelling of the drying of Jatropha fruit: an empirical comparison. *Revista Ciência Argronômica*, 44(2).

Sirisomboon, P., Kitchaiya, P., Pholpho, T. and Mahuttanyavanitch, W. (2007). Physical and mechanical properties of Jatropha Curcas L. fruits, nuts and kenels. *Biosystems Engineering*, 97: 201-207.

Sohpal, V. K., Singh, A. and Dey, A. (2011). Fuzzy modeling to evaluate the effect of temperature on batch tranesterification of Jatropha curcas for biodiesel production. *Bulletin of Chemical Reaction Engineering and Catalysis*, 6(1): 31-38.

Srivastave, A. and Prasad, R. (2000). Triglycerides-based diesel fuels. *Renewable and Sustainable Energy Reviews*, 4: 111-133.

Subramanian, R., Shamanthaka Sastry, M. C. and Venkateshmurthy, K. (1990). Impact dehulling of sunflower seeds: Effect of operating conditions and seed characteristics. *Journal of Food Engineering*, 12: 83-94.

Sun, P., Hou, S., Zhao, Y., Wang, H. and Xia, X. H. *Simulation and Analysis on Internal Flow Field of Horizontal Flow Separator for Urban Garbage*. Paper presented at 2012 International Conference on Ecology, Waste Recycling and Environment, Macau. 1-2 April 2012.

Sunil, K., Alok, C. and Shashi, K. J. (2011). Sustainability issues for promotion of Jatropha biodiesel in Indian scenario: a review. *Renewable and Sustainable Energy Reviews*, 16: 1089-1098.

Swain, A. K., Patra, H. and Roy, G. K. (2011). *Mechanical Operations*. New Delhi: Tata McGraw Hill Education Private Limited.

Syam, A. M., Yunus, R., Ghazi, T. I. M. and Choong, T. S. Y. (2012). Synthesis of Jatropha curcas oil-based biodiesel in a pulsed loop reactor. *Industrial Crops and Products*, 37: 514-519.

Syam, A. M., Hamid, H. A., Yunus, R. and Rashid, U. (2013). Dynamic modeling of reversible methanolysis of Jatropha curcas oil to biodiesel. *The Scientific World Journal*, 2013 (ID 268385): 7 pages.

Syamlal, M., Rogers, W. and O'Brien, T. J. (1993). *MFIX Documentation: Volume 1, Theory Guide, DOE/METC-9411004, NTIS/DE9400087*. VA: National Technical Information Service, Springfield.

Tiwari, A. K., Kumar, A. and Raheman, H. (2007). Biodiesel production from Jatropha (Jatropha curcas) with high free fatty acids: an optimized process. *Biomass and Bioenergy*, 31: 569-575.

Uriarte, F. A. Jr. (2010). *Biofuels from Plant Oils*. Jakarta, Indonesia: ASEAN Foundation.

USDA. (2013). Jatropha Information from Germplasm Resources Information Network (GRIN). Retrieved from http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?20692

Vairavan, K., Thukkaiyannan, P., Paramathma, M., Venkatachalam, P. and Sampathrajan, A. (2007). *Biofuel Crops Cultivation and Management: Jatropha, Sweet Sorghum and Sugarbeet.* India: Agrobios.

Veljkovic, V. B., Lakicevic, S. H., Stamenkovic, O. S., Todorovic, Z. B. and Lazic, K. L. (2006). Biodiesel production from tabacco (Nicotiana tabacum L.) seed oil with a high content of free fatty acids. *Fuel*, 85: 2671-2675.

Wadell, H. (1934). The coefficient of resistance as a function of Reynolds number for solids of various shapes. *Journal of the Franklin Institute*, 217(4): 459-490.

Wahl, N., Hildebrandt, T., Moser, C., Lüdeke-Freund, F., Averdunk, K., Bailis, R., Barua, K., Burritt, R., Groeneveld, J., Klein, A. M., Kügemann, M., Walmsley, D., Schaltegger, S. and Zelt, T. (2012). *Insights into Jatropha Projects Worldwide*. Lüneburg: University of Lüneburg.

Wang, Z., Calderon, M. M. and Lu, Y. (2011). Lifecycle assessment of the economic, environmental and energy performance of Jatropha curcas L. biodiesel in China. *Biomass and Bioenergy*, 35: 2893-2902.

Wendt, J. (2008). *Computational Fluid Dynamics: An introduction*. Berlin: Springer.

Whitaker, M. and Heath, G. (2008). *Life Cycle Assessment of the Use of Jatropha Biodiesel in Indian Locomotives.* United States: National Renewable Energy Laboratory.

White, F. M. (2008). *Fluid Mechanics. Sixth Ed*. New York: McFraw-Hill.

Williams, F. A. (1985). *Combustion Theory, 2nd Ed*. United States: Benjamin/Cummings.

Wilson, E. B. (1990). *An Introduction to Scientific Research*. Toronto, Canada: General Publishing Company Ltd.

Wim, D. G., Maes, J., Simons, B., Balshaw, C. and Miles, D. *Improved Yield and Biodiesel Quality from Jatropha Curcas by Optimized Seed Processing and Oil Pre-treatment*. Paper presented at the AOCS International Congress on Biodiesel, Vienna, Austria. 5-7 November 2007.

Wiskerke, W. T., Dornburg, V., Rubanza, C. D. K., Malimbwi, R. E. and Faaij, A. P. C. (2010). Cost/benefit analysis for biomass energy supply options for rural smallholders in the semi-arid eastern part of Shinyanga region in Tanzania. *Renewable and Sustainable Energy Reviews*, 14: 148-165.

Yakhot, V., and Orszag, S. A. (1986). Renormalization group analysis of turbulence: I. basic theory. *Journal of Scientific Computing*, 1(1): 1-51.

Yang, C. Y., Fang, Z., Li, B. and Long, Y. F. (2012). Review and prospects of Jatropha biodiesel industry in China. *Renewable and Sustainable Energy Reviews*, 16: 2178-2190.

Yang, W. C. (2003). *Handbook of Fludization and Fluid-particle System.* New York: Marcel Dekker, Inc.

Yunus, A. G. and John, M. C. (2010). *Fluid Mechanics: Fundamentals and Applications, Second Edition*. New York: McGraw-Hill.

Zainul, I. F. (2015, June 8). Malaysia to Implement B10 Biodiesel Mandate by October. *Star Media Group Berhad*. Retrieved from http://www.thestar.com.my/Business/Business-News/2015/06/08/Malaysia-to-implement-B10-biodiesel-mandate-by-October/?style=biz

Zarei, A., Amin, N. A. S., Talebian-Kiakalaieh, A. and Zain, N. A. M. (2014). Immobilized lipase-catalyzed transesterification of Jatropha curcas oil: Optimization and modeling. *Journal of the Taiwan Institute of Chemical Engineers*, 45(2): 444-451.

Zhang, C. and Tang, H. (2009). Proceedings from 16th IAHR-APD Congress and 3rd Symposium of IAHR-ISHS: Volume 2: *Advances in Water Resources and Hydraulic Engineering*. Beijing: Tshinghua University Press.

Zhang, L. H., Zhang, W. and Gou, W. (2010). Design and experiment of a Jatropha nut huller. *Journal of Southwest University (Natural Science Edition)*, 32(9): 147-152.

Zheng, Y. I., Wiesenborn, D. P., Tostenson, K. and Kangas, N. (2005). Energy analysis in the screw pressing of whole and dehulled flaxseed. *Journal of Food Engineering*, 66: 193-202.