UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF KENAF FIBRE POLY (LACTIC ACID) - EPOXIDISED JATROPHA OIL BIOCOMPOSITES

SITI HASNAH BINTI KAMARUDIN

IPTPH 2018 6

DEVELOPMENT OF KENAF FIBRE POLY (LACTIC ACID) - EPOXIDISED JATROPHA OIL BIOCOMPOSITES

By

SITI HASNAH BINTI KAMARUDIN

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

June 2018

This humble work is dedicated

to my family, my mentor and my best friend,

who always picked me up on time

and encouraged me to fly toward my dreams;

especially this one.

Let's soar for everlasting love.

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 KENAF FIBRE POLY (LACTIC ACID) - EPOXIDISED JATROPHA OIL BIOCOMPOSITES

By

SITI HASNAH BINTI KAMARUDIN

June 2018

Chairman : **Luqman Chuah Abdullah, PhD**
Institute : **Tropical Forestry and Forest Products**

Poly (lactic acid) (PLA) has been highlighted to be a useful material in substituting the petroleum based polymer due to its promising mechanical properties and biodegradability. However, its brittleness properties and higher price as compared with the common commodity plastics have limited its application. Thus, the addition of epoxidised jatropha oil (EJO), a type of biodegradable plasticiser from natural products was employed to the PLA in response to concern about the environment as well as modifying the brittleness of PLA. Kenaf, one source of environmentally friendly and abundantly cheap natural fibers has been used in this study as reinforcement in PLA. Despite the advantages of using kenaf as a natural fibre, their limitations include, poor moisture resistance, poor wettability by the hydrophobic matrix and insufficient adhesion between fibre and polymeric matrix which can lead to poor properties. Therefore, one way to improve the fibre/matrix interfacial bonding is through the incorporation of fibre surface modification or treatment. The aim of this study is to investigate the effect of EJO as plasticiser on mechanical, physical, thermal and morphology properties of PLA. Furthermore, the effect of NaOH treatment on the properties of PLA/Kenaf composites as well as PLA/Kenaf/EJO composites were studied. Five different weight percentages of EJO ranging from 1 wt.% to 5 9 were melt blended in the Brabender internal mixer prior to compression moulding of blend in a hot press and compared to a neat PLA matrix sample. The mechanical properties of PLA/EJO composites were characterised in terms of tensile strength, tensile modulus, flexural strength, flexural modulus and impact strength. Results showed that the tensile strength, tensile modulus, flexural strength and flexural modulus decreased with increasing content of EJO in the blend. On the other hand, with the further addition of EJO to the PLA composites, the elongation at break properties increased significantly by 8.1% to 78.4%. The FTIR study indicated that miscibility and interaction of PLA and EJO exist as a small shift towards a higher temperature appeared in the absorption peak of PLA/EJO blend. Moreover, the study findings

showed that the water absorption of plasticized PLA decreased significantly by 1.3% to 1.0% with increasing EJO concentration up to 5 wt.%. While for thermal properties, the Differential Scanning Calorimetry (DSC) measurement revealed that the addition of EJO resulted in a decrease of glass transition temperature up to 62.2°C which aids PLA chain mobility in the blend as predicted. In addition, the Thermogravimetric Analysis (TGA) showed that the presence of EJO in the blends reduce the rate of decomposition of PLA by increment of onset temperature up to 388.2°C and enhanced the thermal stability of the blend. The improvement in mechanical, physical and thermal properties of PLA/EJO composites indicating better polymer-plasticiser interaction which is proved by Scanning Electron Micrograph (SEM) analysis. Afterward, five different weight percentages of kenaf fibre loading ranging from 10 wt.% to 50 wt.% were employed in the PLA blends in order to study the optimum fibre loading value in the blend. As a result, 40 wt.% of kenaf fibre loading found to be the optimum value for PLA/kenaf biocomposites. The surface modification treatment with 6% NaOH on kenaf fibre enhanced the properties of biocomposites as compared to the untreated kenaf fibre. The incorporation of EJO as a plasticiser to modify the brittleness of PLA demonstrated that the plasticised PLA/Kenaf bicomposites with good mechanical and thermal properties could be developed. It can be concluded that the addition of plasticiser and the treatment of fibre improved the properties of PLA/Kenaf/EJO biocomposites. Out of the analyses subjected, PLA (57 wt/%) / Kenaf (40 wt.%) /EJO (3 wt.%) reported as the best formulation of biocomposite from this study. Hence, the study findings will pave the way towards a greater usage of vegetable oil as well as natural fibre for the commercialisation and mankind benefits which can replace petroleum-derived products in the long run. Specific applications for the studied materials involved interior parts of the car, environmental packaging, tray and box.

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

PEMBANGUNAN BIOKOMPOSIT GENTIAN KENAF POLI (LAKTIK ASID)-MINYAK JATROPHA TEREPOKSIDA

Oleh

SITI HASNAH BINTI KAMARUDIN

Jun 2018

Pengerusi : Luqman Chuah, PhD
Institut : Institusi Perhutanan Tropika dan Produk Hutan

Poli (laktik asid) telah diketengahkan sebagai bahan yang berguna dalam menggantikan polimer berasaskan petroleum disebabkan oleh ciri-ciri mekanikal yang baik dan terbiodegradasi. Walaubagaimanapun, sifatnya yang rapuh dan harga yang tinggi berbanding komoditi plastik yang normal telah menghadkan penggunaannya. Oleh itu, penambahan minyak jatropha terepoksida, sejenis bahan pemplastik terbiodegradasi daripada sumber asli telah digunakan ke atas poli (laktik asid) dalam menyahut kesedaran tentang persekitaran dan juga mengubahsuai kerapuhan PLA. Kenaf, salah satu sumber gentian semulajadi yang murah dan mesra alam sekitar telah digunakan dalam kajian ini untuk memperkukuh bahan PLA. Walaupun terdapat kelebihan menggunakan kenaf sebagai gentian semulajadi, kekurangannya termasuk modulus yang lebih rendah, kekuatan yang rendah, rintangan kelembapan yang lemah, kebolehbasahan yang lemah oleh matriks hidrofobik dan pelekatan yang tidak mencukupi di antara gentian dan matriks polimer yang boleh membawa kepada sifatsifat yang lemah. Oleh itu, satu cara untuk mempertingkatkan ikatan permukaaan gentian/matriks ialah melalui kaedah pengubahsuaian atau rawatan permukaan gentian. Tujuan kajian ini adalah untuk mengkaji kesan EJO sebagai pemplastik terhadap sifat-sifat mekanikal, fizikal, haba dan morfologi PLA. Tambahan pula, kesan rawatan NaOH terhadap sifat-sifat komposit PLA/kenaf dan komposit PLA/kenaf/EJO dikaji. Lima peratus EJO yang berbeza antara 1% berat sehingga 5% berat telah diadun cair di dalam pengadun dalaman Brabender terlebih dahulu sebelum diadun didalam acuan pemampat panas dan dibandingkan dengan sampel matriks PLA. Sifat-sifat mekanikal komposit PLA/EJO dikaji dalam bentuk kekuatan tegangan, modulus tegangan, kekuatan lenturan, modulus lenturan dan kekuatan impak. Hasil menunjukkan bahawa kekuatan tegangan, modulus tegangan, kekuatan lenturan dan modulus lenturan menurun dengan penambahan EJO di dalam adunan. Sebaliknya, dengan penambahan lanjutan EJO di dalam komposit PLA, sifat pemanjangan sewaktu patah meningkat secara signifikan daripada 8.1% kepada

78.4%. Kajian FTIR menunjukkan keterlarutcampuran dan interaksi antara PLA dan EJO berlaku dimana anjakan kecil terhadap suhu tinggi berlaku di dalam puncak penyerapan adunan PLA/EJO. Tambahan pula, dapatan kajian menunjukkan penyerapan air pemplastik PLA berkurangan daripada 1.3% kepada 1.0% secara signifikan dengan penambahan kepekatan EJO sehingga 5% berat. Sebaliknya untuk ciri-ciri haba, pengukuran kalorimetri pengimbasan pembezaan menunjukkan bahawa penambahan EJO menyebabkan penurunan pada suhu peralihan kaca sehingga 62.2°C yang membantu rantai pergerakan PLA di dalam adunan seperti yang diramal. Tambahan pula, analisis termogravimetri menunjukkan kehadiran EJO di dalam adunan mengurangkan kadar pereputan PLA dengan kenaikan suhu awal sehingga 388.2 °C dan meningkatkan kestabilan haba di dalam adunan. Peningkatan dalam mekanikal, fizikal dan ciri haba komposit PLA/EJO menunjukkan interaksi polimer-pemplastik yang lebih baik seperti yang terbukti oleh analisis mikroskop elektron imbasan. Kemudian, gentian kenaf dengan lima peratus berat bebanan yang berbeza antara 10% berat sehingga 50% berat dimasukkan ke dalam adunan PLA untuk mengkaji nilai bebanan gentian yang optimum di dalam adunan. Keputusannya, 40% berat bebanan gentian kenaf didapati sebagai nilai yang optimum untuk biokomposit PLA/kenaf. Rawatan pengubahsuaian permukaan dengan 6% NaOH pada gentian kenaf meningkatkan ciri-ciri biokomposit dibandingkan dengan gentian kenaf yang tidak dirawat. Penggabungan EJO sebagai pemplastik untuk mengubahsuai kerapuhan PLA menunjukkan bahawa biokomposit pemplastik PLA/Kenaf dengan ciri haba dan mekanikal yang baik boleh dibangunkan.Ini boleh disimpulkan bahawa penambahan pemplastik dan rawatan gentian memperbaiki ciri-ciri biokomposit PLA/Kenaf/EJO. Daripada analisis yang dikaji, PLA (berat 57%)/ Kenaf (berat 40%)/ EJO (berat 3%) adalah merupakan formulasi biokomposit terbaik daripada kajian ini. Justeru, penemuan kajian akan membuka jalan ke arah penggunaan minyak sayuran dan juga gentian kenaf yang lebih meluas untuk pengkomersilan dan memberi manfaat kepada seluruh manusia yang boleh menggantikan produk berasaskan petroleum dalam jangka masa yang panjang. Aplikasi tertentu untuk bahan yang dikaji termasuklah bahagian dalaman kereta, pembungkusan mesra alam, dulang dan kotak.

ACKNOWLEDGEMENTS

In the the name of Allah, The Most Gracious, The Most Merciful.

All praise to Allah SWT for giving me His love, as well as the strength, courage and perseverance to complete this thesis. May the peace and blessing of Allah be upon Prophet Muhammad SAW. This thesis requires a lot of hard work and effort, and it would not be possible to complete this thesis without the contributions of many significant individuals.

I owe huge gratitude to my lovely supervisor, Prof. Dr. Luqman Chuah, for his valuable knowledge and continuing guidance, expensive motivation and continuing support which helps me complete this study. I could not ask for a better supervisor. Prof, thank you for being you. Only Allah can repay you. May Allah grant you jannah for all your patience. I have learned so many things from you, directly and indirectly about the beauty of doing research. I would like to thank all excellent members in my supervisory committee, Dr. Min Min Aung and Dr. Chantara Thevy Ratnam for their encouragement and experience sharing through out my research. I owe Dr. Maizatulnisa Othman who shared her struggles and valuable experiences in her journey.

I also wish to express my gratitude to the technical staff at Malaysian Nuclear Agency, especially to Mr. Wan Ali and Mr. Hafizie, Mdm Roslina, Mr. Ismail, Mdm Eli, Miss Ana from Universiti Putra Malaysia, for their assistance in carrying out the laboratory work.

To my beloved parents, Kamarudin Esa and Maziah Mohd, I sincerely thank you for your unconditional love as well as endless prayers and support me in every way, which serve as a big source of inspiration and for motivating me to higher achievement. Thank you very much for admiring my words and believing me in completing my study.

To my dearest sister, Siti Asiah, a very special thank you for putting your heart and soul and be my witness seeing me at my worst and best along this arduous journey. I could not find the words to truly convey my love and appreciation to you except for a very special thank you. To my dearest best friends, Mohd Nurrazzi Norizan, Saba Rashidi, Syafik Abdul Nasir, thank you very much for always being there for me and having faith in me. You guys took on a role you didn’t ask for and you made it. I am forever grateful that Allah has planned our story. I appreciate my beloved colleagues, Syeed Saifulazry, Emiliana Rose, Sariah, Rabiatuladawiyah, Suhaini, Nas Aulia, Pui San, Zakiah, Aqeela, Marwah, Noraini, Noraniza, and for those not mentioned here, you know who you are, you are forever part of my work.

To dearest Nurul Raihan, Nurul Jannah and Nur Zulaikha thank you for always and always being there. I love all of you, thank you for always giving me comforting words and a shoulder to cry on. Thank you Allah who has preserve our friendship, more than we can imagine.

I must acknowledge the Ministry of Higher Education (MOHE) and Universiti Teknologi MARA for giving me the financial suppot and opportunity to pursue my PhD study in Universiti Putra Malaysia. I would also like to extend my appreciation to Malaysian Nuclear Agency for the use of their facilities.

Finally, I would like to extend my gratitude to my beloved husband, Fadlullah Jili Fursani, my dearest angels, Imaan Irdina and Imaan Khalisha. Their unconditional love, encouragement, support and prayers were the driving force that inspired me to succeed and build my strength and confidence to overcome the many seemingly insurmountable obstacles in life. A very special thanks to my babysitter, Shuhaili who helped me to take care of my beloved girls while I am away for research and studying. Thanks to all of my family members who helped me a lot in this journey. Without them, I cannot hold strong and have determination to finish this line without their unyielding love, understanding and support. Thank you all and Alhamdullillah.

I certify that a Thesis Examination Committee has met on 7 June 2018 to conduct the final examination of Siti Hasnah binti Kamarudin on her thesis entitled "Development of Kenaf Fibre Poly(Lactic Acid)-Epoxidised Jatropha Oil Biocomposites" 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:

Rosfarizan binti Mohamad, PhD
Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Edi Syams bin Zainudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Salmiaton binti Ali, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Martin A. Hubbe, PhD
Professor
North Carolina State University
United States
(External Examiner)

RUSLI HAJI ABDULLAH, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 30 July 2018

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:

Luqman Chuah Abdullah, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Min Min Aung, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Member)

Chantara Thevy Ratnam, PhD
Senior Research Officer
Radiation Processing Technology Division
Malaysian Nuclear Agency
(Member)

____
ROBIAH BINTI YUNUS, 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.: Siti Hasnah binti Kamarudin, GS 38064

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: Professor Dr. Luqman Chuah Abdullah

Signature: ______________________________
Name of Member of Supervisory Committee: Dr. Min Min Aung

Signature: ______________________________
Name of Member of Supervisory Committee: Dr. Chantara Thevy Ratnam

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABS	Acylonithrile butadiene styrene
AOCS	American Oil Chemists' Society
ASTM	American Standard of Testing Materials
BATC	Bionas Agropolitan Technology Corridor
CO_2	Carbon dioxide
DSC	Differential Scanning Calorimetry
EJO	Epoxidised Jatropha Oil
EPO	Epoxidised Palm Oil
ESO	Epoxidised Soybean oil
EVO	Epoxidised Vegetable Oil
FTIR	Fourier Transform Infrared
H_2O	Water
H_2O_2	Hydrogen Peroxide
ISO	International Standards Organisation
JO	Jatropha Oil
KF	Kenaf Fibre
MARDI	Malaysian Agricultural Research and Development Institute
MOHE	Ministry of Higher Education
MRB	Malaysian Rubber Board
NaOH	Sodium Hydroxide
OOC	Oxirane Oxygen Content
PA	Polyamide
PBS	Poly(butylene succinate)
PBSAT	Poly(butylene succinate-co-adipate-co-terephthalate)

PBSL	Poly(butylene succinate-co- L- lactate)
PBT	Poly(butylene terephthalate)
PCBS	Polychlorinated Biphenyls
PCL	Poly(caprolactone)
PE	Polyethylene
PET	Polyethylene terephthalate
PHA	Polyhydroxylalkanoates
PLA	Poly (lactic acid)
PP	Polypropylene
PS	Polystyrene
PTMAT	Polymethylene adipate terephthalate
PUR	Polyurethane
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
SBR	Styrene-butadine Rubber
SEM	Scanning Electron Microscopy
T_g	Glass transition
TGA	Thermogravimetric Analysis
TK	Treated Kenaf
TPS	Thermoplastic Starch
UiTM	Universiti Teknologi MARA
UPM	Universiti Putra Malaysia
UTK	Untreated Kenaf

CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

The tremendous growth of issues concerning the high rate of depletion of petroleum resources, environmental concerns and the introduction of stringent government regulations especially in European and Asian countries has generated vast interest among scientists and researchers in developing renewable raw materials that are sustainable and environmentally friendly. "Greener" materials that are safe and compatible with the environment are being sought and developed as renewable alternatives and a substitute for conventional petroleum–based plastics. By far, the most common renewable raw materials, and those that seem to offer the greatest potential for competing with synthetic polymers is bioplastics such as polyhydroxylalkanoates (PHAs) and poly (lactic acid) (PLA). Natural thermoplastic resin, PLA is a polymer which already has some market exposure for its significant potential properties to help to overcome the accumulation of plastic waste in landfills. Serious issues with large amounts of plastic waste can cause severe environmental impacts. In addition, only limited landfilling areas are available and indeed in some countries this practise is totally restricted. PLA has the advantage of being fully biodegradable by hydrolysis to lactic acid, and eventually to water and carbon monoxide. Since PLA is produced from fieldwaste products, PLA can potentially become a CO_2 sink and contribute to the reduction of greenhouse gases in the long run (Dittenber and Gangarao, 2012).

The utilisation of bio-based polymers in place of petroleum-based polymers has a positive effect in the sense of a reduction of the environmental impact and offsetting the need for petroleum consumption. One of the major challenges to replacing conventional polymers is the high cost of production of bio-based polymers (Mohanty *et al.*, 2000). Another obstacle to deal with in terms of bio-based polymers is the fact that some of these materials exhibit limitations in their properties which cause them to be less preferable to be used as a commodity plastic. Many studies have been conducted in order to reduce the cost and enhance the properties of bio materials such as introducing suitable fillers or reinforcement materials and a compatibiliser or plasticiser into the system. Modification and enhancement of these polymers is a crucial step to be undertaken to meet the expectations of developing eco-friendly materials that are able to function in variety of commercial applications.

In the case of PLA, it has a relatively high cost (RM25/kg) compared to conventional polymers (Mathew *et al.*, 2005). Other limitations of PLA are high brittleness, low toughness and low tensile elongation (Ljunberg and Wesslen, 2005). One way to solve these problems is through the incorporation of plasticisers and natural fillers, which not only reduce the cost but also improve the product performance. The addition of renewable and biodegradable fillers such as natural fibres could optimise the cost-performance balance and improve the mechanical and thermal behaviours (Oksman *et al*., 2013).

Acknowledging Malaysia as a tropical country that has abundant resources of natural fibres, it was decided to emphasise the usage of this type of bio-sourced materials in present composite development. Several researchers have reported that the addition of natural fibres with biopolymers improved the properties of the composite in terms of biodegradability (Mohanty *et al*., 2000). The term 'biodegradable composite' refers to the combination of two materials that can be fully degradable. Biodegradable composites may also be obtained by blending together a biodegradable polymer and biodegradable fillers (Le Degabel and Averous, 2006). As both components are biodegradable, the composite as the integral part is also expected to be biodegradable (Mohanty *et al.*, 2000).

Natural fibre offers both economic and ecological advantages over commercial synthetic fibre as it is a renewable resource and it is also cheap, widely available and non-abrasive. Kenaf fibre has great potential to be used as a filler in polymeric materials. Towards attaining this development goal, the government has increased the allocation budget for a kenaf plantation to RM 110 million under the 11th Malaysian plan (2016-2020), as compared to the total amount of RM 105 million in the previous Malaysian plan. The incorporation of kenaf fibre into PLA will maximise the use of kenaf for development of the production of high value-added products. In particular, kenaf fibre attracts interest because of its environmental friendly features, abundance in nature, low density and most importantly low operational cost (Nishino *et al*., 2003).

Unfortunately, there are some major challenges that have been faced by nearly every researcher who has worked with natural fibre composites. The limitation of processing temperature and the hydrophilic characteristic make the natural fibres incompatible with some matrices and the high moisture absorption by the fibres is a significant problem especially for industrial applications (Bachtiar *et al.*, 2008; Xie *et al*., 2010). Although when PLA is combined with kenaf fibre this produces biocomposite materials that are fully degradable, lightweight and cheaper, the combination presents several limitations. For instance, the incompatible character between hydrophilic kenaf and the hydrophobic PLA matrix results in poor interfacial adhesion between the two components (Ramli *et al*., 2012). Therefore, the matrix and/or fibre require modification for enhanced performance.

Several modifications have been made by previous researchers to improve the interaction between natural fibres and matrices. The properties of composites can be improved by employing two approaches, namely the treatment of fibres and the use of an appropriate additive (Avella *et al*., 2009). Generally, modification of fibre can be classified into physical or chemical treatments. The physical method such as super-heated steam, plasma and corona treatment changes the structural and surface properties of the fibre. The chemical route for the modification of fibre such as silane treatment, alkaline treatment, acetylation, maleated coupling agent and enzymatic treatment is usually aimed at improving the fibre-matrix interaction (Faruk *et al.*, 2012).

Due to the nature of kenaf fibre, NaOH treatment has been used to improve the interaction compatibility between PLA and the kenaf fibre. The aim of chemical modification of natural fibre is to improve interaction of the fibre with the polymer matrix. Several findings have revealed that chemical treatments tend to improve the properties of composites (Vilay *et al*., 2008; Mohanty *et al*., 2001; Mwaikambo and Ansell, 1999). The chemical treatment of fibre is mostly related to improving of the surface of the fibre which promotes better fibre strength properties. Different chemical treatments will be used depending on the objective of the treatment. Normally, the treatment is used to remove the hydrophilic components on the fibre such as hemicelluloses, lignin and wax. These major components of the fibre cause problems during the process of combining with a polymer matrix. Moreover, the cost of processing the material becomes a major factor for the composite production. The use of sodium hydroxide as an alkaline treatment (also known as mercerisation) is very attractive from the point of view of the contribution to decrease the cost of fibre modification for use in composite materials, therefore helping to improve the interface between the fibres and the matrix. During alkalisation, the cementitious materials in the fibres are removed, leading to rougher fibre topography. Even in low NaOH concentrations, fibres can fibrillate which increases the aspect ratio and the bondable surface area. By improving the fibre/matrix adhesion in this manner, the tensile and flexural properties of the composite are improved at the expense of a reduction in impact behaviour (Dittenber and Gangarao, 2012).

In order for the polymer matrix to move closer to the goal of being true 100 % biocomposites, it is crucial that the polymer matrix or a high proportion of it be of biological origin. One of the possible ways this can be achieved is through the usage of plant oil based bioresins. Bioresins, in particular plant or vegetable oil based bioresins, offer a potential viable alternative to petrochemical based resins as the required feed stocks are readily available in most parts of the world (Wool and Sun, 1999).

In response to concern about the environment, plasticisers derived from natural products are currently being employed in biodegradable polymers as a replacement for traditionally used phthalates in the plastics industry and which are characterised by their high toxicity (Fenollar *et al*., 2009). Recently, modified vegetable oils as one type of biodegradable plasticisers, have gained a lot of interest as a renewable source of plasticiser for polymers (Robertson *et al*., 2010). Numerous researchers have reported on the usage of epoxidised vegetable oil (EVO) as a plasticiser for PLA composites (Dai *et al*., 2014; Alam *et al*., 2014; Mulla, 2011). There are few advantages listed for using epoxidised vegetable oil in the polymer industry such as being biodegradable, environmentally friendly, renewable and it is a cheap material (Al-Mulla *et al*., 2010). Furthermore, vegetable oil has potential as an additive for industrial applications that require properties such as cheapness, good lubricity, high index viscosity and good solvency for fluid additives (Lathi and Mattiasson, 2007).

An epoxidation process is needed in order to make sure the vegetable oil feed stocks are converted into epoxidised vegetable oil (EVO). Numerous research projects have been conducted by many researchers involving EVO regarding the characterisation, synthesis, as well as use in biocomposite applications (Wang and Schuman, 2013, Adekunle *et al*., 2010, O'Donnel *et al*., 2004). The benefits of introducing EVO in polymers are that EVO is inexpensive, degradable and easily incorporated into epoxy resins and can be primarily used as a plasticiser or a toughening additive for epoxy resins.

Although the amount of research regarding EVO plasticised PLA composite has increased tremendously, to the best of the knowledge of the current authors, there has not been a study reported of using epoxidised jatropha oil (EJO) as a non-edible vegetable oil as a plasticiser for a PLA/kenaf composite. EJO is derived from jatropha oil which can be obtained from the crushing of the seed of *Jatropha curcas*. The oil has about 21.1 % of saturated fatty acids and 78.9 % of unsaturated fatty acids, mainly oleic acid (43.1 %) and linoleic acid (34.4 %) in the seeds which is relatively higher than other edible oils, for example palm oil. This indicates the great potential of EJO as it can be converted from natural resources of jatropha oil (Sarin *et al*., 2007; Lee *et al*., 1998). Generally, the higher number of C=C unsaturated chains of fatty acids will result in better polarity and stability of the oil that leads to good mechanical properties (Meier *et al*., 2007). For this, the non-edible jatropha oil is a new alternative to be used as a plasticiser for the PLA matrix in this study.

Hence, in this study, novel plasticised PLA biocomposites were fabricated by a combination of poly (lactic acid) (PLA), epoxidised jatropha oil and kenaf fibres, whereby PLA was melt blended with EJO to form one such non-edible vegetable oil material and renewable plasticiser that could withstand practical applications while their biodegradation properties were maintained. In addition, the effect of Epoxidised jatropha oil and alkaline treatment on the performance of the Poly (lactic acid) composites and Poly (lactic acid)/ Kenaf/Epoxidised Jatropha Oil biocomposites was also investigated.

1.2 Problem Statement

The utilisation of bio-based polymers in place of petroleum-based polymers has a positive effect in the sense of a reduction of the environmental impact and offsetting the need for petroleum consumption. One of the major challenges to replacing conventional polymers is the high cost of production of bio-based polymers (Mohanty *et al*., 2000). Another obstacle to deal with in terms of bio-based polymers is the fact that some of these materials exhibit limitations in their properties which cause them to be less preferable to be used as a commodity plastic. Many studies have been conducted in order to reduce the cost and enhance the properties of bio materials such as introducing suitable fillers or reinforcement materials and a compatibiliser or plasticiser into the system. Modification and enhancement of these polymers is a crucial step to be undertaken to meet the expectations of developing eco-friendly materials that are able to function in variety of commercial applications.

In the case of PLA, it has a relatively high cost (RM25/kg) compared to conventional polymers like PP (RM 5/kg) and PE (RM 4.80/kg) (Mathew *et al*., 2005). Other limitations of PLA are high brittleness, low toughness and low tensile elongation (Ljunberg and Wesslen, 2005). One way to solve these problems is through the incorporation of plasticisers and natural fillers, which not only reduce the cost but also improve the product performance. The addition of renewable and biodegradable fillers such as natural fibres could optimise the cost performance balance and improve the mechanical and thermal behaviours (Oksman *et al*., 2013).

Unfortunately, there are some major challenges that have been faced by nearly every researcher who has worked with natural fibre composites. The limitation of processing temperature and the hydrophilic characteristic make the natural fibres incompatible with some matrices and the high moisture absorption by the fibres is a significant problem especially for industrial applications (Bachtiar *et al.*, 2008; Xie *et al*., 2010). Although when PLA is combined with kenaf fibre this produces biocomposite materials that are fully degradable, lightweight and cheaper, the combination presents several limitations. For instance, the incompatible character between hydrophilic kenaf and the hydrophobic PLA matrix results in poor interfacial adhesion between the two components (Ramli *et al*., 2012). Therefore, the matrix and/or fibre require modification for enhanced performance.

Due to the nature of kenaf fibre, NaOH treatment has been used to improve the interaction compatibility between PLA and the kenaf fibre. The aim of chemical modification of natural fibre is to improve interaction of the fibre with the polymer matrix. Several findings have revealed that chemical treatments tend to improve the properties of composites (Vilay *et al*., 2008; Mohanty *et al*., 2001; Mwaikambo and Ansell, 1999). The chemical treatment of fibre is mostly related to improving of the surface of the fibre which promotes better fibre strength properties. Different chemical treatments will be used depending on the objective of the treatment. Normally, the treatment is used to remove the relatively low molecular mass, extractable components on the fibre such as hemicelluloses, lignin and wax. These major components of the fibre cause problems during the process of combining with a polymer matrix. Moreover, the cost of processing the material becomes a major factor for the composite production. The use of sodium hydroxide as an alkaline treatment (also known as mercerisation) is very attractive from the point of view of the contribution to decrease the cost of fibre modification for use in composite materials, therefore helping to improve the interface between the fibres and the matrix. During alkalisation, the cementitious materials in the fibres are removed, leading to rougher fibre topography. Even in low NaOH concentrations, fibres can fibrillate which increases the aspect ratio and the bondable surface area. By improving the fibre/matrix adhesion in this manner, the tensile and flexural properties of the composite are improved at the expense of a reduction in impact behaviour (Dittenber and Gangarao, 2012).

In order for the polymer matrix to move closer to the goal of being true 100 % biocomposites, it is crucial that the polymer matrix or a high proportion of it be of biological origin. One of the possible ways this can be achieved is through the usage of plant oil based bioresins. Bioresins, in particular plant or vegetable oil based bioresins, offer a potential viable alternative to petrochemical based resins as the required feed stocks are readily available in most parts of the world (Wool and Sun, 1999).

Although the amount of research regarding EVO plasticised PLA composite has increased tremendously, to the best of the knowledge of the current authors, there has not been a study reported of using epoxidised jatropha oil (EJO) as a non-edible vegetable oil as a plasticiser for a PLA/kenaf composite. EJO is derived from jatropha oil which can be obtained from the crushing of the seed of *Jatropha curcas*. The oil has about 21.1 % of saturated fatty acids and 78.9 % of unsaturated fatty acids, mainly oleic acid (43.1 %) and linoleic acid (34.4 %) in the seeds which is relatively higher than other edible oils, for example palm oil. This indicates the great potential of EJO as it can be converted from natural resources of jatropha oil (Sarin *et al*., 2007; Lee *et al*., 1998).Generally, the higher number of C=C unsaturated chains of fatty acids will result in better polarity and stability of the oil that leads to good mechanical properties (Meier *et al*., 2007). For this, the non-edible jatropha oil is a new alternative to be used as a plasticiser for the PLA matrix in this study.

Hence, in this study, novel plasticised PLA biocomposites were fabricated by a combination of poly (lactic acid) (PLA), epoxidised jatropha oil and kenaf fibres, whereby PLA was melt blended with EJO to form one such non-edible vegetable oil material and renewable plasticiser that could withstand practical applications while their biodegradation properties were maintained. In addition, the effect of Epoxidised jatropha oil and alkaline treatment on the performance of the Poly (lactic acid) composites and Poly (lactic acid)/ Kenaf/Epoxidised Jatropha Oil biocomposites was also investigated.

1.3 Research Aims and Objectives

This research attempts to carry out investigation into the feasibility of producing biodegradable blends of biocomposites by enhancing the properties of natural polymer, PLA with the incorporation of EJO as a non-edible type of natural plasticiser and by impregnating the kenaf fibres to match the requirements of biocomposites. In order to achieve this objective, specific sub-objectives have been identified as follows:

1. To evaluate the plasticising effect of epoxidised jatropha oil (EJO) as a nonedible vegetable based plasticiser with various EJO loadings (1, 2, 3, 4 and 5 wt.%) on the chemical, physical, mechanical, thermal and morphological properties of PLA matrix.
2. To optimise the kenaf fibre loading (10, 20, 30, 40 and 50 wt.%) on the mechanical, thermal and morphological properties of PLA/EJO/kenaf biocomposites.
3. To investigate the effect of alkali treatment on kenaf fibre filled PLA/EJO biocomposites.
4. To determine the best formulation of PLA/ treated kenaf/EJO biocomposites in terms of chemical, physical, mechanical, thermal and morphological properties.

1.4 Scope of the Study

The scope of the study can be discussed as stated below:

a. The production of epoxidised jatropha oil (EJO) from unsaturated crude jatropha oil via an “in situ” epoxidation process in the molar ratio of 1: 0.6: 1.7 – jatropha oil: formic acid: hydrogen peroxide at temperature of 60°C will be obtained. Epoxidised jatropha oil produced from this epoxidation process will be used in the preparation of a Poly (lactic acid)/Epoxidised Jatropha Oil (PLA/EJO) blend.
b. The preparation of a PLA/EJO blend by the melt blending technique through the combination of PLA with different ratios of epoxidised jatropha oil loading formulations (1, 2, 3, 4 and 5 wt.%). PLA/EJO sheets will later be produced by a hot and cold press machine. The sheets will be analysed for their physical, chemical, mechanical and morphological properties characterisations.
c. The optimisation of short kenaf fibre loading on the properties of PLA/kenaf biocomposites will be acquired. Five different kenaf fibre loading formulations (10, 20, 30, 40 and 50 wt.%) will be introduced to the PLA/ kenaf biocomposites. The mechanical properties of biocomposites will be investigated.
d. The optimisation of the alkaline surface modification treatment of kenaf fibre on the PLA/kenaf biocomposites is to be evaluated by varying the percentage of alkaline treatment from 2, 4, 6 and 8 wt.%. The biocomposites will be characterised in terms of mechanical and morphology properties.

e. PLA/EJO/kenaf biocomposites will be developed by a combination of optimum PLA/EJO blend formulation and an optimum kenaf fibre loading formulation. The performance of the biocomposites in terms of chemical, physical, mechanical, thermal and morphological properties will be investigated.

1.5 Significance of the Research

1. A novel research into the potential of a Malaysian bio-sourced plant-derived type material, EJO as an alternative plasticiser for PLA kenaf biocomposites.
2. Development of novel biocomposites from PLA, EJO and kenaf fibre which will be suitable for various types of application.

1.6 General Overview of the Thesis

The thesis consists of six chapters. Chapter 1 serves as an introduction to the research which includes the overview of the study, problem statement, statement and significance of the problem, aim and objectives, as well as the significance of the research.

Chapter 2 presents a literature review of polymer composites, PLA as matrix for biocomposites, plasticiser for polymer blends, filler and reinforcing materials, and biocomposites derived from epoxidised vegetable oil. This chapter also reviews major issues and the challenges of using natural fibre in biocomposites and previous findings concerning plastic-related composites in terms of chemical, physical, mechanical, thermal and morphological properties.

Chapter 3 focuses on the materials and methodology involved in the multistage preparation and characterisation of PLA/EJO/kenaf biocomposites. The objectives in Chapter 3 are to evaluate the plasticising effect of epoxidised jatropha oil (EJO) as a non-edible vegetable based plasticiser with various EJO loadings (1, 2, 3, 4 and 5 wt.%) on the chemical, physical, mechanical, thermal and morphological properties of the PLA matrix. To conclude, a PLA/EJO film with optimum characteristics will be chosen for further combination with a matrix-plasticiser as continued in Chapter 4.

Chapter 4 and Chapter 5 are the working chapters where the results and discussion are conveyed accordingly to the objectives set in Section 1.3.

Chapter 4 begins with the optimisation of EJO loading on the properties of PLA/EJO blends. Analyses of effect of EJO at various concentration (wt.%) is completed to examine the mechanical, thermal and morphological properties of PLA/EJO blends. To conclude, a PLA/EJO blend formulation with optimum characteristics is determined and further applied in Chapter 5.

Chapter 5 discusses the effect of alkali treatment on kenaf fibre filled PLA/EJO biocomposites. NaOH surface modification is applied at various weight percent treatments (2, 4, 6 and 8 %) on kenaf fibre. The effect of treated kenaf fibre filled PLA biocomposites on the mechanical and morphological properties is investigated. Furthermore, this chapter presents an important practical evaluation on the optimised PLA/EJO/kenaf blends in terms of their chemical, physical, mechanical, thermal and morphological properties. To conclude, a PLA/kenaf treated/EJO biocomposite with optimum characteristics is determined.

As the final working chapter, Chapter 6 presents the overall conclusions of the research and recommendations for future research.

REFERENCES

d'Almeida, J. R. M., Aquino, R. C. M. P., & Monteiro, S. N. (2006). Tensile mechanical properties, morphological aspects and chemical characterization of piassava (Attalea funifera) fibers. Composites Part A: Applied Science and Manufacturing, 37(9), 1473-1479.

'Alvarez, C. (2010). Desarrolo de tableros aglomerados auto-enlazados a partir de fibras de la vena central de la hoja de pla'tano. PhD thesis. Universidad Pontificia Bolivariana, Medellin-Colombia.

Abraham, E., Deepa, B., Pothan, L. A., Jacob, M., Thomas, S., Cvelbar, U., & Anandjiwala, R. (2011). Extraction of nanocellulose fibrils from lignocellulosic fibres: A novel approach. *Carbohydrate Polymers*, *86*(4), 1468-1475.

Abral, H., Gafar, M. F., Andriyanto, H., Ilhamdi, Sapuan, S. M., Ishak, M. R., & Evitayani. (2012). Alkali treatment of screw pine (Pandanus Odoratissimus) fibers and its effect on unsaturated polyester composites. *Polymer-Plastics Technology and Engineering*, *51*(1), 12-18.

Adekunle, K., Åkesson, D., & Skrifvars, M. (2010). Synthesis of reactive soybean oils for use as a biobased thermoset resins in structural natural fiber composites. *Journal of applied polymer science*, *115*(6), 3137-3145.

Adhvaryu, A., & Erhan, S. Z. (2002). Epoxidized soybean oil as a potential source of high-temperature lubricants. *Industrial Crops and Products*, *15*(3), 247-254.

Agrawal, R., Saxena, N. S., Sharma, K. B., Thomas, S., & Sreekala, M. S. (2000). Activation energy and crystallization kinetics of untreated and treated oil palm fibre reinforced phenol formaldehyde composites. *Materials Science and Engineering: A*, *277*(1-2), 77-82.

Ahmad, S. H., Rasid, R., Bonnia, N. N., Zainol, I., Mamun, A. A., Bledzki, A. K., & Beg, M. D. H. (2011). Polyester-kenaf composites: effects of alkali fiber treatment and toughening of matrix using liquid natural rubber. *Journal of Composite Materials*, *45*(2), 203-217.

Aji, I. S., Sapuan, S. M., Zainudin, E. S., & Abdan, K. (2009). Kenaf fibres as reinforcement for polymeric composites: a review. *International Journal of Mechanical and Materials Engineering*, *4*(3), 239-248. Akbar, E., Yaakob, Z., Kamarudin, S. K., Ismail, M., & Salimon, J. (2009). Characteristic and composition of Jatropha curcas oil seed from Malaysia and its potential as biodiesel feedstock feedstock. *European Journal of Scientific Research*, *29*(3), 396-403.

Akbar, E., Yaakob, Z., Kamarudin, S. K., Ismail, M., & Salimon, J. (2009). Characteristic and composition of Jatropha curcas oil seed from Malaysia and its potential as biodiesel feedstock feedstock. *European Journal of Scientific Research*, *29*(3), 396-403.

Akil, H. M., Cheng, L. W., Ishak, Z. M., Bakar, A. A., & Rahman, M. A. (2009). Water absorption study on pultruded jute fibre reinforced unsaturated polyester composites. *Composites Science and Technology*, *69*(11-12), 1942-1948.

Akil, H., Omar, M. F., Mazuki, A. A. M., Safiee, S. Z. A. M., Ishak, Z. M., & Bakar, A. A. (2011). Kenaf fiber reinforced composites: A review. *Materials & Design*, *32*(8-9), 4107-4121.

Alam, A. M., Mina, M. F., Beg, M. D. H., Mamun, A. A., Bledzki, A. K., & Shubhra, Q. T. H. (2014). Thermo-mechanical and morphological properties of short natural fiber reinforced poly (lactic acid) biocomposite: effect of fiber treatment. *Fibers and Polymers*, *15*(6), 1303-1309.

Alemdar, A., & Sain, M. (2008). Biocomposites from wheat straw nanofibers: morphology, thermal and mechanical properties. *Composites Science and Technology*, *68*(2), 557-565.

Ali, F., Chang, Y. W., Kang, S. C., & Yoon, J. Y. (2009). Thermal, mechanical and rheological properties of poly (lactic acid)/epoxidized soybean oil blends. *Polymer Bulletin*, *62*(1), 91-98.

Al-Mulla, E. A. J., Ibrahim, N. A. B., Shameli, K., Ahmad, M. B., & Yunus, W. M. Z. W. (2014). Effect of epoxidized palm oil on the mechanical and morphological properties of a PLA–PCL blend. *Research on Chemical Intermediates*, *40*(2), 689-698.

Al-Mulla, E. A. J., Suhail, A. H., & Aowda, S. A. (2011). New biopolymer nanocomposites based on epoxidized soybean oil plasticized poly (lactic acid)/fatty nitrogen compounds modified clay: Preparation and characterization. *Industrial Crops and Products*, *33*(1), 23-29.

Al-Mulla, E. A. J., Yunus, W. M. Z. W., Ibrahim, N. A. B., & Rahman, M. Z. A. (2010). Properties of epoxidized palm oil plasticized polytlactic acid. *Journal of Materials Science*, *45*(7), 1942-1946.

Alvarez, V. A., & Vázquez, A. (2004). Thermal degradation of cellulose derivatives/starch blends and sisal fibre biocomposites. *Polymer Degradation and Stability*, *84*(1), 13-21.

Amirou, S., Zerizer, A., Haddadou, I., & Merlin, A. (2013). Effects of corona discharge treatment on the mechanical properties of biocomposites from polylactic acid and Algerian date palm fibres. *European Journal of Wood and Wood Products*, *71(*6), 717-723.

Anderson, K. S., & Hillmyer, M. A. (2004). The influence of block copolymer microstructure on the toughness of compatibilized polylactide/polyethylene blends. *Polymer*, *45*(26), 8809-8823.

Ansell, M. P., & Mwaikambo, L. Y. (1999). The effect of chemical treatment on the properties of hemp, sisal, jute and kapok for composite reinforcement. *Angewandte Makromolekulare Chemie*, *272*(1), 108-116.

Anuar, H., & Zuraida, A. (2011). Improvement in mechanical properties of reinforced thermoplastic elastomer composite with kenaf bast fibre. *Composites Part B: Engineering*, *42*(3), 462-465.

Anuar, H., Zuraida, A., Kovacs, J. G., & Tabi, T. (2012). Improvement of mechanical properties of injection-molded polylactic acid–kenaf fiber biocomposite. *Journal of Thermoplastic Composite Materials*, *25*(2), 153-164.

Arbelaiz, A., Fernandez, B., Ramos, J. A., Retegi, A., Llano-Ponte, R., & Mondragon, I. (2005). Mechanical properties of short flax fibre bundle/polypropylene composites: Influence of matrix/fibre modification, fibre content, water uptake and recycling. *Composites Science and Technology*, *65*(10), 1582-1592.

Arrieta, M. P., Fortunati, E., Dominici, F., Rayón, E., López, J., & Kenny, J. M. (2014). Multifunctional PLA–PHB/cellulose nanocrystal films: Processing, structural and thermal properties. *Carbohydrate Polymers*, *107*, 16-24.

Ashori, A. (2006). Nonwood fibers—A potential source of raw material in papermaking. Polymer-Plastics Technology and Engineering, 45(10), 1133-1136.

Ashori, A., Harun, J., Raverty, W. D., & Yusoff, M. N. M. (2006). Chemical and morphological characteristics of Malaysian cultivated kenaf (Hibiscus cannabinus) fiber. *Polymer-Plastics Technology and Engineering*, *45*(1), 131-134.

Avella, M., Buzarovska, A., Errico, M. E., Gentile, G., & Grozdanov, A. (2009). Eco-challenges of bio-based polymer composites. *Materials*, *2*(3), 911-925.

Averous, L., Moro, L., Dole, P., & Fringant, C. (2000). Properties of thermoplastic blends: starch–polycaprolactone. *Polymer*, *41*(11), 4157-4167.

Azwa, Z. N., Yousif, B. F., Manalo, A. C., & Karunasena, W. (2013). A review on the degradability of polymeric composites based on natural fibres. *Materials & Design*, *47*, 424-442.

Bachtiar, D., Sapuan, S. M., & Hamdan, M. M. (2008). The effect of alkaline treatment on tensile properties of sugar palm fibre reinforced epoxy composites. *Materials & Design*, *29*(7), 1285-1290.

Baiardo, M., Frisoni, G., Scandola, M., Rimelen, M., Lips, D., Ruffieux, K., & Wintermantel, E. (2003). Thermal and mechanical properties of plasticized poly (L-lactic acid). *Journal of Applied Polymer Science*, *90*(7), 1731-1738.

Baiardo, M., Zini, E., & Scandola, M. (2004). Flax fibre–polyester composites. *Composites Part A: Applied Science and Manufacturing*, *35*(6), 703-710.

Baillie, C. (Ed.). (2005). *Green Composites: Polymer Composites and the Environment*. CRC Press.

Balakrishnan, H., Hassan, A., & Wahit, M. U. (2010). Mechanical, thermal, and morphological properties of polylactic acid/linear low density polyethylene blends. *Journal of Elastomers & Plastics*, *42*(3), 223-239.

Balakrishnan, H., Hassan, A., Wahit, M. U., Yussuf, A. A., & Razak, S. B. A. (2010). Novel toughened polylactic acid nanocomposite: mechanical, thermal and morphological properties. *Materials & Design*, *31*(7), 3289-3298.

Barison, Y., & Ma, A. N. (2000). Malaysian palm oil industry: moving towards the future. *Palm Oil Development*, *32*, 1-9.

Bax, B., & Müssig, J. (2008). Impact and tensile properties of PLA/Cordenka and PLA/flax composites. *Composites Science and Technology*, *68*(7-8), 1601-1607.

Beckermann, G. W., & Pickering, K. L. (2008). Engineering and evaluation of hemp fibre reinforced polypropylene composites: fibre treatment and matrix modification. *Composites Part A: Applied Science and Manufacturing*, *39*(6), 979-988.

Beg, M. D. H., & Pickering, K. L. (2008). Mechanical performance of Kraft fibre reinforced polypropylene composites: Influence of fibre length, fibre beating and hygrothermal ageing. *Composites Part A: Applied Science and Manufacturing*, *39*(11), 1748-1755.

Bengtsson, M., Le Baillif, M., & Oksman, K. (2007). Extrusion and mechanical properties of highly filled cellulose fibre–polypropylene composites. *Composites Part A: Applied Science and Manufacturing*, *38*(8), 1922-1931.

Bera, M., Alagirusamy, R., & Das, A. (2010). A study on interfacial properties of jute-PP composites. *Journal of Reinforced Plastics and Composites*, *29*(20), 3155-3161.

Bergquist, P., Zhu, Y., Jones, A. A., & Inglefield, P. T. (1999). Plasticization and antiplasticization in polycarbonates: the role of diluent motion. *Macromolecules*, *32*(23), 7925-7931.

Bionas. (2011). BATC Development Company Profile., pp. 1–26, Retrieved from http://bionas-usa.com/file/BATC%20%20Company%20Profile.pdf

Bisanda, E. T. N., & Ansell, M. P. (1991). The effect of silane treatment on the mechanical and physical properties of sisal-epoxy composites. *Composites Science and Technology*, *41*(2), 165-178.

Bisanda, E. T. N. (2000). The effect of alkali treatment on the adhesion characteristics of sisal fibres. *Applied Composite Materials*, *7*(5-6), 331-339.

Bismarck, A., Baltazar-Y-Jimenez, A., & Sarikakis, K. (2006). Green composites as panacea? Socio-economic aspects of green materials. *Environment, Development and Sustainability*, 8(3), 445-463.

Bismarck, S. M., Mishra, S., Lampke, T., Mohanty, A. K., Misra, M., & Drzal, L. T. (2005). Natural fibres. *Biopolymers and Biocomposites*, *37*.

Bismarck, A., Mishra, S. & Lampke, T. (2005). Plant Fibers as Reinforcement for Green Composites. In: Mohanty, A. K., Misra, M. & Drzal, L. T. *Natural Fibers, Biopolymers and Biocomposite*, CRC Taylor and Francis.

Bledzki, A. K., & Gassan, J. (1999). Composites reinforced with cellulose based fibres. *Progress in Polymer Science*, *24*(2), 221-274.

Bledzki, A. K., Mamun, A. A., & Volk, J. (2010). Physical, chemical and surface properties of wheat husk, rye husk and soft wood and their polypropylene composites. *Composites Part A: Applied Science and Manufacturing*, *41*(4), 480-488.

Bledzki, A. K., Jaszkiewicz, A., & Scherzer, D. (2009). Mechanical properties of PLA composites with man-made cellulose and abaca fibres. *Composites Part A: Applied science and manufacturing*, *40*(4), 404-412.

Bledzki, A. K., Zhang, W., & Faruk, O. (2005). Microfoaming of flax and wood fibre reinforced polypropylene composites. *Holz als Roh-und Werkstoff*, *63*(1), 30-37.

Bodmeier, R., & Paeratakul, O. (1997). Plasticizer uptake by aqueous colloidal polymer dispersions used for the coating of solid dosage forms. *International Journal of Pharmaceutics*, *152*(1), 17-26.

Bogoeva-Gaceva, G., Avella, M., Malinconico, M., Buzarovska, A., Grozdanov, A., Gentile, G., & Errico, M. E. (2007). Natural fiber eco-composites. *Polymer Composites*, *28*(1), 98-107.

Boonfaung, P., Wasutchanon, P., & Somwangthanaroj, A. (2011). Development of packaging film from bioplastic polylactic acid (PLA) with plasticizers. In *Pure and Applied Chemistry International Conference* (Vol. 2011, pp. 621-625).

Bouajila, J., Limare, A., Joly, C., & Dole, P. (2005). Lignin plasticization to improve binderless fiberboard mechanical properties. Polymer Engineering & Science, 45(6), 809-816.

Bouchareb, B., & Benaniba, M. T. (2008). Effects of epoxidized sunflower oil on the mechanical and dynamical analysis of the plasticized poly (vinyl chloride). *Journal of Applied Polymer Science*, *107*(6), 3442-3450.

Bourgois, J., Bartholin, M. C., & Guyonnet, R. (1989). Thermal treatment of wood: analysis of the obtained product. *Wood Science and Technology*, *23*(4), 303-310.

Broz, M. E., VanderHart, D. L., & Washburn, N. R. (2003). Structure and mechanical properties of poly (D, L-lactic acid)/poly (ε-caprolactone) blends. *Biomaterials*, *24*(23), 4181-4190.

Burgos, N., Martino, V. P., & Jiménez, A. (2013). Characterization and ageing study of poly (lactic acid) films plasticized with oligomeric lactic acid. *Polymer Degradation and Stability*, *98*(2), 651-658.

Campanella, A., Baltanas, M. A., Capel-Sanchez, M. C., Campos-Martin, J. M., & Fierro, J. L. G. (2004). Soybean oil epoxidation with hydrogen peroxide using an amorphous Ti/SiO 2 catalyst. *Green Chemistry*, *6*(7), 330-334.

Cañigueral, N., Vilaseca, F., Méndez, J. A., López, J. P., Barberà, L., Puig, J., & Mutjé, P. (2009). Behavior of biocomposite materials from flax strands and starch-based biopolymer. *Chemical Engineering Science*, *64*(11), 2651-2658.

Cao, Y., Shibata, S., Fukumoto, 1. (2006). Mechanical Properties of Biodegradable Composites Reinforce with Bagasse Fiber Before and After Alkali Treatments. *Composites Part A*, *37*, 423—9.

Cao, X., Habibi, Y., & Lucia, L. A. (2009). One-pot polymerization, surface grafting, and processing of waterborne polyurethane-cellulose nanocrystal nanocomposites. *Journal of Materials Chemistry*, *19*(38), 7137-7145.

Cao, X., Mohamed, A., Gordon, S. H., Willett, J. L., & Sessa, D. J. (2003). DSC study of biodegradable poly (lactic acid) and poly (hydroxy ester ether) blends. *Thermochimica Acta*, *406*(1-2), 115-127.

Chandrashekar, P., Lokesh, B. R., & Krishna, A. G. (2010). Hypolipidemic effect of blends of coconut oil with soybean oil or sunflower oil in experimental rats. *Food Chemistry*, *123*(3), 728-733.

Chen, C. C., Chueh, J. Y., Tseng, H., Huang, H. M., & Lee, S. Y. (2003). Preparation and characterization of biodegradable PLA polymeric blends. *Biomaterials*, *24*(7), 1167-1173.

Chen, G. X., Kim, H. S., Kim, E. S., & Yoon, J. S. (2005). Compatibilization-like effect of reactive organoclay on the poly (L-lactide)/poly (butylene succinate) blends. *Polymer*, *46*(25), 11829-11836.

Chen, J., Shi, Y. Y., Yang, J. H., Zhang, N., Huang, T., & Wang, Y. (2013). Improving interfacial adhesion between immiscible polymers by carbon nanotubes. *Polymer*, *54*(1), 464-471.

Cheung, H. Y., Lau, K. T., Tao, X. M., & Hui, D. (2008). A potential material for tissue engineering: Silkworm silk/PLA biocomposite. *Composites Part B: Engineering*, *39*(6), 1026-1033.

Chiellini, E., Chiellini, F. and Cinelli, P. (2002). Polymers from renewable resources. In *Degradable Polymers Principles and Applications*, ed. Scott, G, 163-233. Netherlands: Kluwer Academic Publisher.

Chieng, B. W., Ibrahim, N. A., Then, Y. Y., & Loo, Y. Y. (2014). Epoxidized vegetable oils plasticized poly (lactic acid) biocomposites: mechanical, thermal and morphology properties. *Molecules*, *19*(10), 16024-16038.

Chow, C. P. L., Xing, X. S., & Li, R. K. Y. (2007). Moisture absorption studies of sisal fibre reinforced polypropylene composites. *Composites Science and Technology*, *67*(2), 306-313.

Chowdhury, M. F. M., & Lavelli, A. (2013). FBK-irst: A multi-phase kernel based approach for drug-drug interaction detection and classification that exploits linguistic information. In *Second Joint Conference on Lexical and Computational Semantics (* SEM), Volume 2: Proceedings of the Seventh International Workshop on Semantic Evaluation (SemEval 2013)* (Vol. 2, pp. 351-355).

Clark, R. A., & Ansell, M. P. (1986). Jute and glass fibre hybrid laminates. *Journal of Materials Science*, *21*(1), 269-276.

Clayton, A.M. Epoxy Resins: Chemistry and Technology, CRC Press: Boca Raton, FL, 1988, 1–4.

Collard, F. X., & Blin, J. (2014). A review on pyrolysis of biomass constituents: Mechanisms and composition of the products obtained from the conversion of cellulose, hemicelluloses and lignin. *Renewable and Sustainable Energy Reviews*, *38*, 594-608.

Dahlke, B., Larbig, H., Scherzer, H. D., & Poltrock, R. (1998). Natural fiber reinforced foams based on renewable resources for automotive interior applications. *Journal of Cellular Pthenlastics*, *34*(4), 361-379.

Dai, X., Xiong, Z., Na, H., & Zhu, J. (2014). How does epoxidized soybean oil improve the toughness of microcrystalline cellulose filled polylactide acid composites?. *Composites Science and Technology*, *90*, 9-15.

Dehbari, N., Moazeni, N., & Rahman, W. A. (2014). Effects of Kenaf core on properties of poly (lactic acid) bio-composite. *Polymer Composites*, *35*(6), 1220-1227.

Devappa, R. K., Makkar, H. P., & Becker, K. (2010). Jatropha toxicity—a review. *Journal of Toxicology and Environmental Health, Part B*, *13*(6), 476-507.

Dhakal, H. N., Zhang, Z. Y., & Richardson, M. O. W. (2007). Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites. *Composites Science and Technology*, *67*(7-8), 1674-1683.

Dinda, S., Patwardhan, A. V., Goud, V. V., & Pradhan, N. C. (2008). Epoxidation of cottonseed oil by aqueous hydrogen peroxide catalysed by liquid inorganic acids. *Bioresource Technology*, *99*(9), 3737-3744.

Dittenber, D. B., & GangaRao, H. V. (2012). Critical review of recent pubLications on use of natural composites in infrastructure. *Composites Part A: Applied Science and Manufacturing*, *43*(8), 1419-1429.

Dobreva, T., Pereña, J. M., Pérez, E., Benavente, R., & García, M. (2010). Crystallization behavior of poly (L-lactic acid)-based ecocomposites prepared with kenaf fiber and rice straw. *Polymer Composites*, *31*(6), 974-984.

Drzal, L. T., Mohanty, A. K., Tummala, P., & Misra, M. (2002). Environmentally friendly bio-composites from soy-based bio-plastic and natural fiber. *Polymeric Materials Science and Engineering(USA)*, *87*, 117-118.

Dufresne, A. (2008). Polysaccharide nano crystal reinforced nanocomposites. *Canadian Journal of Chemistry*, *86*(6), 484-494.

Dweib, M. A., Hu, B., Shenton, H. W., Wool, R. P. (2006). Bio-based composite roof structure: manufacturing and processing issues. *Compos. Struct.*, 74(4), 379.

Edeerozey, A. M., Akil, H. M., Azhar, A. B., & Ariffin, M. Z. (2007). Chemical modification of kenaf fibers. *Materials Letters*, *61*(10), 2023-2025.

El-Shekeil, Y. A., Sapuan, S. M., Abdan, K., & Zainudin, E. S. (2012). Influence of fiber content on the mechanical and thermal properties of Kenaf fiber reinforced thermoplastic polyurethane composites. *Materials & Design*, *40*, 299-303.

El-Shekeil, Y. A., Sapuan, S. M., Khalina, A., Zainudin, E. S., & Al-Shuja'a, O. M. (2012). Influence of chemical treatment on the tensile properties of kenaf fiber reinforced thermoplastic polyurethane composite. *Express Polymer Letters*, *6*(12).

El-Shekeil, Y. A., Sapuan, S. M., Khalina, A., Zainudin, E. S., & Al-Shuja'a, O. M. (2012). Effect of alkali treatment on mechanical and thermal properties of Kenaf fiber-reinforced thermoplastic polyurethane composite. *Journal of Thermal Analysis and Calorimetry*, *109*(3), 1435-1443.

Facaa, A. G., Korschort, M., & Yan, N. (2006). Predicting the Elastic Modulus of Natural Fibers Reinforced Thermoplastic," Composite: Part A: Applied Science and Manufacturing, Vol. 13, 278-292.

Faruk, O., Bledzki, A. K., Fink, H. P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. *Progress in Polymer Science*, *37*(11), 1552-1596.

Felby, C., Thygesen, L. G., Sanadi, A., & Barsberg, S. (2004). Native lignin for bonding of fiber boards—evaluation of bonding mechanisms in boards made from laccase-treated fibers of beech (Fagus sylvatica). Industrial Crops and Products, 20(2), 181-189.

Fenollar, O., García, D., Sánchez, L., López, J., & Balart, R. (2009). Optimization of the curing conditions of PVC plastisols based on the use of an epoxidized fatty acid ester plasticizer. *European Polymer Journal*, *45*(9), 2674-2684.

Ferreira, R. B., & Rieger, J. A. (2004). *U.S. Patent No. 6,762,138*. Washington, DC: U.S. Patent and Trademark Office.

Ferri, J. M., Garcia-Garcia, D., Montanes, N., Fenollar, O., & Balart, R. (2017). The effect of maleinized linseed oil as biobased plasticizer in poly (lactic acid)-based formulations. *Polymer International*, *66*(6), 882-891.

Finkenstadt, V. L., Liu, C. K., Evangelista, R., Liu, L., Cermak, S. C., Hojilla-Evangelista, M., & Willett, J. L. (2007). Poly (lactic acid) green composites using oilseed coproducts as fillers. Industrial Crops and Products, 26(1), 36-43.

Fischer, E. W., Sterzel, H. J., & Wegner, G. K. Z. Z. (1973). Investigation of the structure of solution grown crystals of lactide copolymers by means of chemical reactions. *Kolloid-Zeitschrift und Zeitschrift für Polymere*, *251*(11), 980-990.

Frigione, M., & Lettieri, M. (2008). Procedures conditioning the absorption/desorption behavior of cold-cured epoxy resins. *Journal of Polymer Science Part B: Polymer Physics*, *46*(13), 1320-1336.

Fu, S. Y., Feng, X. Q., Lauke, B., & Mai, Y. W. (2008). Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. *Composites Part B: Engineering*, *39*(6), 933-961.

Gamage, P. K., O'Brien, M., & Karunanayake, L. (2009). Epoxidation of some vegetable oils and their hydrolysed products with peroxyformic acid-optimised to industrial scale. *Journal of the National Science Foundation of Sri Lanka*, *37*(4).

Gao, S. L., & Mäder, E. (2006). Jute/polypropylene composites I. Effect of matrix modification. *Composites Science and Technology*, *66*(7-8), 952-963.

Garcia, M. A., Martino, M. N., & Zaritzky, N. E. (2000). Microstructural Characterization of Plasticized Starch-Based Films. *Starch‐Stärke*, *52*(4), 118-124.

Garlotta, D. (2002) A literature review of poly (lactic acid). *Journal of Polymers and the Environment*, *9*, 63 – 84.

Garlotta, D., Doane, W., Shogren, R., Lawton, J., & Willett, J. L. (2003). Mechanical and thermal properties of starch-filled poly (D, L-lactic acid)/poly (hydroxy ester ether) biodegradable blends. *Journal of Applied Polymer Science*, *88*(7), 1775-1786.

George, J., Sreekala, M. S., & Thomas, S. (2001). A review on interface modification and characterization of natural fiber reinforced plastic composites. *Polymer Engineering & Science*, *41*(9), 1471-1485.

Gerbase, A. E., Gregório, J. R., Martinelli, M., Brasil, M. C., & Mendes, A. N. (2002). Epoxidation of soybean oil by the methyltrioxorhenium-CH 2 Cl 2/H 2 O 2 catalytic biphasic system. *Journal of the American Oil Chemists' Society*, *79*(2), 179-181.

Gerbase, A. E., Petzhold, C. L., & Costa, A. P. O. (2002). Dynamic mechanical and thermal behavior of epoxy resins based on soybean oil. *Journal of the American Oil Chemists' Society*, *79*(8), 797-802.

Glasser, W. G., Taib, R., Jain, R. K., & Kander, R. (1999). Fiber-reinforced cellulosic thermoplastic composites. *Journal of Applied Polymer Science*, *73*(7), 1329-1340.

Goda, K., Sreekala, M. S., Gomes, A., Kaji, T., & Ohgi, J. (2006). Improvement of plant based natural fibers for toughening green composites—Effect of load application during mercerization of ramie fibers. *Composites Part A: Applied Science and Manufacturing*, *37*(12), 2213-2220.

Godavarti, S. (2005). Thermoplastic wood fiber composites. *Natural Fibers, Biopolymers, and Biocomposites*, 347-389.

Gomes, A., Matsuo, T., Goda, K., & Ohgi, J. (2007). Development and effect of alkali treatment on tensile properties of curaua fiber green composites. *Composites Part A: Applied Science and Manufacturing*, *38*(8), 1811-1820.

Goud, V. V., Patwardhan, A. V., & Pradhan, N. C. (2006). Studies on the epoxidation of mahua oil (Madhumica indica) by hydrogen peroxide. *Bioresource Technology*, *97*(12), 1365-1371.

Goud, V. V., Patwardhan, A. V., Dinda, S., & Pradhan, N. C. (2007). Kinetics of epoxidation of jatropha oil with peroxyacetic and peroxyformic acid catalysed by acidic ion exchange resin. *Chemical Engineering Science*, *62*(15), 4065-4076.

Gubeladze, K. M. (1987). The effect of plasticisers on the structure of crosslinked high-elastic materials. *Kauch. i Rezina*, *2*, 29.

Gübitz, G. M., Mittelbach, M., & Trabi, M. (1999). Exploitation of the tropical oil seed plant Jatropha curcas L. *Bioresource Technology*, *67*(1), 73-82.

Güner, F. S., Yağcı, Y., & Erciyes, A. T. (2006). Polymers from triglyceride oils. *Progress in Polymer Science*, *31*(7), 633-670.

Gupta, A. P. & Kumar, V. (2007) New emerging trends in synthetic biodegradable polymers – Polylactide: a critique. *European Polymer Journal*, *43*, 4053 – 4074.

Habibi, Y., El-Zawawy, W. K., Ibrahim, M. M., & Dufresne, A. (2008). Processing and characterization of reinforced polyethylene composites made with lignocellulosic fibers from Egyptian agro-industrial residues. *Composites Science and Technology*, *68*(7-8), 1877-1885.

Han, S. O., Karevan, M., Sim, I. N., Bhuiyan, M. A., Jang, Y. H., Ghaffar, J., & Kalaitzidou, K. (2012). Understanding the reinforcing mechanisms in kenaf fiber/PLA and kenaf fiber/PP composites: a comparative study. *International Journal of Polymer Science*, *2012*.

Hashim, M. Y., Roslan, M. N., Amin, A. M., Zaidi, A. M. A., & Ariffin, S. (2012). Mercerization treatment parameter effect on natural fiber reinforced polymer matrix composite: A brief review. *World Academy of Science, Engineering and Technology*, *68*, 1638-1644.

Hashim, M. Y., Roslan, M. N., Mahzan, S., Zin, M., & Ariffin, S. (2013). Determination of Alkali Treatment Conditions Effects Which Influence the Variability of Kenaf Fiber Mean Cross Sectional Area. *International Journal of Mechanical, Aerospace, Industrial and Mechatronic Engineering*, *7*(10).

Hassan, A., Salema, A. A., Ani, F. N. and Abu Bakar, A. (2010). A review on oil palm empty fruit bunch fiber-reinforced polymer composite materials. *Polymer Composites*, 31(12): 2079-2101.

Hazmi, A. S. A., Aung, M. M., Abdullah, L. C., Salleh, M. Z., & Mahmood, M. H. (2013). Producing Jatropha oil-based polyol via epoxidation and ring opening. *Industrial Crops and Products*, *50*, 563-567.

Henton, D. E., Gruber, P., Lunt, J., & Randall, J. (2005). Polylactic acid technology. *Natural Fibers, Biopolymers, and Biocomposites*, *16*, 527-577.

Hill, C. A. S., & Abdul Khalil, H. P. S. (2000). Effect of fiber treatments on mechanical properties of coir or oil palm fiber reinforced polyester composites. *Journal of Applied Polymer Science*, *78*(9), 1685-1697.

Hu, R., & Lim, J. K. (2007). Fabrication and mechanical properties of completely biodegradable hemp fiber reinforced polylactic acid composites. *Journal of Composite Materials*, *41*(13), 1655-1669.

Huda, M. S., Drzal, L. T., Misra, M., & Mohanty, A. K. (2006). Wood-fiber-reinforced poly (lactic acid) composites: evaluation of the physicomechanical and morphological properties. *Journal of Applied Polymer Science*, *102*(5), 4856-4869.

Huda, M. S., Drzal, L. T., Misra, M., Mohanty, A. K., Williams, K., & Mielewski, D. F. (2005). A study on biocomposites from recycled newspaper fiber and poly (lactic acid). *Industrial & Engineering Chemistry Research*, *44*(15), 5593-5601.

Huda, M. S., Drzal, L. T., Mohanty, A. K., & Misra, M. (2006). Chopped glass and recycled newspaper as reinforcement fibers in injection molded poly (lactic acid) (PLA) composites: a comparative study. *Composites Science and Technology*, *66*(11-12), 1813-1824.

Huda, M. S., Drzal, L. T., Mohanty, A. K., & Misra, M. (2008). Effect of fiber surface-treatments on the properties of laminated biocomposites from poly (lactic acid) (PLA) and kenaf fibers. *Composites Science and Technology*, *68*(2), 424-432.

Iannace, S., Nocilla, G., & Nicolais, L. (1999). Biocomposites based on sea algae fibers and biodegradable thermoplastic matrices. *Journal of Applied Polymer Science*, *73*(4), 583-592.

Ibrahim, M. M., Agblevor, F. A., & El-Zawawy, W. K. (2010). Isolation and characterization of cellulose and lignin from steam-exploded lignocellulosic biomass. *BioResources*, *5*(1), 397-418.

Ibrahim, N. A., Hadithon, K. A., & Abdan, K. (2010). Effect of fiber treatment on mechanical properties of kenaf fiber-ecoflex composites. *Journal of Reinforced Plastics and Composites*, *29*(14), 2192-2198.

Ibrahim, N. A., Yunus, W. M. Z. W., Othman, M., & Abdan, K. (2011). Effect of chemical surface treatment on the mechanical properties of reinforced plasticized poly (lactic acid) biodegradable composites. *Journal of Reinforced Plastics and Composites*, *30*(5), 381-388.

Ibrahim, N. A., Yunus, W. M. Z. W., Othman, M., Abdan, K., & Hadithon, K. A. (2010). Poly (lactic acid) (PLA)-reinforced kenaf bast fiber composites: The effect of triacetin. *Journal of Reinforced Plastics and Composites*, *29*(7), 1099-1111.

Ishak, M. R., Sapuan, S. M., Leman, Z., Rahman, M. Z. A., Anwar, U. M. K., & Siregar, J. P. (2013). Sugar palm (Arenga pinnata): Its fibres, polymers and composites. *Carbohydrate Polymers*, *91*(2), 699-710.

Islam, M. S., Pickering, K. L., & Foreman, N. J. (2010). Influence of alkali treatment on the interfacial and physico-mechanical properties of industrial hemp fibre reinforced polylactic acid composites. *Composites Part A: Applied Science and Manufacturing*, *41*(5), 596-603.

Islam, M. S., Pickering, K. L., & Foreman, N. J. (2011). Influence of alkali fiber treatment and fiber processing on the mechanical properties of hemp/epoxy composites. *Journal of Applied Polymer Science*, *119*(6), 3696-3707.

Ismail, H., & Leong, H. C. (2001). Curing characteristics and mechanical properties of natural rubber/chloroprene rubber and epoxidized natural rubber/chloroprene rubber blends. *Polymer Testing*, *20*(5), 509-516.

Ismail, H., Norjulia, A. M., & Ahmad, Z. (2010). The effects of untreated and treated kenaf loading on the properties of kenaf fibre-filled natural rubber compounds. *Polymer-Plastics Technology and Engineering*, *49*(5), 519-524.

Ismail, H., Shaari, S. M., & Othman, N. (2011). The effect of chitosan loading on the curing characteristics, mechanical and morphological properties of chitosan-filled natural rubber (NR), epoxidised natural rubber (ENR) and styrene-butadiene rubber (SBR) compounds. *Polymer Testing*, *30*(7), 784-790.

Janu, C., Kumar, D. R., Reshma, M. V., Jayamurthy, P., Sundaresan, A., & Nisha, P. (2014). Comparative study on the total phenolic content and radical scavenging activity of common edible vegetable oils. *Journal of Food Biochemistry*, *38*(1), 38-49.

Jayaraman, K. (2003). Manufacturing sisal–polypropylene composites with minimum fibre degradation. *Composites Science and Technology*, *63*(3-4), 367-374.

Jia, Z., Tan, J., Han, C., Yang, Y., & Dong, L. (2009). Poly (ethylene glycol-co-propylene glycol) as a macromolecular plasticizing agent for polylactide: Thermomechanical properties and aging. *Journal of Applied Polymer Science*, *114*(2), 1105-1117.

Jiang, L., Wolcott, M. P. & Zhang, J. (2006) Study of biodegradable polylactide/poly (butylene adipate-co-terephthalate) blends. *Biomacromolecules*, *7*, 199 – 207.

Jimenez, G., Ogata, N., Kawai, H., & Ogihara, T. (1997). Structure and thermal/mechanical properties of poly (ϵ-caprolactone)-clay blend. *Journal of Applied Polymer Science*, *64*(11), 2211-2220.

Jin, F. L., & Park, S. J. (2008). Impact-strength improvement of epoxy resins reinforced with a biodegradable polymer. *Materials Science and Engineering: A*, *478*(1-2), 402-405.

Jin, F. L., & Park, S. J. (2008). Thermomechanical behavior of epoxy resins modified with epoxidized vegetable oils. *Polymer International*, *57*(4), 577-583.

Johansson, C., Bras, J., Mondragon, I., Nechita, P., Plackett, D., Simon, P., & Aucejo, S. (2012). Renewable fibers and bio-based materials for packaging applications–a review of recent developments. *BioResources*, *7*(2), 2506-2552.

John, M. J., & Anandjiwala, R. D. (2008). Recent developments in chemical modification and characterization of natural fiber-reinforced composites. *Polymer Composites*, *29*(2), 187-207.

John, M. J., & Thomas, S. (2008). Biofibres and biocomposites. *Carbohydrate Polymers*, *71*(3), 343-364.

John, M. J., Francis, B., Varughese, K. T., & Thomas, S. (2008). Effect of chemical modification on properties of hybrid fiber biocomposites. *Composites Part A: Applied Science and Manufacturing*, *39*(2), 352-363.

Johnson, K., Hathaway, R., Leung, P., & Franz, R. (1991). Effect of triacetin and polyethylene glycol 400 on some physical properties of hydroxypropyl methylcellulose free films. *International Journal of Pharmaceutics*, *73*(3), 197-208.

Jonoobi, M., Harun, J., Mishra, M., & Oksman, K. (2009). Chemical composition, crystallinity and thermal degradation of bleached and unbleached kenaf bast (Hibiscus cannabinus) pulp and nanofiber. *BioResources*, *4*(2), 626-639.

Joshi, S. V., Drzal, L. T., Mohanty, A. K., & Arora, S. (2004). Are natural fiber composites environmentally superior to glass fiber reinforced composites? *Composites Part A: Applied Science and Manufacturing*, *35*(3), 371-376.

Kabir, M. M., Wang, H., Aravinthan, T., Cardona, F., & Lau, K. T. (2011, April). Effects of natural fibre surface on composite properties: A review. In *Proceedings of the 1st international postgraduate conference on engineering, designing and developing the built environment for sustainable wellbeing (eddBE2011)* (pp. 94-99). Queensland University of Technology.

Kalam, A., Berhan, M. N., & Ismail, H. (2010). Physical and mechanical characterizations of oil palm fruit bunch fiber filled polypropylene composites. *Journal of Reinforced Plastics and Composites*, *29*(21), 3173-3184.

Karmarkar, A., Chauhan, S. S., Modak, J. M., & Chanda, M. (2007). Mechanical properties of wood–fiber reinforced polypropylene composites: Effect of a novel compatibilizer with isocyanate functional group. *Composites Part A: Applied Science and Manufacturing*, *38*(2), 227-233.

Khalil, H. A., Aprilia, N. S., Bhat, A. H., Jawaid, M., Paridah, M. T., & Rudi, D. (2013). A Jatropha biomass as renewable materials for biocomposites and its applications. *Renewable and Sustainable Energy Reviews*, *22*, 667-685.

Khot, S. N., Lascala, J. J., Can, E., Morye, S. S., Williams, G. I., Palmese, G. R., Kusefoglu, S. H., & Wool, R. P. (2001). Development and application of triglyceridebased polymers and composites. *Journal of Applied Polymer Science*, 82(3), 703–723.

Kibazohi, O., & Sangwan, R. S. (2011). Vegetable oil production potential from Jatropha curcas, Croton megalocarpus, Aleurites moluccana, Moringa oleifera and Pachira glabra: assessment of renewable energy resources for bio-energy production in Africa. *Biomass and Bioenergy*, *35*(3), 1352-1356.

Kim, S., Kim, J., Lim, S. H., Jo, W. H., & Choe, C. R. (1999). Effects of mixing temperatures on the morphology and toughness of epoxy/polyamide blends. *Journal of Applied Polymer Science*, *72*(8), 1055-1063.

Kim, H. S., Lee, B. H., Lee, S., Kim, H. J. and Dorgan, J. R. (2011). Enhanced interfacial adhesion, mechanical, and thermal properties of natural flour-filled biodegradable polymer bio-composites. *J Therm Anal Calorim*, 104: 331–338.

Knothe, G., & Derksen, J. T. (Eds.). (1999). *Recent developments in the synthesis of fatty acid derivatives*. The American Oil Chemists Society.

Kolybaba, M., Tabil, L. G., Panighari, S., Crerar, W.J., Powell,T. and Wang, B. *Biodegradable polymers: Past, Present and Future*. Paper presented at the 2003 CSAE/ASAE Annual Intersectional Meeting, Fargo. October 2003.

Kricheldorf, H. R. (2001). Syntheses and application of polylactides. *Chemosphere*, *43*(1), 49-54.

Kulinski, Z., & Piorkowska, E. (2005). Crystallization, structure and properties of plasticized poly (L-lactide). *Polymer*, *46*(23), 10290-10300.

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

Lai, C. Y., Sapuan, S. M., Ahmad, M., Yahya, N., & Dahlan, K. Z. H. M. (2005). Mechanical and electrical properties of coconut coir fiber-reinforced polypropylene composites. *Polymer-Plastic Technology and Engineering*, *44*(4), 619-632.

Lathi, P. S., & Mattiasson, B. (2007). Green approach for the preparation of biodegradable lubricant base stock from epoxidized vegetable oil. *Applied Catalysis B: Environmental*, *69*(3-4), 207-212.

Le Digabel, F., & Avérous, L. (2006). Effects of lignin content on the properties of lignocellulose-based biocomposites. *Carbohydrate Polymers*, *66*(4), 537-545.

Le Troedec, M., Sedan, D., Peyratout, C., Bonnet, J. P., Smith, A., Guinebretiere, R., ... & Krausz, P. (2008). Influence of various chemical treatments on the composition and structure of hemp fibres. *Composites Part A: Applied Science and Manufacturing*, *39*(3), 514-522.

Lee, B. H., Kim, H. S., Lee, S., Kim, H. J., & Dorgan, J. R. (2009). Bio-composites of kenaf fibers in polylactide: Role of improved interfacial adhesion in the carding process. *Composites Science and Technology*, *69*(15-16), 2573-2579.

Lee, D. S., Noh, B. S., Bae, S. Y., & Kim, K. (1998). Characterization of fatty acids composition in vegetable oils by gas chromatography and chemometrics. *Analytica Chimica Acta*, *358*(2), 163-175.

Lee, K. Y., Delille, A., & Bismarck, A. (2011). Greener surface treatments of natural fibres for the production of renewable composite materials. *Cellulose Fibers: Bio-and Nano-polymer Composites*, 155-178).

Lee, S. M., Cho, D., Park, W. H., Lee, S. G., Han, S. O., & Drzal, L. T. (2005). Novel silk/poly (butylene succinate) biocomposites: the effect of short fibre content on their mechanical and thermal properties. *Composites Science and Technology*, *65*(3-4), 647-657.

Lee, S. R., Park, H. M., Lim, H., Kang, T., Li, X., Cho, W. J., & Ha, C. S. (2002). Microstructure, tensile properties, and biodegradability of aliphatic polyester/clay nanocomposites. *Polymer*, *43*(8), 2495-2500.

Lee, S., Lee, Y., & Lee, J. W. (2007). Effect of ultrasound on the properties of biodegradable polymer blends of poly (lactic acid) with poly (butylene adipate-co-terephthalate). *Macromolecular Research*, *15*(1), 44-50.

Lee, Y. H., Wang, K. H., Park, C. B., & Sain, M. (2007). Effects of clay dispersion on the foam morphology of LDPE/clay nanocomposites. *Journal of Applied Polymer Science*, *103*(4), 2129-2134.

Li, S. M., Jia, N., Ma, M. G., Zhang, Z., Liu, Q. H., & Sun, R. C. (2011). Cellulose–silver nanocomposites: Microwave-assisted synthesis, characterization, their thermal stability, and antimicrobial property. *Carbohydrate Polymers*, *86*(2), 441-447.

Li, Y., Mai, Y. W., & Ye, L. (2000). Sisal fibre and its composites: a review of recent developments. *Composites Science and Technology*, *60*(11), 2037-2055.

Li, X., Tabil, L. G., & Panigrahi, S. (2007). Chemical treatments of natural fiber for use in natural fiber-reinforced composites: a review. *Journal of Polymers and the Environment*, *15*(1), 25-33.

Li, X., Tabil, L. G., Panigrahi, S., & Crerar, W. J. (2006). The influence of fiber content on properties of injection molded flax fiber-HDPE biocomposites. In *2006 ASAE Annual Meeting* (p. 1). American Society of Agricultural and Biological Engineers.

Li, H., Wang, L., Jacob, K., & Wong, C. P. (2002). Syntheses and characterizations of thermally degradable epoxy resins. III. *Journal of Polymer Science Part A: Polymer Chemistry*, *40*(11), 1796-1807.

Lin, B., Yang, L., Dai, H., & Yi, A. (2008). Kinetic studies on oxirane cleavage of epoxidized soybean oil by methanol and characterization of polyols. *Journal of the American Oil Chemists' Society*, *85*(2), 113-117.

Ling, P. A., & Ismail, H. (2012). Tensile properties, water uptake, and thermal properties of polypropylene/waste pulverized tire/kenaf (PP/WPT/KNF) composites. *BioResources*, *8*(1), 806-817.

Liu, L., Cheng, L., Huang, L., & Yu, J. (2012). Enzymatic treatment of mechanochemical modified natural bamboo fibers. *Fibers and Polymers*, *13*(5), 600-605.

Liu, W., Drzal, L. T., Mohanty, A. K., & Misra, M. (2007). Influence of processing methods and fiber length on physical properties of kenaf fiber reinforced soy based biocomposites. *Composites Part B: Engineering*, *38*(3), 352-359.

Liu, W., Misra, M., Askeland, P., Drzal, L. T., & Mohanty, A. K. (2005). ‘Green’composites from soy based plastic and pineapple leaf fiber: fabrication and properties evaluation. *Polymer*, *46*(8), 2710-2721.

Liu, W., Mohanty, A. K., Askeland, P., Drzal, L. T., & Misra, M. (2004). Influence of fiber surface treatment on properties of Indian grass fiber reinforced soy protein based biocomposites. *Polymer*, *45*(22), 7589-7596.

Liu, X. Y., & Dai, G. C. (2007). Surface modification and micromechanical properties of jute fiber mat reinforced polypropylene composites. *Express Polymer Letters*, *1*(5), 299-307.

Ljungberg, N., & Wesslen, B. (2005). Preparation and Properties of Plasticized Poly (lactic) Films. *Biomacromolecules*, *6*, 1789-1796.

Ljungberg, N., Andersson, T., & Wesslén, B. (2003). Film extrusion and film weldability of poly (lactic acid) plasticized with triacetine and tributyl citrate. *Journal of Applied Polymer Science*, *88*(14), 3239-3247.

Lunt, J. (1998). Large-scale production, properties and commercial applications of polylactic acid polymers. *Polymer Degradation and Stability*, *59*(1-3), 145-152.

Maglio, G., Malinconico, M., Migliozzi, A., & Groeninckx, G. (2004). Immiscible Poly (L-lactide)/Poly (ε-caprolactone) Blends: Influence of the Addition of a Poly (L-lactide)-Poly (oxyethylene) Block Copolymer on Thermal Behavior and Morphology. *Macromolecular chemistry and physics*, *205*(7), 946-950.

Mandana, F. 2012. A Study of Fibre-Matrix Interactions in Biodegradable Kraft Pulp Fibre-Reinforced Polylactic Acid Composites, University of Toronto, Canada.

Mariatti, M., Jannah, M., Abu Bakar, A., & Khalil, H. A. (2008). Properties of banana and pandanus woven fabric reinforced unsaturated polyester composites. *Journal of Composite Materials*, *42*(9), 931-941.

Markarian, J. (2008). Biopolymers present new market opportunities for additives in packaging. *Plastics, Additives and Compounding*, *10*(3), 22-25.

Martin, O., & Averous, L. (2001). Poly (lactic acid): plasticization and properties of biodegradable multiphase systems. *Polymer*, *42*(14), 6209-6219.

Masirek, R., Kulinski, Z., Chionna, D., Piorkowska, E., & Pracella, M. (2007). Composites of poly (L-lactide) with hemp fibers: Morphology and thermal and mechanical properties. *Journal of Applied Polymer Science*, *105*(1), 255-268.

Matheson, G. L., & Maass, O. (1929). The properties of pure hydrogen peroxide. VI. *Journal of the American Chemical Society*, *51*(3), 674-687.

Mathew, A. P., Oksman, K., & Sain, M. (2005). Mechanical properties of biodegradable composites from poly lactic acid (PLA) and microcrystalline cellulose (MCC). *Journal of Applied Polymer Science*, *97*(5), 2014-2025.

Mauck, S. C., Wang, S., Ding, W., Rohde, B. J., Fortune, C. K., Yang, G., & Robertson, M. L. (2016). Biorenewable tough blends of polylactide and acrylated epoxidized soybean oil compatibilized by a polylactide star polymer. *Macromolecules*, *49*(5), 1605-1615.

Mbada, N. I., Aponbiede, O., Ause, T., & Alabi, A. (2016). Effects of Mercerization Treatment on Kenaf Fibre (Hibiscus cannabinus L.). *International Journal of Materials Engineering*, *6*(1), 8-14.

Mehta, G., Mohanty, A. K., Misra, M., & Drzal, L. T. (2004). Effect of novel sizing on the mechanical and morphological characteristics of natural fiber reinforced unsaturated polyester resin based bio-composites. *Journal of Materials Science*, *39*(8), 2961-2964.

Meshram, P. D., Puri, R. G., & Patil, H. V. (2011). Epoxidation of wild safflower (Carthamus oxyacantha) Oil with peroxy acid in presence of strongly acidic cation exchange resin IR-122 asCatalyst". *Int J Chem Tech Res*, *3*(3), 1152-1163.

Meier, M. A., Metzger, J. O., & Schubert, U. S. (2007). Plant oil renewable resources as green alternatives in polymer science. *Chemical Society Reviews*, *36*(11), 1788-1802.

Meyer, P. P., Techaphattana, N., Manundawee, S., Sangkeaw, S., Junlakan, W., & Tongurai, C. (2008). Epoxidation of soybean oil and jatropha oil. *Thammasat Int J Sci Technol*, *13*, 1-5.

Mielke, T. (2014). Global supply, demand and prices outlook of oil and fats, impacts on palm oil. *Malaysian Oil and Science Technology*, *23*(1), 13–27.

Mielke, T. (2018). World Markets for Vegetable Oils and Animal Fats. *Biokerosene*, 147-188. Springer, Berlin, Heidelberg.

Miracle, D. B. and Donaldson, S. L. (2001). *Introduction to composites.* United States: ASM International.

Mishra, S., Mohanty, A. K., Drzal, L. T., Misra, M., Parija, S., Nayak, S. K., & Tripathy, S. S. (2003). Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites. *Composites Science and Technology*, *63*(10), 1377-1385.

Mofijur, M., Masjuki, H. H., Kalam, M. a., Hazrat, M. a., Liaquat, a. M., Shahabuddin, M., & Varman, M. (2012). Prospects of biodiesel from Jatropha in Malaysia. *Renewable and Sustainable Energy Reviews*, *16*(7), 5007–5020.

Mohamad, M. (2010). Natural fibres for the 3rd millennium. *JEC Composites Magazine*, 24-28.

Mohan, R., Subha, J., Alam, J., & Ali, F. B. (2016). Influence of Multiwalled Carbon Nanotubes on Biodegradable Poly (lactic acid) Nanocomposites for Electroactive Shape Memory Actuator. *Advances in Polymer Technology*.

Mohanty, A. K., Khan, M. A., & Hinrichsen, G. (2000). Surface modification of jute and its influence on performance of biodegradable jute-fabric/Biopol composites. *Composites Science and Technology*, *60*(7), 1115-1124.

Mohanty, A. K., Misra, M., & Drzal, L. T. (2001). Surface modifications of natural fibers and performance of the resulting biocomposites: an overview. *Composite Interfaces*, *8*(5), 313-343.

Mohanty, A. K., Misra, M., & Drzal, L. T. (2002). Sustainable bio-composites from renewable resources: opportunities and challenges in the green materials world. *Journal of Polymers and the Environment*, *10*(1-2), 19-26.

Mohanty, A. K., Misra, M., & Drzal, L. T. (Eds.). (2005). *Natural Fibers, Biopolymers, and Biocomposites*. CRC press.

Moore, G. R. P., Martelli, S. M., Gandolfo, C., do Amaral Sobral, P. J., & Laurindo, J. B. (2006). Influence of the glycerol concentration on some physical properties of feather keratin films. *Food Hydrocolloids*, *20*(7), 975-982.

Morita, M., Higuchi, M., & Sakata, I. (1987). Binding of heavy metal ions by chemically modified woods. Journal of applied polymer science, 34(3), 1013-1023.

Mutasher, S. A., Poh, A., Than, A. M., & Law, J. (2011). The effect of alkali treatment mechanical properties of kenaf fiber epoxy composite. *Key Engineering Materials*, *471*, 191-196. Trans Tech Publications.

Mwaikambo, L. Y. (2009). Tensile properties of alkalised jute fibres.

Mwaikambo, L. Y., & Ansell, M. P. (2002). Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization. *Journal of Applied Polymer Science*, *84*(12), 2222-2234.

Nacos, M. K., Katapodis, P., Pappas, C., Daferera, D., Tarantilis, P. A., Christakopoulos, P., & Polissiou, M. (2006). Kenaf xylan–a source of biologically active acidic oligosaccharides. *Carbohydrate Polymers*, *66*(1), 126-134.

Nagarajan, V., Mohanty, A. K., & Misra, M. (2016). Perspective on polylactic acid (PLA) based sustainable materials for durable applications: Focus on toughness and heat resistance. *ACS Sustainable Chemistry & Engineering*, *4*(6), 2899-2916.

Naguib, H. F., Aziz, M. S. A., Sherif, S. M., & Saad, G. R. (2011). Synthesis and thermal characterization of poly (ester-ether urethane) s based on PHB and PCL-PEG-PCL blocks. *Journal of Polymer Research*, *18*(5), 1217-1227.

Nevell, T. P., & Zeronian, S. H. (1985). Cellulose chemistry and its applications. *Ellis Horwood, New York*, 30-83.

Nielsen, N. P. K., Nørgaard, L., Strobel, B. W., & Felby, C. (2009). Effect of storage on extractives from particle surfaces of softwood and hardwood raw materials for wood pellets. European Journal of Wood and Wood Products, 67(1), 19.

Nielsen, F., Erik Schurmann, A. D. P. P., Dajolka, N. A., GAIA, C. F., & Movement, K. R. A. (2011). End report FACT pilot project "Jatropha oil for local development in Mozambique". *Wageningen: FACT Foundation*.

Nijenhuis, A. J., E. Colstee, D. W. Grijpma and A. J. Pennings, 1996, High molecular weight poly(L-lactide) and poly(ethylene oxide) blends: thermal characterization and physical properties, *Polymer*, 37, 5849-5857.

Nishino, T., Hirao, K., Kotera, M., Nakamae, K., & Inagaki, H. (2003). Kenaf reinforced biodegradable composite. *Composites Science and Technology*, *63*(9), 1281-1286.

Nishino, T., Matsuda, I., & Hirao, K. (2004). All-cellulose composite. *Macromolecules*, *37*(20), 7683-7687.

Nordin, N. I. A. A., Ariffin, H., Andou, Y., Hassan, M. A., Shirai, Y., Nishida, H., & Ibrahim, N. A. (2013). Modification of oil palm mesocarp fiber characteristics using superheated steam treatment. *Molecules*, *18*(8), 9132-9146.

Nosbi, N., Akil, H. M., Ishak, Z. A. M., & Bakar, A. A. (2011). Behavior of kenaf fibers after immersion in several water conditions. *BioResources*, *6*(2), 950-960.

O'Donnel, S. M., Sidebottom, H. W., Wenger, J. C., Mellouki, A., & Le Bras, G. (2004). Kinetic studies on the reactions of hydroxyl radicals with a series of alkoxy esters. *The Journal of Physical Chemistry A, 108*(36), 7386-7392.

Oksman, K., Mathew, A. P., Jonoobi, M., Hietala, M., & Vargas, N. H. (2013). Cellulose nanocomposites processing using extrusion. Production and Applications of Cellulose Nanomaterials, TAPPI Press, 99-102.

Oksman, K., Skrifvars, M., & Selin, J. F. (2003). Natural fibres as reinforcement in polylactic acid (PLA) composites. *Composites Science and Technology*, *63*(9), 1317-1324.

Ovitt, T. M., & Coates, G. W. (1999). Stereoselective ring-opening polymerization of meso-lactide: synthesis of syndiotactic poly (lactic acid). *Journal of the American Chemical Society*, *121*(16), 4072-4073.

Özturk, S. (2010). Effect of fiber loading on the mechanical properties of kenaf and fiberfrax fiber-reinforced phenol-formaldehyde composites. *Journal of Composite Materials*, *44*(19), 2265-2288.

Pandey, K. K., Hughes, M., & Vourinen, T. (2010). Dimensional stability, UV resistance and static mechanical properties of scots pine chemically modified with alkylene epoxides. *BioResources*, *5*(2), 598-615.

Park, J. W., & Im, S. S. (2003). Miscibility and morphology in blends of poly (L-lactic acid) and poly (vinyl acetate-co-vinyl alcohol). *Polymer*, *44*(15), 4341-4354.

Park, S. J., Jin, F. L., & Lee, J. R. (2004). Effect of biodegradable epoxidized castor oil on physicochemical and mechanical properties of epoxy resins. *Macromolecular Chemistry and Physics*, *205*(15), 2048-2054.

Patel, M., & Narayan, R. (2005). How sustainable are biopolymers and biobased products? The hope, the doubts, and the reality. *Natural Fibers, Biopolymers and Biocomposites, AK Mohanty, M. Misra and LT Drazl, editors. CRC Press (Taylor & Francis Group), New York, USA*, 833-853.

Petinakis, E., Yu, L., Edward, G., Dean, K., Liu, H., & Scully, A. D. (2009). Effect of matrix–particle interfacial adhesion on the mechanical properties of poly (lactic acid)/wood-flour micro-composites. *Journal of Polymers and the Environment*, *17*(2), 83.

Petrovic, Z. S. (2010). Polymers from Biological Oils. *Contemporary Materials*, *1*, 39–50.

Phua, Y. J., Chow, W. S., & Ishak, Z. M. (2011). The hydrolytic effect of moisture and hygrothermal aging on poly (butylene succinate)/organo-montmorillonite nanocomposites. *Polymer Degradation and Stability*, *96*(7), 1194-1203.

Pickering, K. L., Efendy, M. A., & Le, T. M. (2016). A review of recent developments in natural fibre composites and their mechanical performance. *Composites Part A: Applied Science and Manufacturing*, *83*, 98-112.

Pillin, I., Montrelay, N., & Grohens, Y. (2006). Thermo-mechanical characterization of plasticized PLA: Is the miscibility the only significant factor?. *Polymer*, *47*(13), 4676-4682.

Piorkowska, E., Kulinski, Z., Galeski, A., & Masirek, R. (2006). Plasticization of semicrystalline poly (L-lactide) with poly (propylene glycol). *Polymer*, *47*(20), 7178-7188.

Plackett, D., Andersen, T. L., Pedersen, W. B., & Nielsen, L. (2003). Biodegradable composites based on L-polylactide and jute fibres. *Composites Science and Technology*, *63*(9), 1287-1296.

Pothan, L. A., Oommen, Z., & Thomas, S. (2003). Dynamic mechanical analysis of banana fiber reinforced polyester composites. *Composites Science and Technology*, *63*(2), 283-293.

Premalal, H. G., Ismail, H., & Baharin, A. (2002). Comparison of the mechanical properties of rice husk powder filled polypropylene composites with talc filled polypropylene composites. *Polymer Testing*, *21*(7), 833-839.

Pritchard, G. (2005). *Plastics additives: a Rapra market report*. iSmithers Rapra Publishing.

Ragoubi, M., Bienaimé, D., Molina, S., George, B., & Merlin, A. (2010). Impact of corona treated hemp fibres onto mechanical properties of polypropylene composites made thereof. *Industrial Crops and Products*, *31*(2), 344-349.

Rajanaidu, N., & Jalani, B. S. (1994). Prospects for breeding for kernels in oil palm (Elaeis guineensis). *Planter*, *70*(820), 307-318.

Raju, G., Ratnam, C. T., Ibrahim, N. A., Rahman, M. Z. A., & Yunus, W. M. Z. W. (2007). Graft copolymerization of methyl acrylate onto oil palm empty fruit bunch (OPEFB) fiber. *Polymer-Plastics Technology and Engineering*, *46*(10), 949-955.

Rajulu, A. V., Rao, G. B., Rao, B., Reddy, A., He, J., & Zhang, J. (2002). Properties of ligno-cellulose fiber Hildegardia. *Journal of Applied Polymer Science*, *84*(12), 2216-2221.

Ramli, R., Yunus, R. M., Beg, M. D. H., & Prasad, D. M. R. (2012). Oil palm fiber reinforced polypropylene composites: Effects of fiber loading and coupling agents on mechanical, thermal, and interfacial properties. *Journal of Composite Materials*, *46*(11), 1275-1284.

Rashdi, A. A. A., Sapuan, S. M., Ahmad, M. M. H. M., & Khalina, A. (2010). Combined Effects of Water Absorption Due to Water Immersion, Soil Buried and Natural Weather on Mechanical Properties Of Kenaf Fibre Unsaturated Polyester Composites (KFUPC). *International Journal of Mechanical and Materials Engineering*, *5*(1), 11-17.

Ray, D., Sarkar, B. K., & Bose, N. R. (2002). Impact fatigue behaviour of vinylester resin matrix composites reinforced with alkali treated jute fibres. *Composites Part A: Applied Science and manufacturing*, *33*(2), 233-241.

Razak, N. W. A., & Kalam, A. (2012). Effect of OPEFB size on the mechanical properties and water absorption behaviour of OPEFB/PPnanoclay/PP hybrid composites. *Procedia Engineering*, *41*, 1593-1599.

Razali, N., Salit, M. S., Jawaid, M., Ishak, M. R., & Lazim, Y. (2015). A study on chemical composition, physical, tensile, morphological, and thermal properties of roselle fibre: Effect of fibre maturity. *BioResources*, *10*(1), 1803-1824.

Reddad, Z., Gérente, C., Andrès, Y., Ralet, M. C., Thibault, J. F., & Le Cloirec, P. (2002). Ni (II) and Cu (II) binding properties of native and modified sugar beet pulp. Carbohydrate Polymers, 49(1), 23-31.

Reddy, N., & Yang, Y. (2005). Biofibers from agricultural byproducts for industrial applications. *TRENDS in Biotechnology*, *23*(1), 22-27.

Reed, P. E., & Beva, L. (1993). Impact damage in a composite material. *Polymer Composites*, *14*(4), 286-291.

Ren, Z., Dong, L. & Yang, Y. (2006). Dynamic mechanical and thermal properties of plasticized poly(lactic acid). *Journal of Applied Polymer Science*, *101*, 1583 – 1590.

Renstad, R., Karlsson, S., Sandgren, Å., & Albertsson, A. C. (1998). Influence of processing additives on the degradation of melt-pressed films of poly (ε-caprolactone) and poly (lactic acid). *Journal of Environmental Polymer Degradation*, *6*(4), 209-221.

Rios, L. a., Echeverri, D. a., & Franco, A. (2011). Epoxidation of jatropha oil using heterogeneous catalysts suitable for the Prileschajew reaction: Acidic resins and immobilized lipase. *Applied Catalysis A: General*, *394*(1-2), 132–137.

Robertson, M. L., Chang, K., Gramlich, W. M., & Hillmyer, M. A. (2010). Toughening of polylactide with polymerized soybean oil. *Macromolecules*, *43*(4), 1807-1814.

Rodriguez, E. S., Stefani, P. M., & Vazquez, A. (2007). Effects of fibers' alkali treatment on the resin transfer molding processing and mechanical properties of Jute—Vinylester composites. *Journal of Composite Materials*, *41*(14), 1729-1741.

Rouison, D., Sain, M., & Couturier, M. (2004). Resin transfer molding of natural fiber reinforced composites: cure simulation. *Composites Science and Technology*, *64*(5), 629-644.

Rosa, M. F., Medeiros, E. S., Malmonge, J. A., Gregorski, K. S., Wood, D. F., Mattoso, L. H. C., & Imam, S. H. (2010). Cellulose nanowhiskers from coconut husk fibers: Effect of preparation conditions on their thermal and morphological behavior. *Carbohydrate Polymers*, *81*(1), 83-92.

Roy, A., Chakraborty, S., Kundu, S. P., Basak, R. K., Majumder, S. B., & Adhikari, B. (2012). Improvement in mechanical properties of jute fibres through mild alkali treatment as demonstrated by utilisation of the Weibull distribution model. *Bioresource Technology*, *107*, 222-228.

Rozman, H. D., Musa, L., & Abubakar, A. (2005). Rice husk–polyester composites: the effect of chemical modification of rice husk on the mechanical and dimensional stability properties. *Journal of Applied Polymer Science*, *97*(3), 1237-1247.

Rozman, H. D., Tay, G. S., Abubakar, A., & Kumar, R. N. (2001). Tensile properties of oil palm empty fruit bunch–polyurethane composites. *European Polymer Journal*, *37*(9), 1759-1765.

Rozman, H. D., Tay, G. S., Kumar, R. N., Abusamah, A., Ismail, H., & Ishak, Z. M. (2001). Polypropylene–oil palm empty fruit bunch–glass fibre hybrid composites: a preliminary study on the flexural and tensile properties. *European Polymer Journal*, *37*(6), 1283-1291.

Saad, M. J. (2010). Effect of maleated polypropylene (MAPP) on the tensile, impact and thickness swelling properties of kenaf core–polypropylene composites. *Journal of Science and Technology*, *2*(1).

Saha, P., Manna, S., Chowdhury, S. R., Sen, R., Roy, D., & Adhikari, B. (2010). Enhancement of tensile strength of lignocellulosic jute fibers by alkali-steam treatment. *Bioresource Technology*, *101*(9), 3182-3187.

Saheb, D. N., & Jog, J. P. (1999). Natural fiber polymer composites: a review. *Advances in Polymer Technology*, *18*(4), 351-363.

Salehiyan, R., Yoo, Y., Choi, W. J., & Hyun, K. (2014). Characterization of morphologies of compatibilized polypropylene/polystyrene blends with nanoparticles via nonlinear rheological properties from FT-rheology. *Macromolecules*, *47*(12), 4066-4076.

Sanadi, A. R., Caulfield, D. F., Jacobson, R. E., & Rowell, R. M. (1994, December). Reinforcing polypropylene with agricultural fibers. In *Proceedings: international jute and allied fibre symposium on biocomposites and blends. New Dehli, India* (pp. 163-167).

Sanchez-Garcia, M. D., Gimenez, E., & Lagaron, J. M. (2008). Morphology and barrier properties of solvent cast composites of thermoplastic biopolymers and purified cellulose fibers. *Carbohydrate Polymers*, *71*(2), 235-244.

Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., & Sahari, J. (2016). Effect of sugar palm-derived cellulose reinforcement on the mechanical and water barrier properties of sugar palm starch biocomposite films. *BioResources*, *11*(2), 4134-4145.

Saravari, O., & Praditvatanakit, S. (2013). Preparation and properties of urethane alkyd based on a castor oil/jatropha oil mixture. *Progress in Organic Coatings*, *76*(4), 698-704.

Saremi, K., Tabarsa, T., SHakeri, A., & Babanalbandi, A. (2012). Epoxidation of soybean oil. *Annals of biological research*, *3*(9), 4254-4258.

Sarin, R., Sharma, M., Sinharay, S., & Malhotra, R. K. (2007). Jatropha–palm biodiesel blends: an optimum mix for Asia. *Fuel*, *86*(10-11), 1365-1371.

Satyanarayana, K. G., Wypych, F., Guimarães, J. L., Amico, S. C., Sydenstricker, T. H. D., & Ramos, L. P. (2005). Studies on natural fibers of Brazil and green composites. *Metals Materials and Processes*, *17*, 183–194.

Saurabh, T., Patnaik, M., Bhagt, S. L., & Renge, V. C. (2011). Epoxidation of vegetable oils: a review. *Int. J. Adv. Eng. Technol*, *2*(4), 491-501.

Scarponi, C., & Pizzinelli, C. S. (2009). Interface and mechanical properties of natural fibres reinforced composites: a review. *International Journal of Materials and Product Technology*, *36*(1-4), 278-303.

Schmook, B., & Seralta-Peraza, L. (1997). J. curcas: distribution and uses in the Yucatan Peninsula of Mexico. *Biofuels and Industrial Products from Jatropha Curcas*, 53-57.

Sears, J. K., & Darby, J. R. (1982). Mechanism of plasticizer action. *The Technology of Plasticizers*, 35-77.

Seki, Y., Sarikanat, M., Sever, K., Erden, S., & Gulec, H. A. (2010). Effect of the low and radio frequency oxygen plasma treatment of jute fiber on mechanical properties of jute fiber/polyester composite. *Fibers and Polymers*, *11*(8), 1159-1164.

Senawi, R., Alauddin, S. M., Saleh, R. M., & Shueb, M. I. (2013). Polylactic acid/empty fruit bunch fiber biocomposite: Influence of alkaline and silane treatment on the mechanical properties. *International Journal of Bioscience, Biochemistry and Bioinformatics*, *3*(1), 59.

Serizawa, S., Inoue, K., & Iji, M. (2006). Kenaf-fiber-reinforced poly (lactic acid) used for electronic products. *Journal of Applied Polymer Science*, *100*(1), 618-624.

Serizawa, S., Inoue, K., & Iji, M. (2008). *U.S. Patent No. 7,445,835*. Washington, DC: U.S. Patent and Trademark Office.

Sgriccia, N., Hawley, M. C., & Misra, M. (2008). Characterization of natural fiber surfaces and natural fiber composites. *Composites Part A: Applied Science and Manufacturing*, *39*(10), 1632-1637.

Shanks, R. A., Hodzic, A., & Ridderhof, D. (2006). Composites of poly (lactic acid) with flax fibers modified by interstitial polymerization. *Journal of Applied Polymer Science*, *99*(5), 2305-2313.

Shebani, A. N., Van Reenen, A. J., & Meincken, M. (2008). The effect of wood extractives on the thermal stability of different wood species. *Thermochimica Acta*, *471*(1-2), 43-50.

Shibata, M., Someya, Y., Orihara, M. & Miyosho, M. (2006) Thermal and mechanical properties of plasticized poly(L-lactide) nanocomposite with organo-modified montmorillonites. *Journals of Applied Polymer Science*, Vol. 99, 2594 – 2602.

Shibata, M., Varman, M., Tono, Y., Miyafuji, H., & Saka, S. (2008). Characterization in chemical composition of the oil palm (Elaeis guineensis). *Journal-Japan Institute of Energy*, *87*(5), 383.

Shibata, S., Cao, Y., & Fukumoto, I. (2005). Effect of bagasse fiber on the flexural properties of biodegradable composites. *Polymer Composites*, *26*(5), 689-694.

Shinoj, S., Visvanathan, R., Panigrahi, S. and Kochubabu, M. (2011). Oil palm fiber (OPF) and its composites: A review. *Industrial Crops and Products*, 33: 7-22.

Siepmann, J., Paeratakul, O., & Bodmeier, R. (1998). Modeling plasticizer uptake in aqueous polymer dispersions. *International Journal of Pharmaceutics*, *165*(2), 191-200.

Signori, F., Coltelli, M. B., & Bronco, S. (2009). Thermal degradation of poly (lactic acid)(PLA) and poly (butylene adipate-co-terephthalate)(PBAT) and their blends upon melt processing. *Polymer Degradation and Stability*, *94*(1), 74-82.

Silverajah, V. S., Ibrahim, N. A., Yunus, W. M. Z. W., Hassan, H. A., & Woei, C. B. (2012). A comparative study on the mechanical, thermal and morphological characterization of poly (lactic acid)/epoxidized palm oil blend. *International Journal of Molecular Sciences*, *13*(5), 5878-5898.

Silverajah, V. S., Ibrahim, N. A., Zainuddin, N., Yunus, W. M. Z. W., & Hassan, H. A. (2012). Mechanical, thermal and morphological properties of poly (lactic acid)/epoxidized palm olein blend. *Molecules*, *17*(10), 11729-11747.

Sin, L. T. (2012). *Polylactic acid: PLA biopolymer technology and applications*. William Andrew.

Singh, B., Verma, A., & Gupta, M. (1998). Studies on adsorptive interaction between natural fiber and coupling agents. *Journal of Applied Polymer Science*, *70*(9), 1847-1858.

Sinha, E., & Panigrahi, S. (2009). Effect of plasma treatment on structure, wettability of jute fiber and flexural strength of its composite. *Journal of Composite Materials*, *43*(17), 1791-1802.

Sreekala, M. S., & Thomas, S. (2003). Effect of fibre surface modification on water-sorption characteristics of oil palm fibres. *Composites Science and Technology*, *63*(6), 861-869.

Sreekala, M. S., Kumaran, M. G., & Thomas, S. (1997). Oil palm fibers: Morphology, chemical composition, surface modification, and mechanical properties. *Journal of Applied Polymer Science*, *66*(5), 821-835.

Suardana, N. P. G., Piao, Y., & Lim, J. K. (2011). Mechanical properties of hemp fibers and hemp/pp composites: effects of chemical surface treatment. *Materials Physics and Mechanics*, *11*(1), 1-8.

Sun, R. C., & Tompkinson, J. (2003). Comparative study of organic solvent and water-soluble lipophilic extractives from wheat straw I: yield and chemical composition. *Journal of wood science*, 49(1), 0047-0052.

Suryanegara, L., Nakagaito, A. N., & Yano, H. (2009). The effect of crystallization of PLA on the thermal and mechanical properties of microfibrillated cellulose-reinforced PLA composites. *Composites Science and Technology*, *69*(7-8), 1187-1192.

Symington, M. C., Banks, W. M., West, O. D., & Pethrick, R. A. (2009). Tensile testing of cellulose based natural fibers for structural composite applications. *Journal of Composite Materials*, *43*(9), 1083-1108.

Tabi, T., Sajó, I. E., Szabó, F., Luyt, A. S., & Kovács, J. G. (2010). Crystalline structure of annealed polylactic acid and its relation to processing. *Express Polymer Letters*, *4*(10).

Taib, R. M., Ramarad, S., Ishak, Z. A. M., & Todo, M. (2010). Properties of kenaf fiber/polylactic acid biocomposites plasticized with polyethylene glycol. *Polymer Composites*, *31*(7), 1213-1222.

Tan, S. G., & Chow, W. S. (2010). Thermal properties, fracture toughness and water absorption of epoxy-palm oil blends. *Polymer-Plastics Technology and Engineering*, *49*(9), 900-907.

Tawakkal, I. S. M., Talib, R. A., Abdan, K., & Ling, C. N. (2012). Mechanical and physical properties of kenaf-derived cellulose (KDC)-filled polylactic acid (PLA) composites. *BioResources*, *7*(2), 1643-1655.

Tellez, G.L.; Santiago, E.V. & Lopez, S.H. (2009). Characterization of linseed oil epoxidized at different percentages. *Superficies y Vacio*., *22*, 5–10.

Ten, E., Jiang, L., & Wolcott, M. P. (2012). Crystallization kinetics of poly (3-hydroxybutyrate-co-3-hydroxyvalerate)/cellulose nanowhiskers composites. *Carbohydrate Polymers*, *90*(1), 541-550.

Then, Y. Y., Ibrahim, N. A., Zainuddin, N., Ariffin, H., Yunus, W. M. Z. W., & Chieng, B. W. (2014). The influence of green surface modification of oil palm mesocarp fiber by superheated steam on the mechanical properties and dimensional stability of oil palm mesocarp fiber/poly (butylene succinate) biocomposite. *International Journal of Molecular Sciences*, *15*(9), 15344-15357.

Then, Y. Y., Ibrahim, N. A., Zainuddin, N., Ariffin, H., Yunus, W. M. Z. W., & Chieng, B. W. (2014). Surface modifications of oil palm mesocarp fiber by superheated steam, alkali, and superheated steam-alkali for biocomposite applications. *BioResources*, *9*(4), 7467-7483.

Thomas, S., & Pothan, L. A. (Eds.). (2009). *Natural Fibre Reinforced Polymer Composites: from Macro to Nanoscale*. Archives contemporaines.

Thomas, S., Paul, S. A., Pothan, L. A. & Deepa, B. (2011). Natural Fibres: Structure, Properties and Applications. *Cellulose Fibers: Bio- and Nano-Polymer Composites, ed. S. Kalia, B. S. Kaith and I. Kaur*, 3-42, Springer.

Thomas, S., Pothan, L. A., & Cherian, B. M. (2009). Advances in natural fibre reinforced polymer composites: macro to nanoscales. *International Journal of Materials and Product Technology*, *36*(1-4), 317-333.

Tiemann, K. J., Gardea-Torresdey, J. L., Gamez, G., Dokken, K., Sias, S., Renner, M. W., & Furenlid, L. R. (1999). Use of X-ray absorption spectroscopy and esterification to investigate Cr (III) and Ni (II) ligands in alfalfa biomass. Environmental science & technology, 33(1), 150-154.

Tserki, V., Zafeiropoulos, N. E., Simon, F., & Panayiotou, C. (2005). A study of the effect of acetylation and propionylation surface treatments on natural fibres. *Composites Part A: Applied Science and Manufacturing*, *36*(8), 1110-1118.

Vanholme, R., Demedts, B., Morreel, K., Ralph, J., & Boerjan, W. (2010). Lignin biosynthesis and structure. *Plant Physiology*, *153*(3), 895-905.

Velde, K. V. & Kiekens, P. (2002) Biopolymers: overview of several properties and consequences on their applications. *Polymer Testing*, *21*, 433 – 442.

Verhey, S. A., & Laks, P. E. (2002). Wood particle size affects the decay resistance of woodfiber/thermoplastic composites. *Forest Products Journal*, *52*(11/12), 78.

Verma, K. C., & Gaur, A. K. (2009). Jatropha curcas L.: substitute for conventional energy. *World Journal of Agricultural Sciences*, *5*(5), 552-556.

Vieira, A. C., Marques, A. T., Guedes, R. M., & Tita, V. (2011). Material model proposal for biodegradable materials. *Procedia Engineering*, *10*, 1597-1602.

Vieira, M. G. A., da Silva, M. A., dos Santos, L. O., & Beppu, M. M. (2011). Natural-based plasticizers and biopolymer films: A review. *European Polymer Journal*, *47*(3), 254-263.

Vijayarajan, S. (2013). *Continuous Blending Approach in the Manufacture of Epoxidized Soybean-plasticized Poly (lactic Acid) Sheets and Films for Packaging Applications*. Michigan State University. Packaging.

Vijayarajan, S., Selke, S. E., & Matuana, L. M. (2014). Continuous Blending Approach in the Manufacture of Epoxidized Soybean-Plasticized Poly (lactic acid) Sheets and Films. *Macromolecular Materials and Engineering*, *299*(5), 622-630.

Vilay, V., Mariatti, M., Taib, R. M., & Todo, M. (2008). Effect of fiber surface treatment and fiber loading on the properties of bagasse fiber–reinforced unsaturated polyester composites. *Composites Science and Technology*, *68*(3-4), 631-638.

Viswanathan, S., & Dadmun, M. D. (2003). Optimizing hydrogen-bonding in creating miscible liquid crystalline polymer blends by structural modification of the blend components. *Macromolecules*, *36*(9), 3196-3205.

Vroman, I. and Tighzert, L. (2009). Biodegradable polymers. *Materials,* 2: 307-344.

Wadhi, M. M., & Weliam, R. (2014). Effect of epoxidized sunflower oil on polylactic acid properties. *Research on Chemical Intermediates*, *40*(1), 399-406.

Wahit, M. U., Akos, N. I., & Laftah, W. A. (2012). Influence of natural fibers on the mechanical properties and biodegradation of poly (lactic acid) and poly (ε-caprolactone) composites: A review. *Polymer Composites*, *33*(7), 1045-1053.

Wambua, P., Ivens, J., & Verpoest, I. (2003). Natural fibres: can they replace glass in fibre reinforced plastics?.*Composites Science and Technology*, *63*(9), 1259-1264.

Wang, C. N., & Torng, J. H. (2001). Experimental study of the absorption characteristics of some porous fibrous materials. *Applied Acoustics*, *62*(4), 447-459.

Wang, J. H., Schertz, D. M., Soerens, D. A., & Rhim, H. (1999). *U.S. Patent No. 5,945,480*. Washington, DC: U.S. Patent and Trademark Office.

Wang, J., Zhai, W., & Zheng, W. (2012). Poly (ethylene glycol) grafted starch introducing a novel interphase in poly (lactic acid)/poly (ethylene glycol)/starch ternary composites. *Journal of Polymers and the Environment*, *20*(2), 528-539.

Wang, L., Ma, W., Gross, R. A., & McCarthy, S. P. (1998). Reactive compatibilization of biodegradable blends of poly (lactic acid) and poly (ε-caprolactone). *Polymer Degradation and Stability*, *59*(1-3), 161-168.

Wang, X. H., Zhang, H. X., Wang, Z. G., & Jiang, B. Z. (1997). Toughening of poly (butylene terephthalate) with epoxidized ethylene propylene diene rubber. *Polymer*, *38*(7), 1569-1572.

Wang, Y., Tong, B., Hou, S., Li, M., & Shen, C. (2011). Transcrystallization behavior at the poly (lactic acid)/sisal fibre biocomposite interface. *Composites Part A: Applied Science and Manufacturing*, *42*(1), 66-74.

Wasanasuk, K., & Tashiro, K. (2011). Crystal structure and disorder in Poly (l-lactic acid) δ form (α′ form) and the phase transition mechanism to the ordered α form. *Polymer*, *52*(26), 6097-6109.

Williams, G. I., & Wool, R. P. (2000). Composites from natural fibers and soy oil resins. *Applied Composite Materials*, *7*(5-6), 421-432.

Wirawan, R., Sapuan, S. M., Abdan, K., & Yunus, R. B. (2011). Tensile and impact properties of sugarcane bagasse/poly (vinyl chloride) composites. *Key Engineering Materials* , *471*, 167-172.

Widsten, P., & Kandelbauer, A. (2008). Adhesion improvement of lignocellulosic products by enzymatic pre-treatment. Biotechnology Advances, 26(4), 379-386.

Wirawan, R., Sapuan, S. M., Robiah, Y., & Khalina, A. (2011). Elastic and viscoelastic properties of sugarcane bagasse-filled poly (vinyl chloride) composites. *Journal of Thermal Analysis and Calorimetry*, *103*(3), 1047-1053.

Woo, E. M., Sun, Y. S., & Yang, C. P. (2001). Polymorphism, thermal behavior, and crystal stability in syndiotactic polystyrene vs. its miscible blends. *Progress in Polymer Science*, *26*(6), 945-983.

Wool, R. P., & Sun, X. S. (1999). Bio-based polymers and composites, 2005. *New York: Elsevier*.

Wu, D., Zhang, Y., Zhang, M., & Zhou, W. (2008). Phase behavior and its viscoelastic response of polylactide/poly (ε-caprolactone) blend. *European Polymer Journal*, 44(7), 2171-2183.

Xia, C., Shi, S. Q., & Cai, L. (2015). Vacuum-assisted resin infusion (VARI) and hot pressing for CaCO 3 nanoparticle treated kenaf fiber reinforced composites. *Composites Part B: Engineering*, *78*, 138-143.

Xia, Y., & Larock, R. C. (2010). Vegetable oil-based polymeric materials: synthesis, properties, and applications. *Green Chemistry*, *12*(11), 1893–1909.

Xie, Y., Hill, C. A., Xiao, Z., Militz, H., & Mai, C. (2010). Silane coupling agents used for natural fiber/polymer composites: A review. *Composites Part A: Applied Science and Manufacturing*, *41*(7), 806-819.

Xiong, Z., Yang, Y., Feng, J., Zhang, X., Zhang, C., Tang, Z., & Zhu, J. (2013). Preparation and characterization of poly (lactic acid)/starch composites toughened with epoxidized soybean oil. *Carbohydrate Polymers*, *92*(1), 810-816.

Xu, Y. Q., & Qu, J. P. (2009). Mechanical and rheological properties of epoxidized soybean oil plasticized poly (lactic acid). *Journal of Applied Polymer Science*, *112*(6), 3185-3191.

Yahaya, R., Sapuan, S. M., Jawaid, M., Leman, Z., & Zainudin, E. S. (2015). Effect of layering sequence and chemical treatment on the mechanical properties of woven kenaf–aramid hybrid laminated composites. *Materials & Design*, *67*, 173-179.

Yamamoto, Y., Inoue, Y., Onai, T., Doshu, C., Takahashi, H., & Uehara, H. (2007). Deconvolution analyses of differential scanning calorimetry profiles of β-crystallized polypropylenes with synchronized X-ray measurements. *Macromolecules*, *40*(8), 2745-2750.

Yang, F., Xu, C. Y., Kotaki, M., Wang, S., & Ramakrishna, S. (2004). Characterization of neural stem cells on electrospun poly (L-lactic acid) nanofibrous scaffold. *Journal of Biomaterials Science, Polymer Edition*, *15*(12), 1483-1497.

Yang, H. S., Kim, D. J., Lee, Y. K., Kim, H. J., Jeon, J. Y., & Kang, C. W. (2004). Possibility of using waste tire composites reinforced with rice straw as construction materials. *Bioresource Technology*, *95*(1), 61-65.

Yang, H. S., Kim, H. J., Son, J., Park, H. J., Lee, B. J., & Hwang, T. S. (2004). Rice-husk flour filled polypropylene composites; mechanical and morphological study. *Composite Structures*, *63*(3-4), 305-312.

Yao, F., Wu, Q., Lei, Y., Guo, W., & Xu, Y. (2008). Thermal decomposition kinetics of natural fibers: activation energy with dynamic thermogravimetric analysis. Polymer Degradation and Stability, 93(1), 90-98.

Yelle, D., Goodell, B., Gardner, D. J., Amirbahman, A., Winistofer, P., & Shaler, S. (2004). Bonding of wood fiber composites using a synthetic chelator-lignin activation system. Forest products journal. Vol. 54, no. 4 (Apr. 2004): Pages 73-78.

Yew, G. H., Yusof, A. M., Ishak, Z. M., & Ishiaku, U. S. (2005). Water absorption and enzymatic degradation of poly (lactic acid)/rice starch composites. *Polymer Degradation and Stability*, *90*(3), 488-500.

Yew, M. K., Bin Mahmud, H., Ang, B. C., & Yew, M. C. (2015). Effects of low volume fraction of polyvinyl alcohol fibers on the mechanical properties of oil palm shell lightweight concrete. *Advances in Materials Science and Engineering*, *2015*.

Yuan, Y., & Lee, T. R. (2013). Contact angle and wetting properties. In *Surface science techniques* (pp. 3-34). Springer Berlin Heidelberg.

Yussuf, A. A., Massoumi, I., & Hassan, A. (2010). Comparison of polylactic acid/kenaf and polylactic acid/rise husk composites: the influence of the natural fibers on the mechanical, thermal and biodegradability properties. *Journal of Polymers and the Environment*, *18*(3), 422-429.

Zampaloni, M., Pourboghrat, F., Yankovich, S. A., Rodgers, B. N., Moore, J., Drzal, L. T., & Misra, M. (2007). Kenaf natural fiber reinforced polypropylene composites: a discussion on manufacturing problems and solutions. *Composites Part A: Applied Science and Manufacturing*, *38*(6), 1569-1580.

Zhao, Q., Tao, J., Yam, R. C., Mok, A. C., Li, R. K., & Song, C. (2008). Biodegradation behavior of polycaprolactone/rice husk ecocomposites in simulated soil medium. *Polymer Degradation and Stability*, *93*(8), 1571-1576.

Zimniewska, M., Wladyka-Przybylak, M., & Mankowski, J. (2011). Cellulosic bast fibers, their structure and properties suitable for composite applications. *Cellulose Fibers: Bio-and Nano-Polymer Composites*, 97-119.

Zou, J., Ma, T., Zhang, J., He, W., & Huang, F. (2011). Preparation and characterization of PLLA–ESO/surface-grafted silica nanocomposites. *Polymer Bulletin, 67(7), 1261.*