



**UNIVERSITI PUTRA MALAYSIA**

**FIBRE REINFORCED PLASTIC COMPOSITES: KENAF (HIBUSCUS  
CANNABUNUSL.) FIBRE- POLYPROPYLENE BLEND**

**TAN KHIM SEONG**

**FH 2002 9**



**FIBRE REINFORCED PLASTIC COMPOSITES: KENAF  
(*HIBUSCUS CANNABUNUS* L.) FIBRE- POLYPROPYLENE BLEND**

**By**

**TAN KHIM SEONG**

**Thesis Submitted to the School of Graduates Studies, Universiti Putra  
Malaysia, In Fulfilment of the Requirement for the Degree of Master of  
Science**

**March 2002**



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

**FIBRE REINFORCED PLASTIC COMPOSITES: KENAF  
(*HIBISCUS CANNABINUS*. L.) FIBRE- POLYPROPYLENE BLEND**

**By**

**TAN KHIM SEONG**

**March 2002**

**Chairman: Jalaluddin Harun, Ph.D.**

**Faculty: Forestry**

This study aimed to evaluate the chemical compositions, analytical and Mechanical properties of Kenaf (*Hibiscus cannabinus*, L.) fibres blended with polypropylene at various fibre loading and fibre length. The effects of electron beam irradiation at dose 10 kGray and 1% maleated polypropylene (MAPP) on this composite were also investigated.

Kenaf stalks with the age of 4 months obtained from MARDI, Serdang were defibrated with two types of processing method, namely wet atmospheric pressurized refiner mechanical pulping (RMP) and dry hammermill process. The fibres and particles from these two processes were oven dried and screened into three different sizes: 1-2 mm, 0.5- 1 mm, and <0.5 mm.



Fibres with length between 0.5- 1 mm were used for chemical analysis process. Results showed that kenaf fibre has higher cellulose and lower lignin content than rubber wood fibre. The ash content of kenaf fibre was also lower than empty fruit bunch.

Fibres with different sizes were then blended with various fibre loadings (0%, 20%, 30%, 40%, and 50%) by means of Brabender Plasti Corder PL2000-6. All mixing were done for 12.5 minutes at temperature of 180 °C and rotor speed of 40 rpm. The compounded samples were then hot pressed into test samples for various analytical and mechanical assessments such as specific gravity, water absorption, thickness swelling, tensile strength, tensile modulus, flexural strength, flexural modulus, notched izod impact strength, and Rockwell hardness, in accordance with ASTM and British standards.

. Overall, as fibre loading for every fibre length category increases properties such as specific gravity, water absorption, thickness swelling, tensile modulus, flexural modulus, and notched izod impact strength were also increased. However, properties such as tensile strength, flexural strength, and Rockwell hardness decreased. The results showed that kenaf fibre produced from RMP showed better analytical and mechanical properties at the same fibre loading and fibre length category than hammermill fibre

An introduction of irradiation process was found to increase more of the analytical and mechanical properties of kenaf fibre blended with polypropylene. Composite with the composition of irradiated polypropylene and unirradiated kenaf fibre showed favourable properties compare to other composition such as irradiated polypropylene with irradiated fibre, irradiated fibre with unirradiated polypropylene, and unirradiated fibre with unirradiated polypropylene.

However, composite with the addition of 1% MAPP produces the best analytical and mechanical properties compare to other unirradiated and irradiated samples except for flexural modulus property.

Lastly, all evaluations are statistically analysed at 5% level of significance. Supportive photographic evidences of the above results are shown by Scanning Electron Micrographs.

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

**KOMPOSIT GABUNGAN PLASTIK DAN GENTIAN:  
GENTIAN KENAF (*HIBUSCUS CANNABICUS* L)- POLIPROPILENA**

Oleh

**TAN KHIM SEONG**

**Mac 2002**

**Pengerusu: Jalaluddin Harun, Ph.D.**

**Fakulti: Perhutanan**

Penyelidikan ini bertujuan untuk menilai komposisi kimia, sifat-sifat analitikal dan mekanikal gentian kenaf (*Hibiscus cannabinus*, L) dengan polipropelena dalam pelbagai komposisi dan saiz gentian. Kesan alur electron pada 10 kGray dan kehadiran 1% maleated polipropilena (MAPP) ke atas komposit in juga dikaji.

Batang kenaf yang berumur 4 bulan diperolehi dari MARDI, Serdang dicarikkan kepada gentian melalui dua kaedah memproses iaitu pengecil mekanikal pulpa bertekanan atmosfera basah (RMP) dan proses pengisar tukul. Gentian daripada dua proses in dikeringkan dan ditapis kepada tiga jenis kepanjangan iaitu: 1-2 mm, 0.5-1 mm, dan <0.5 mm.

Gentian dengan kepanjangan 0.5-1 mm diginakan untuik proses analisis komponen kimia. Keputusan menunjukkan kenaf gentian mempunyai kandungan selulosa yang lebih tinggi dan kandungan lignin yang rendah berbanding dengan

gentian kayu getah. Kandungan serbuk yang lebih tinggi berbanding dengan gentian buah kelapa sawit.

Gentian dengan kepanjangan masing-masing kemudiannya diadunkan dengan polipropilena dalam pelbagai komposisi (0%, 20%, 30%, 40%, dan 50%) dengan menggunakan mesin Brabender Plastic Corder PL2000-6. Kesemua process adunan dijalankan dengan masa adunan selama 12.5 minit pada suhu 180 °C dengan kelajuan pemutar pada 40 rpm. Kesemua kompaun adunan kemudiannya ditekan untuk membentuk sampel ujian untuk mendapatkan pelbagai maklumat analitikal dan mekanikal seperti ketumpatan bandingan, kadar penyerapan air, kadar ketebalan, kekuatan ketegangan, modulus ketegangan, kekuatan lenturan, modulus lenturan, ketahanan hentaman Izod dengan lekuk, dan kekerasan Rockwell mengikut piawaian ASTM dan British.

Secara umum, apabila komposisi gentian bertambah pada setiap kategori kepanjangan gentian, sifat-sifat seperti ketumpatan bandingan, kadar penyerapan air, kadar ketebalan, modulus ketegangan, modulus lenturan, dan ketahanan hentaman Izod dengan lekuk juga akan bertambah. Walaubagaimanapun, sifat-sifat seperti kekuatan ketegangan, kekuatan lenturan, dan kekerasan Rockwell didapati menurun. Keputusan yang diperolehi menunjukkan gentian kenaf yang diperolehi melalui RMP mempunyai kesemua sifat analitikal dan mekanikal yang lebih baik berbanding dengan gentian 'hammermill' pada setiap komposisi gentian dan kategori kepanjangan gentian.

Pengenalan process radiasi didapati menambahkan lagi sifat-sifat analitikal dan mekanikal komposit gentian kenaf yang diadun dengan polipropilena. Komposit dengan komposisi campuran polipropilena yang telah diradiasikan dengan gentian kenaf tanpa radiasi didapati menunjukkan sifat-sifat yang lebih baik berbanding dengan komposisi lain seperti radiasi polipropilena dengan radiasi gentian, radiasi gentian dengan polipropilena tanpa radiasi, dan gentian tanpa radiasi dengan polipropilena tanpa radiasi.

Walaupun bagaimanapun, komposit dengan kehadiran 1% MAPP didapati menghasilkan sifat-sifat analitikal dan mekanikal yang terbaik berbanding dengan sampel yang tanpa dan telah diradiasikan kecuali sifat modulus kelenturan.

Akhir sekali, kesemua penilaian dianalisa secara statistik pada tahap 5% signifikansi. Bukti sokongan untuk keputusan di atas diperkuatkan lagi melalui gambar yang diperolehi daripada "Scanning Electron Micrographs".



## AKNOWLEDGEMENTS

I would like to express my utmost appreciation and gratitude to my Supervisory Committee, Dr. Jalaluddin bin Harun (Chairman), Dr. Khairul Zaman Haji Mohd. Dahlan, Dr. Azmi bin Yahya, and Dr. Paridah Md. Tahir for their guidance, persistence encouragement, and associated aid throughout this study.

Profound gratitude is also extended to Universiti Putra Malaysia (UPM), Malaysia Institute for Nuclear Technology Research (MINT), and Forest Institute Malaysia (FRIM) in providing the needed facilities and equipment. Additionally, I would like to thank MARDI and Sabutek (M) Sdn. Bhd., which generously supplied kenaf plant and kenaf fibre respectively for the study.

Special thanks are also due to Dr. Chantara Theyy and Dr. Gloria A. Manarpaac for their assistance and constructive advice during the experimental work.

Last but by no means least; sincere thanks are dedicated to my dearest parents, brother, and Julie, for their constant support and care that made all things possible.



## TABLE OF CONTENTS

	<b>Page</b>
ABSTRACT	ii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL SHEETS	ix
DECLARATION FORM	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvi
LIST OF ABBREVIATION	xix
 <b>CHAPTER</b>	
<b>1 INTRODUCTION</b>	<b>1</b>
1.1 Background of the Study	1
1.2 Objectives of the Study	4
 <b>2 LITERATURE REVIEW</b>	 <b>5</b>
2.1 Phases of Materials	5
2.2 Plastics	6
2.2.1 Thermoplastics and Thermosets	7
2.2.2 Homopolymer and Copolymer	8
2.2.3 Mechanical Properties of Plastics	8
2.2.4 Analytical Properties of Plastics	10
2.2.5 Melt Flow Index	11
2.2.6 Factors Affecting Properties of Plastics	12
2.3 Polypropylene	13
2.4 Kenaf	16
2.4.1 Retting Process	17
2.4.2 Refining Process	18
2.5 Polymeric Composite Materials	19
2.5.1 Types of Alternative Reinforcement Fibre	21
2.5.2 Types of Filler for Plastic Composites	22
2.5.3 Cellulosic Fibre Reinforced Plastic Composites	24
2.6 Radiation Process on Fibre Reinforced Composites	27
2.6.1 Irradiation of Cellulose	29
2.6.2 Irradiation of Polypropylene	30
2.6.3 Mechanism of Electron Beam Processing Of Natural Fibre-Plastic Composites	 31
 <b>3 MATERIALS AND METHODS</b>	 <b>34</b>
3.1 Raw Materials	34
3.2 Methodology	35



3.2.1	Separation of Core and Bast Section Process	35
3.2.2	Chemical Analysis of Kenaf	35
3.2.3	Melt Flow Index of Polypropylene and MAPP	36
3.2.4	Kenaf Fibre Preparation	37
3.2.5	Fibre Plastic Composite Fabrication	38
3.2.6	Pressing and Moulding	38
3.2.7	Conditioning	39
3.3	Analytical and Mechanical Properties Assessment Techniques	39
3.3.1	Specific Gravity	40
3.3.2	Water Absorption	41
3.3.3	Thickness Swelling	42
3.3.4	Moisture Content	42
3.3.5	Tensile Properties	43
3.3.6	Flexural Properties	44
3.3.7	Notched Izod Impact Resistance	45
3.3.8	Rockwell Hardness	46
3.4	Test Matrices	46
3.4.1	Experiment A	46
3.4.2	Experiment B	47
3.4.3	Experiment C	48
3.4.4	Experiment D	49
3.5	Surface Analysis of Kenaf-PP Composites by SEM	49
3.6	Statistical Analysis	50
<b>4</b>	<b>RESULTS AND DISCUSSIONS</b>	<b>51</b>
4.1	Results of the Preliminary Study of Raw Materials	51
4.1.1	Chemical Composition of Kenaf Fibre	51
4.1.2	Melt Flow Index of Polypropylene and MAPP	53
4.1.3	Optimisation Process of Kenaf-PP Composites	54
4.2	Results of Kenaf-PP Composites	59
4.2.1	Specific Gravity of Kenaf-PP Composites	61
4.2.2	Water Absorption of Kenaf-PP Composites	63
4.2.3	Thickness Swelling of Kenaf-PP Composites	65
4.2.4	Tensile Strength of Kenaf-PP Composites	67
4.2.5	Tensile Modulus of Kenaf-PP Composites	69
4.2.6	Flexural Strength of Kenaf-PP Composites	71
4.2.7	Flexural Modulus of Kenaf-PP Composites	72
4.2.8	Notched Izod Impact Resistance Strength of Kenaf-PP Composites	74
4.2.8	Rockwell Hardness of Kenaf-PP Composites	76
4.3	Comparisons of The Best Analytical and Mechanical Between RMP-PP and Hammermill-PP Composites	78
4.4	Effect of Irradiation on Analytical and Mechanical Properties of Kenaf-PP Composites	79

4.4.1	Analytical Properties of Irradiated RMP-PP Composites	80
4.4.2	Mechanical Properties of Irradiated RMP-PP Composites	82
4.5	Effect of Additive on Analytical and Mechanical Properties of Kenaf-PP Composites	86
4.5.1	Analytical Properties of Kenaf-PP Composites with Additives	87
4.5.2	Mechanical Properties of Kenaf-PP Composites with Additives	89
4.6	SEM Analysis for Fibres and Composites	96
<b>5</b>	<b>CONCLUSIONS AND RECOMMENDATION FOR FURTHER STUDIES</b>	<b>101</b>
5.1	Conclusions	101
5.2	Recommendation for Further Studies	103
	<b>REFERENCES</b>	<b>104</b>
	<b>VITA</b>	<b>111</b>

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
1	Experimental Variables and Its Content Level in Experiment B	47
2	Chemical Composition of Kenaf Fibre	53
3	Melt Flow Index of Polypropylene and MAPP	54
4	Results of ANOVA Showing Levels of Significance of Experimental Factors and Their Interactions on the Analytical and Mechanical Properties	60
5	Comparisons of The Best Analytical and Mechanical Properties Between RMP-PP and Hammermill-PP Composites	78
6	Analytical and Mechanical Properties of RMP-PP Composites at Different Fibre Loading and Fibre Length Category	93
7	Analytical and Mechanical Properties of Hammermill PP Composites at Different Fibre Loading and Fibre Length Category	95



## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
1	Types of Material Phases at Normal Temperature	5
2	Formulas for Monomer and Polymer of Polypropylene with 'n' Represents The Number of Repeating Units	14
3	Schematic Diagram of A Specific Gravity, Water Absorption, Thickness Swelling, and Moisture Content Test Specimen (Adapted from BS1142)	40
4	Schematic Diagram of A Tensile Specimen (Adapted from ASTM D638M-96)	43
5	Schematic Diagram of A Flexural Specimen (Adapted from ASTM D790-96a)	45
6	Results of Optimization Process of 40% RMP-PP Composites at Various Production Parameters. (a)Tensile Strength; (b) Tensile Modulus; (c) Flexural Strength; (d) Flexural Modulus	57
7	Results of Optimization Process of 50% RMP-PP Composites at Various Production Parameters. (a)Tensile Strength; (b) Tensile Modulus; (c) Flexural Strength; (d) Flexural Modulus	58
8	Specific Gravity at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	62
9	Water Absorption at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	63
10	Thickness Swelling at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	66
11	Tensile Strength at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	67

12	Tensile Modulus at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	70
13	Flexural Strength at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	71
14	Flexural Modulus at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	73
15	Notched Izod Impact Strength at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (a) Hammermill-PP Composites	75
16	Rockwell Hardness at Various Fibre Loading and Fibre Length. (a) RMP-PP Composites; (b) Hammermill-PP Composites	77
17	Effect of Irradiation Process on Analytical Properties of 50% RMP-PP Composites. (a) Specific Gravity; (b) Water Absorption; (c) Thickness Swelling	81
18	Effect of Irradiation Process on Mechanical Properties of 50% RMP-PP Composite. (a) Tensile Strength; (b) Tensile Modulus; (c) Flexural Strength; (d) Flexural Modulus; (e) Notched Izod Impact Strength; (f) Rockwell Hardness	84
19	Effect of 1% MAPP on Analytical Properties of 50% RMP-PP Composites. . (a) Specific Gravity; (b) Water Absorption; (c) Thickness Swelling	88
20	Effect of 1% MAPP on Mechanical Properties of 50% RMP-PP Composites. (a) Tensile Strength; (b) Tensile Modulus; (c) Flexural Strength; (d) Flexural Modulus; (e) Notched Izod Impact Strength; (f) Rockwell Hardness	91
21	Physical Appearance of RMP Fibre (magnification: 100X)	97
22	Physical Appearance of Hammermill Fibre (magnification: 100X)	97
23	Fracture Surface of An Untreated Specimen Broken in Tensile Test (magnification: 230X)	98

24 Fracture Surface 1% MAPP Treated Specimen Broken  
in Tensile Test (magnification: 230X)

99





## LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
CTMP	Chemi-Thermo Mechanical Pulping
DMRT	Duncan Multiple Range Test
EDXA	Dynamic Mechanical Thermal Analysis
EPDM	Ethylene Propylene Diene Rubber
FRIM	Forest Research Institute of Malaysia
FRPC	Fibre Reinforced Plastic Composite
MA	Maleated Anyhride
MAPP	Maleated Polypropylene
MFI	Melt Flow Index
MINT	Malaysian Institute for Nuclear Technology
NIIRS	Notched Izod Impact Resistance Strength
PBT	Poly(butylenes) terephthalate
PP	Polypropylene
Pph	Part perhundred
PUR	Polyurethane
RA	Reactive Additives
RMP	Refiner Mechanical Pulping
SBS	Styrene-Butadiene-Styrene
Sdn. Bhd.	Sendirian Berhad



TAPPI	Technical Association of Pulp and Paper
TEM	Transmission Electron Microscopy
UPM	Universiti Putra Malaysia
Wt	Weight



# CHAPTER I

## INTRODUCTION

### 1.1 Background of the Study

Presently, the world is losing nine million hectares of forest each year despite an increase in plantations especially in Africa, Latin America, and Asia. Although the rate of deforestation has fallen by 20% since 1995, each of the world's inhabitants was continuing to lose an average of 12 square meter of forest a year (Anon., 2001). Thus, in order to efficiently conserve the future of our forest, other non-wood lignocelluloses materials need to be explored and commercialized in order to substitute timber consumption. One of the most promising non-wood products that catch the attention of many researchers is kenaf.

Kenaf (*Hibiscus cannabinus* L.) is a herbaceous plant that originated from Africa about 4000 years ago. It is a fast growing species that can achieve the height of 5-6 m and diameter of 25-35 mm over a period of six months under good condition either in temperate and tropical climates. Generally, the primary usage of this plant was for the production of jute-type sacking, rope and cordage.

Modern research on Kenaf fibres was initiated during World War II by the United States as a result of the disruption of jute and abaca imports from

Southeast Asia. Research was also conducted on the fibres to replace hemp, whose production in the United States was outlawed in 1933 (Sellers et al., 1999). In 1960s, through extensive research, the U.S Department of Agriculture (USDA) has identified kenaf as a promising alternative fibrous raw material especially for papermaking (Bagby, 1977).

However, the usage of kenaf fibre remained unpopular until 1980s, when the technology that can separate kenaf bark and core into two distinct fractions was invented. Since then, much research and development on this plant has been done not only in United States but also other developing countries such as Thailand, India, Indonesia, Bangladesh, Myanmar (Burma), and Vietnam (Sellers et al., 1999)

Numerous commercial applications for the kenaf fibre whether it is separated or not have been discovered through product development research. These include uses for high quality animal bedding, woven and non-woven textiles, animal feed, oil absorption and fibre composite boards and paper.

A fibre composite is broadly defined as a material consisting of a large number of fibres embedded in a continuous phase or matrix, which gives it a definite shape and durable surface (Chum, 1991). Ease of forming and manufacturing process, uniformity strength distribution, low cost of raw materials, and recyclable are the several factors that make fibre composite a competitive substitute for solid wood.

Fibre reinforced plastic composite (FRPC) is an example of fibre composite. It is a mixture of thermoplastic and fibre. These fibres can be either synthetic fibre (fibreglass, carbon or graphite fibres and aramids fibre) or natural fibre (Strong, 2000). The present of these fibres will either act as a filler or reinforcement agent to the matrix. The examples of thermoplastic that can act as a matrix in FRPC are polypropylene, polystyrene and polyvinyl chloride. The major usage of FRPC are found in automobile, construction, packaging, furniture, electrical and electronics components.

At the moment, although the environment merits of cultivating agriculture fibres specifically as replacements for wood are debatable (Bowyer, 1995(a); Bowyer, 1995(b); Seber, 1995), efficient use of agricultural by products is certainly desirable especially in FRPC (Youngquist, 1995). Moreover, building materials and other daily usage products made from local agricultural fibres are attractive options in regions of the world where wood is in short supply and wood products are expensive to import (Grace, 1996; Spelter, 1996).

In Malaysia, the utilization of kenaf fibre and other agriculture fibres are still at preliminary stage as there is not much literature review on the FRPC product. Rubber wood, oil palm, and bamboo are currently being explored actively as the potential sources for agricultural fibres (Liew, 1998; Jamaludin, 1999; Low, 1999). Although there are still many other agricultural fibres that are relatively cheap and abundance in Malaysia, the emerging of kenaf fibre will surely diversify and maximize our fibre utilization more broadly and efficiently in

the near future. Eventually, this will assist forest conservation that will help to minimize the deforestation activities.

## **1.2 Objectives of the Study**

The objectives of this project are stated as below:

- a. To quantify the chemical compositions of kenaf fibre used in this experiment.
- b. To evaluate the mechanical and analytical properties of kenaf-PP composite at various fibre loadings and fibre lengths.
- c. To investigate the effect of electron beam irradiation on the properties of kenaf-PP composite materials.
- d. To assess the mechanical and analytical properties of irradiated kenaf-PP composite with the presence of compatibilizer agent (MAPP).