



UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION OF CYRTOSTACHYS RENDA / KENAF (*Hibiscus cannabinus L.*) / MULTI-WALLED CARBON NANOTUBES / BIO-PHENOLIC HYBRID COMPOSITES FOR AIRCRAFT TRAY TABLES

TAMIL MOLI A/P LOGANATHAN

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By

TAMIL MOLI A/P LOGANATHAN

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

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TAMIL MOLI A/P LOGANATHAN

October 2021

Chair : Mohamed Thariq Hameed Sultan, PhD, PEng, CEng, PTech
Faculty: Engineering

Aircraft utilize carbon fiber, glass fiber, and aramid fibers reinforced for structural parts. Their waste management has far-reaching environmental implications. This has reignited interest in green biodegradable sources. From the experimental results, leaf stalk of *Cyrtostachys renda* (CR) was identified as a potential reinforcement in comparison to *Ptychosperma macarthurii* (PM) fibers, in the polymeric composites for lightweight applications. Experimental was based on a few parameters of NaOH treatment found that 3 wt.% NaOH for an hour yields ideal effects on the CR fiber properties. The composites were prepared using a hot press machine. Mechanical, physical and flammability properties of CR fiber as reinforcement in bio-phenolic composites were analysed. Composites with 3 wt.% of NaOH CR fiber length in the ranges of 1.18-0.6, 0.6-0.3 and less than 0.3 mm in 20 wt.% and 40 wt.% were prepared and found that, composite containing 40 wt.% fiber of length less than 0.3 mm has the highest tensile and flexural strengths. The evaluation of the influence of CR fiber and the effects of multi-walled carbon nanotubes (MWCNT) on the morphology, thermal, mechanical, and flammability properties of bio-phenolic composites was performed. The presence of MWCNT in phenolic, enhanced the flexural, tensile and impact strength as much as 6.5%, 20% and 8.7% respectively compared to pristine phenolic. The addition of CR fiber, however, strengthened MWCNT filled phenolic composites, by improving the flexural, tensile and impact strength by as much as 16.7%, 45 %, and 194 %, respectively. Mechanical, thermal and flammability were performed on the effect of hybridization different hybrid *Cytostachys Renda* (CR) / kenaf fiber (K) (10C:0K, 7C:3K, 5C:5K, 3C:7K, 0C:10K) reinforced 0.5 wt.% MWCNT filled phenolic composites. The highest tensile and flexural properties was found for weight fraction of CR and kenaf fiber at 5C:5K (44.96 MPa) and 3C:7K (90.89 MPa) composites respectively, while the highest impact properties were obtained for 0C:10K composites (10.26 kJ/m²). The TGA, DTG and DSC results revealed that, 7C:3K composite revealed as the most thermal stability hybrid composites

of CR and kenaf fiber. The highest time to ignition (TTI) and fire performance index (FPI), the lowest total heat release (THR) and average mass loss rate (MLRAVG), with the lowest fire growth rate index (FIGRA) and maximum average rate of heat emission (MARHE) index, 3C:7K composite shows the best fire-retardant performance. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach considered 3C:7K composite to be the most desirable for use as a hybrid CR/kenaf fiber modified phenolic composite. A free fall drop test was performed to analyse the performance of the aircraft tray table. Non-destructive testing such as visual examination, dye penetration, Digital Detector Array (DDA), and Computed Tomography (CT-scan) method were carried out to investigate the damage mechanism and crack length. From the results it was observed that, as the impact energy increased from 1.50 J to 3.0 J, the crack length increased. There are 3-15% difference in crack sizing between dye penetration and DDA, indicating that DDA is more accurate. The research findings provision that hybridization of CR fiber and kenaf / MWCNT / phenolic composites has the potential to be used as green and biodegradable composites for interior components of the aviation sector, particularly tray table applications.

Keywords: Cyrtostachys renda; MWCNT; Phenolic; Mechanical, Thermal and Flammability properties

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

PENCIRIAN HYBRID CYRTOSTACHYS RENDA / KENAF (*Hibiscus cannabinus* L.) / NANOTIUB KARBON BERDINDING LAPISAN / FENOLIC BIO-KOMPOSIT BAGI MEJA DULANG PESAWAT

Oleh

TAMIL MOLI A/P LOGANATHAN

Oktober 2021

Pengerusi : Mohamed Thariq Hameed Sultan, PhD. Peng. CEng. PTech.
Fakulti : Kejuruteraan

Pesawat menggunakan serat karbon, gentian kaca, dan serat diperkuat aramid untuk bahagian strukturnya. Pengurusan sisa buangan tersebut memberikan implikasi terhadap keadaan persekitaran. Ini telah mencetuskan semula minat terhadap sumber biodegrasi hijau. Hasil daripada keputusan eksperimen mendapat bahawa tangkai daun *Cyrtostachys renda* (CR) berpotensi sebagai penguat berbanding dengan serat *Ptychosperma macarthurii* (PM) dalam komposit polimer yang boleh diaplikasikan pada bahagian struktur ringan. Berdasarkan eksperimen, terhadap beberapa parameter rawatan NaOH selama satu jam mendapat bahawa 3 wt.% NaOH boleh menghasilkan kesan yang ideal terhadap sifat serat CR. Komposit disediakan menggunakan mesin penekan panas. Analisa terhadap sifat mekanikal, fizikal dan kemudahbakaran serat CR sebagai pengukuhan dalam komposit bio-fenolik telah dilaksanakan. Bahan komposit yang dirawat dengan 3 wt.% NaOH CR dengan panjang gentian diantara julat 1.18-0.6, 0.6-0.3 dan kurang daripada 0.3 mm dalam 20 wt.% dan 40 wt.% telah disediakan dan didapati bahawa komposit yang mengandungi 40 wt.% dan panjang serat yang kurang daripada 0.3 mm menghasilkan daya tegangan dan lenturan tertinggi. Penilaian terhadap pengaruh serat CR dan kesan nanotiub karbon berdinding lapisan (MWCNT) terhadap sifat morfologi, haba, mekanikal dan sifat kemudahbakaran komposit bio-fenolik telah dijalankan. Kehadiran MWCNT didalam komposit fenolik telah meningkatkan daya tegangan, lenturan dan kekuatan hentaman masing-masing sebanyak 6.5%, 20% dan 8.7% dibandingkan dengan fenolik tulen. Tambahan pula, penambahan serat CR juga telah mengukuhkan kekuatan komposit fenolik diisi MWCNT dengan menambahbaik kekuatan lenturan, daya tegangan, dan kekuatan hentaman masing-masing sebanyak 16.7%, 45% dan 194%. Kaedah pengujian mekanikal, suhu dan kemudahbakaran telah dilaksanakan terhadap hibrid yang berlainan iaitu *Cystostachys Renda* (CR)/ serat kenaf (K) (10C:0K, 7C:3K, 5C:5K, 3C:7K, 0C:10K) diperkuat dengan komposit fenolik yang diubahsuai 0.5 wt% MWCNT. Sifat tegangan dan lenturan yang tertinggi

diperolehi bagi pecahan berat CR dan serat kenaf masing-masing pada 5C: 5K (44.96 MPa) dan 3C:7K (90.89 MPa), manakala kekuatan hentaman yang tertinggi diperolehi pada komposit 0C:10K (10.26 kJ/m²). Hasil keputusan TGA, DTG dan DSC menunjukkan bahawa komposit 7C:3K memberikan ketabilan tertinggi termal terhadap komposit hibrid CR dan serat kenaf. Masa yang paling tinggi untuk pencucuhan (TTI) dan indeks prestasi api (FPI), jumlah pembebasan haba yang paling rendah (THR) dan kadar pengurangan jisim purata (MLRAVG), dengan kadar indeks pertumbuhan api paling rendah (FIGRA) dan kadar indeks purata maksimum pelepasan haba (MARHE) menunjukkan komposit 3C:7K memberikan prestasi tahan api yang terbaik. Melalui pendekatan Teknik untuk Keutamaan Pesanan Persamaan Dengan Penyelesaian Ideal (TOPSIS) menunjukkan komposit 3C:7K adalah yang paling wajar untuk digunakan sebagai hibrid CR / serat kenaf diubahsuai komposit fenolik. Kaedah ujian jatuh bebas dilakukan bagi menganalisa prestasi prototaip meja dulang pesawat. Ujian tanpa musnah seperti kaedah pemeriksaan visual, penembusan pewarna, Array Pengesan Digital (DDA), dan Tomografi (CT-scan) telah dilaksanakan bagi menilai kemusnahan dan kesan rekahan. Hasil daripada keputusan kajian ini menunjukkan bahawa apabila tenaga hentaman meningkat dari 1.50 J kepada 3.0 J maka kesan rekahan turut meningkat. Terdapat perbezaan diantara 3-15% terhadap ukuran kesan rekahan diantara penggunaan kaedah penembusan pewarna dan DDA, menunjukkan bahawa kaedah DDA adalah lebih tepat. Hasil kajian menunjukkan bahawa hibridisasi serat CR dan kenaf / MWCNT/ fenolik yang diperkuat kenaf berpotensi digunakan sebagai komposit hijau yang mempunyai sifat biodegradasi untuk komponen dalam sektor penerangan, terutama pada aplikasi meja dulang.

Kata kunci: Cyrtostachys renda; MWCNT; Fenolik; Sifat Mekanikal, Termal dan Kemudahbakaran

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Mohamed Thariq bin Hameed Sultan, PhD, PEng, CEng, PTech.

Professor, Ir. Ts.

Faculty of Engineering

Universiti Putra Malaysia

(Chairman)

Abd Rahim bin Abu Talib, PhD, PEng, PTech

Professor, Ir. Ts.

Faculty of Engineering

Universiti Putra Malaysia

(Member)

Adi Azriff bin Basri, PhD

Senior Lecturer

Faculty of Engineering

Universiti Putra Malaysia

(Member)

Mohammad Jawaid, PhD

Research Fellow

Institute of Tropical Forestry and Forest Products

Universiti Putra Malaysia

(Member)

ZALILAH MOHD SHARIFF, PhD

Professor and Dean

School of Graduate Studies

Universiti Putra Malaysia

Date: 10 February 2022

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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Signature: _____

Name of Chairman

of Supervisory Committee: Prof. Ir. Ts. Dr. Mohamed Thariq bin Hameed Sultan

Signature: _____

Name of Member

of Supervisory Committee: Prof. Ir. Ts. Dr. Abd Rahim bin Abu Talib

Signature: _____

Name of Member

of Supervisory Committee: Dr. Adi Azriff bin Basri

Signature: _____

Name of Member

of Supervisory Committee: Dr. Mohammad Jawaid

TABLE OF CONTENTS

	Page
ABSTRACT	i
ABSTRAK	iii
ACKNOWLEDGEMENTS	v
APPROVAL	vi
DECLARATION	viii
LIST OF TABLES	xiv
LIST OF FIGURES	xviii
LIST OF ABBREVIATIONS	xxiv
 CHAPTER	
 1 INTRODUCTION	 1
1.1 Background	1
1.2 Problem statement	4
1.3 Objectives of the study	5
1.3.1 Specific Objectives	5
1.4 Significance of this study	6
1.5 Scope of this study	6
1.6 Thesis outline	7
1.6.1 Chapter 1	7
1.6.2 Chapter 2	7
1.6.3 Chapter 3	7
1.6.4 Chapter 4 (Objective 1: Article 1)	7
1.6.5 Chapter 5 (Objective 1: Article 2)	8
1.6.6 Chapter 6 (Objective 1: Article 3)	8
1.6.7 Chapter 7 (Objective 2: Article 4)	8
1.6.8 Chapter 8 (Objective 2: Article 5)	8
1.6.9 Chapter 9 (Objective 3: Article 6)	9
1.6.10 Chapter 10 (Objective 4: Article 7)	9
1.6.11 Chapter 11 (Objective 4: Article 8)	9
1.6.12 Chapter 12 (Objective 5: Article 9)	9
1.6.13 Chapter 13	10
 2 LITERATURE REVIEW	 11
2.1 Introduction	11
2.2 Natural fiber	11
2.3 Chemical modification of the natural fiber	12
2.4 Natural fiber reinforced polymeric composites	13
2.5 Phenolic composites	13
2.5.1 Natural fiber reinforced phenolic composite	14

2.5.2	Hybrid fiber reinforced phenolic composites	15
2.6	Effect of MWCNT filler on the properties of phenolic nano-composites	17
2.7	Physical properties of natural fiber / nanofiller-based hybrid phenolic composites	18
2.8	Mechanical properties of natural hybrid fiber based phenolic composites	19
2.9	Thermal, dynamic mechanical and flammability properties of natural hybrid based phenolic composites	19
2.10	NDT inspection on natural composites	20
2.11	Application	21
2.11.1	Aircraft cabin interior composites	21
2.11.2	Aircraft tray table	23
2.12	Literature gap	26
2.13	Summary	28
3	MATERIALS AND METHODS	29
3.1	Introduction	29
3.2	Overall structure of the research	29
3.3	Selection of suitable part of fiber from CR and PM of landscaping plant	31
3.4	NaOH treatment on the selected fiber	31
3.5	Material	31
3.6	Composite fabrication	32
3.6.1	CR fiber reinforced phenolic composites	32
3.6.2	CR fiber reinforced MWCNT / phenolic composites	33
3.6.3	Hybrid kenaf / CR reinforced MWCNT / phenolic composites	34
3.7	Characterization	35
3.7.1	FTIR	35
3.7.2	Chemical composition analysis	36
3.7.3	Density of fiber	36
3.7.4	X-ray diffraction (XRD)	36
3.7.5	Thermogravimetric analysis (TGA)	36
3.7.6	Single fiber tensile test	37
3.7.7	Interfacial shear stress (IFSS)	37
3.7.8	Density and void content of composite	37
3.7.9	Water absorption and thickness swelling composite	38
3.7.10	Tensile testing	38
3.7.11	Flexural testing	39
3.7.12	Impact testing	39
3.7.13	Low velocity Impact (LVI)	39
3.7.14	Free fall drop test	40
3.7.15	Dynamic Mechanical Analysis (DMA)	40

	3.7.16	Underwriters Laboratories test (UL-94)	40
	3.7.17	Limiting oxygen index (LOI)	40
	3.7.18	Cone calorimetry	41
	3.7.19	Smoke density	41
	3.7.20	Scanning Electron Microscopy (SEM)	41
	3.7.21	Field Emission Scanning Electron Microscopy (FE-SEM)	42
	3.7.22	Statistical analysis	42
	3.8	Summary	42
4	CHARACTERIZATION OF NEW CELLULOSIC CYRTOSTACHYS RENDA AND PTYCHOSPERMA MACARTHURII FIBERS FROM LANDSCAPING PLANTS		43
	Article 1		43
	Acceptance letter		60
	Copyright permission		61
5	COMPARATIVE STUDY OF MECHANICAL PROPERTIES OF CHEMICALLY TREATED AND UNTREATED CYRTOSTACHYS RENDA FIBERS		62
	Article 2		62
	Acceptance letter		81
	Copyright permission		82
6	CHARACTERIZATION OF ALKALI TREATED NEW CELLULOSIC FIBER FROM CYRTOSTACHYS RENDA		83
	Article 3		83
	Acceptance letter		99
	Copyright permission		100
7	PHYSICO-MECHANICAL AND FLAMMABILITY PROPERTIES OF CYRTOSTACHYS RENDA FIBERS REINFORCED PHENOLIC RESIN BIO-COMPOSITES		101
	Article 4		101
	Acceptance letter		126
	Copyright permission		127
8	INFRARED THERMOGRAPHIC AND ULTRASONIC INSPECTION OF RANDOMLY ORIENTED SHORT-NATURAL FIBER-REINFORCED POLYMERIC COMPOSITES		128
	Article 5		128
	Acceptance letter		143
	Copyright permission		144

9	EFFECT OF CYRTOSTACHYS RENDA FIBER LOADING ON THE MECHANICAL, MORPHOLOGY, AND FLAMMABILITY PROPERTIES OF MULTI-WALLED CARBON NANOTUBES/PHENOLIC BIO-COMPOSITES	145
	Article 6	145
	Acceptance letter	172
	Copyright permission	173
10	PHYSICAL, MECHANICAL, AND MORPHOLOGICAL PROPERTIES OF HYBRID CYRTOSTACHYS RENDA/KENAF FIBER REINFORCED WITH MULTI-WALLED CARBON NANOTUBES (MWCNT)-PHENOLIC COMPOSITES	174
	Article 7	174
	Acceptance letter	197
	Copyright permission	198
11	THERMAL DEGRADATION, VISCO-ELASTIC AND FIRE RETARDANT BEHAVIOR OF HYBRID CYRTOSTACHYS RENDA / KENAF FIBER REINFORCED MWCNT MODIFIED PHENOLIC COMPOSITES	199
	Article 8	199
	Submission Notice	227
12	LOW VELOCITY IMPACT, FREE FALL DROP TEST OF PROTOTYPE AND FAILURE ANALYSIS OF HYBRID CR/KENAF REINFORCED MWCNT - PHENOLIC COMPOSITES	228
	Article 9	228
	Submission Notice	251
13	CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH	252
13.1	Conclusions	252
13.2	Recommendations for future research	254
	REFERENCES	255
	BIODATA OF STUDENT	292
	LIST OF PUBLICATIONS	293

LIST OF TABLES

Table		Page
2.1	Natural fiber reinforced phenolic composites	15
2.2	Effect of hybridization on the properties of phenolic composites	17
2.3	Physical properties of natural / natural fiber hybrid phenolic composites	18
2.4	Mechanical properties of natural / natural fiber hybrid based phenolic composites	19
2.5	Thermal, dynamic mechanical properties and flammability of natural / natural fiber hybrid phenolic composites	20
2.6	Passing requirements of the FAR 25.853a test	24
2.7	Passing requirements of the rate of heat release (OSU)	24
2.8	Properties of High-Performance Engineering Polymers in Cabin Interior for Tray Tables	25
2.9	Recent research conducted on bio-composites	27
3.1	Physical and mechanical properties of CR and kenaf fiber	32
3.2	Formulations of CR fiber reinforced phenolic composites	33
3.3	Formulation of composites	34
3.4	Formulation of hybrid composites	35
4.1	Density of CR and PM fibers compared to other palm fibers	49
4.2	Chemical composition of CR and PM in comparison with other palm fibers	50
4.3	Percentage of crystallinity index of different parts of CR and PM	53
4.4	Thermogravimetric data for leaf stalk of CR and PM fibers	54

4.5	Tensile properties of leaf stalk of CR and with other palm fibers	57
4.6	Interfacial shear stress for CR fiber in comparison with other natural fibers	58
5.1	Parameters of NaOH treatment reported in the literature	64
5.2	Conditions of Cyrtostachys renda (CR) fiber treatment	65
5.3	Tensile properties of untreated and NaOH-treated CR fiber	68
5.4	ANOVA results for tensile strength and interfacial shear strength	75
6.1	Mechanical properties of untreated and treated areca reinforced polymer composites	85
6.2	The chemical composition of untreated and NaOH-treated CR fiber	91
6.3	The corresponding peak for the untreated and treated CR fiber.	93
6.4	Thermal degradation and char residual of the raw and NaOH-treated CR fiber	97
7.1	Formulations of CR fiber reinforced phenolic composites	106
7.2	A comparison of tensile modulus obtained from theoretical and experimental of randomly oriented discontinuous fiber	117
7.3	UL 94 and LOI for CR reinforced phenolic composites	124
8.1	Size and content of palm fiber in phenolic composites	132
8.2	Result of Temperature-Time Diagram for tensile testing of palm-fiber reinforced phenolic composites	138
8.3	Time taken for the tensile specimen to fracture	139
8.4	Impact properties of palm-fiber-reinforced phenolic composites	140
8.5	A-scan of attenuation of various sizes and contents of palm fiber in phenolic composites	141
9.1	Composites formulation	150

9.2	Characteristics of criteria	153
9.3	Density and void content of CR fiber-reinforced MWCNT / phenolic composites	154
9.4	Comparison of CR fiber-reinforced MWCNT / Phenolic composites with CR fiber-reinforced phenolic composites	158
9.5	UL 94 and LOI for CR fiber-reinforced MWCNT / Phenolic composites	168
9.6	Decision Matrix	169
9.7	The normalized matrix	169
9.8	The weighted normalized matrix	169
9.9	The positive and negative ideal values	169
9.10	Distance to positive, negative ideal points and the relative closeness value and ranking	169
10.1	Physical and mechanical properties of CR and kenaf fiber	178
10.2	Formulation of hybrid composites	178
10.3	Characteristics of Criteria	182
10.4	Density and void content of hybrid CR/K reinforced phenolic composites	184
10.5	Hybridization of fibers phenolic composites on tensile properties	188
10.6	Decision matrix	193
10.7	The normalized matrix	193
10.8	The weighted normalized matrix	194
10.9	The positive and negative ideal values	194
10.10	Distance to positive, negative ideal points, and the relative closeness value and ranking	194
11.1	Formulation of hybrid composites	204
11.2	Characteristics of Criteria	207

11.3	Profiles of decomposition of hybrid composites in nitrogen environment	209
11.4	Result obtained from DSC graph	211
11.5	Results of DMA analysis on C, K, and hybrid composites	215
11.6	Data obtained for UL-94 Horizontal and LOI testing for hybrid (C and K) fiber reinforced MWCNT/ phenolic composites	219
11.7	Cone calorimetry data for CR/ kenaf reinforced phenolic composites	220
11.8	Smoke emission properties of CR/ kenaf reinforced phenolic hybrid composites	223
11.9	Decision Matrix	224
11.10	The normalized matrix	224
11.11	The weighted normalized matrix	224
11.12	The positive and negative ideal values	224
11.13	Distance to positive, negative ideal points and the relative closeness value and ranking	225
12.1	Physical and mechanical properties of CR and kenaf fiber	231
12.2	Data tabulation of low velocity impact of 3C:7K hybrid bio-composite	238
12.3	Tri-axial linear accelerometer for horizontal b) vertical position of tray table	241
12.4	Results of NDT inspection on LVI specimens	246
12.5	Results of NDT inspection on Prototype of tray table	248

LIST OF FIGURES

Figure		Page
1.1	(a) <i>Cyrtostachys renda</i> (CR) and (b) <i>Ptychosperma macarthurii</i> (PM)	2
1.2	Material selection strategies for aircraft tray tables	3
2.1	The complex hierarchical structure of elementary bio-fiber	12
2.2	Basic chemistry of structure of resole and novolac formation from Phenol Formaldehyde	14
2.3	Composites parts of the aircraft cabin interior	23
3.1	Overall structure this research	30
3.2	NaOH treatment on CR fiber	31
3.3	Sample preparation in powder form for chemical analysis, FTIR, XRD, and TGA	32
3.4	Fabrication of CR fiber reinforced phenolic composites	33
3.5	Schematic diagram of the fabrication of CR fiber-reinforcement MWCNT Phenolic composites by dry dispersion method	34
3.6	Schematic diagram of hybrid composite preparation	35
4.1	Selected part from (a) <i>Cyrtostachys renda</i> (CR) and (b) <i>Ptychosperma macarthurii</i> (PM)	45
4.2	Sample preparation in powder form for chemical analysis, FTIR, XRD, and TGA	46
4.3	Procedure of micro-droplet testing	48
4.4	FTIR of different parts of (a) CR (b) PM	51
4.5	XRD pattern on (a) CR (b) PM fibers	52
4.6	TGA-DTG thermograms of leaf stalk of (a) CR and (b) PM	55
4.7	Tensile strength versus diameter of CR fiber	57
4.8	Tensile strength versus diameter of CR fiber	57

4.9	SEM morphology on the fractured surface of tensile of the fiber	59
5.1	Adjacent sides were cut before tensile testing	66
5.2	Schematic diagram of the micro-droplet test from a side view	67
5.3	Tensile stress-strain curves of untreated and NaOH-treated single CR fibers	70
5.4a	Tensile properties of untreated and alkali-treated CR fiber: (a) tensile strength	71
5.4b	(b) Young's modulus, and (c) strain at failure	72
5.5	IFSS testing on untreated and NaOH treated <i>Cyrtostachys renda</i> (CR) fibers	73
5.6	Contact surface between alkali-treated fiber and matrix	74
5.7	Micrographs of surface and fractured surface of untreated and treated CR fiber	77
5.8	Breakdown of ester or ether bonding due to NaOH treatment	79
6.1	Extraction of CR fibers	87
6.2	Alkali treatment on CR fibers	87
6.3	Density of the untreated and NaOH-treated CR fiber	90
6.4	FTIR spectra of the untreated and NaOH-treated CR fiber	92
6.5	X-ray diffractometry of the untreated and NaOH-treated CR fiber	94
6.6	The crystallinity index (CI%) vs the cellulose content of CR fiber	94
6.7	Visual inspection of leaf stalk of CR fiber before and after the NaOH treatment	95
6.8	(a) TGA and (b) DTG of the untreated and NaOH-treated stalk leaf of CR fiber	96
7.1	Preparation of CR fiber	105
7.2	Density and voids content of CR/phenolic composites	110

7.3	Water absorption of CR reinforced phenolic composites	112
7.4	Schematic diagram on probable distribution and dispersion of CR fibers in phenolic composites	112
7.5	Thickness swelling of CR reinforced phenolic composites	113
7.6	Effect of water molecules on CR reinforced phenolic composites	114
7.7	The graph of water absorption and thickness swelling on fiber length	114
7.8	Tensile strength and Modulus of CR/phenolic composites	116
7.9	SEM micrographs of CR reinforced phenolic composites	119
7.10	a) Debonding stage before fiber pull out b) CR fiber with length A, c) CR fiber with length B, d) CR fiber with length C	120
7.11	Flexural strength and modulus of CR/phenolic composites	121
7.12	Impact strength of CR/phenolic composites	123
8.1	(A) IR-thermography mapping during the tensile testing (B) Snapshot obtained from a video recorded with the infra-red camera tracking the hotspot (Area 1, 1 × 1 pixel measurement area) and (C) Example of Temperature-Time Diagram for tensile testing after being tested	133
8.2	(A) Transducer and (B) Ultrasonic imaging of (A-scan, B-scan and C-scan)	135
8.3	The thermographic images of specimen-40S during tensile testing (A) before fracture (B) at the failure time (C) after fractured	137
9.1	Schematic diagram of the fabrication of CR fiber-reinforcement MWCNT-Phenolic composites by dry dispersion method	149
9.2	Density and voids content of CR fiber-reinforced MWCNT-Phenolic composites	155
9.3	(a) Percentage of water absorption and (b) Thickness swelling of CR reinforced MWCNT-Phenolic composites	156

9.4	Diffusion of water molecules into CR fiber-reinforced MWCNT-Phenolic composites	157
9.5	Schematic diagram of water absorption of CR fiber-reinforced MWCNT-Phenolic composites	157
9.6	CR fiber loading on tensile strength and Modulus of MWCNT-Phenolic composites	159
9.7	Chemical structure and bonding of MWCNT-Phenolic	160
9.8	FESEM micrographs of the bio-composites filled with MWCNT and CR fiber (a1,a2) MWCNT + PH, (b1,b2) 40% CR + MWCNT + PH, (c1,c2) 50% CR + MWCNT + PH, (c1,c2) 50% CR + MWCNT + PH, (d1,d2) 60% CR + MWCNT + PH	162
9.9	Effect of CR fiber loading on flexural strength and Modulus of MWCNT-Phenolic composites	163
9.10	Effect of the fiber loading on impact strength of MWCNT-Phenolic composites	164
9.11	Schematic diagram of the impact energy propagation in CR fiber-reinforced MWCNT-Phenolic composite	166
9.12	Relative closeness factor of phenolic composites	173
10.1	Schematic diagram of hybrid composite preparation	179
10.2	Water absorption percentage of CR and/or kenaf reinforced phenolic composites	185
10.3	Thickness swelling percentage of CR and/or kenaf reinforced phenolic composites	186
10.4	(a) Tensile stress vs. strain curve, (b) tensile strength and modulus, of hybridization between C and K fibers	187
10.5	FE-SEM images of tensile fractured specimens of (a) 10C:0K, (b) 7C:3K, (c) 5C:5K, (d) 3C:7K (e) 0C:10K composites at magnification of $\times 1000$, (f) 10C:0K composites at magnification of $\times 50,000$	190
10.6	Schematic illustration of tensile fracture on CR and kenaf fiber	191
10.7	(a) Flexural stress vs. strain curve and (b) flexural strength and modulus, of hybridization between CR and K fibers	192

10.8	Impact strength of hybridization between C and K fibers	193
10.9	Relative closeness factor of C and/or K hybrid MWCNT–phenolic composite	195
11.1	a) Horizontal UL-94 testing b) Limiting Oxygen Index (LOI) testing	206
11.2	TGA and DTG curve of hybrid CR and Kenaf reinforced phenolic composites	209
11.3	Graphical represents of the thermal degradation pathway of CR/Kenaf reinforced MWCNT/phenolic hybrid composites	210
11.4	DSC graph of hybrid composites	211
11.5	Results of DMA a) Storage Modulus, b) Loss Modulus, c) $\tan \delta$	213
11.6	Chemical bonding of natural fiber with phenolic resin	214
11.7	Cole–Cole plots of the C, K and hybrid composites	217
11.8	The char formation during the pyrolysis process of the composite	219
11.9	Heat release rate curves as function of time for C/K reinforced MWCNT modified phenolic composites	222
11.10	Relative closeness factor of C and/ or K hybrid modified phenolic composite	225
12.1	Schematic diagram of hybrid composite preparation for LVI and prototype of tray table	232
12.2	Drop-weight impact testing for low velocity impact	233
12.3	a) Prototype of tray table, b) A free fall drop tester, c) Prototype dropped in horizontal position and d) vertical position	234
12.4	Procedure of dye penetration testing	235
12.5	Digital Detector Array Radiography	236
12.6	CT scanning	236
12.7	Force vs displacement curve of 3C:7K hybrid bio-composites	237

12.8	Energy vs time curve of 3C:7K hybrid bio-composites	238
12.9	Data entry for Environment in King Design software	239
12.10	Gravitational acceleration versus time at a) horizontal position, b) vertical position	240
12.11	Energy conversion	241
12.12	Sizing of the cracks from DDA images of a) 1.5 J, b) 2.0 J, c) 2.5 J d) 3.0 J	243
12.13	FE-SEM images of 3C:7K specimens at magnification of x50000	244
12.14	Crack propagation during impact energy on composite sample	245

LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
AFRA	Aircraft Fleet Recycling Association
CO	Carbon monoxide
CR	<i>Cyrtostachys renda</i>
CT-scan	Computed Tomography
D	Diameters of every single fiber
DMA	Dynamic Mechanical Analysis
DSC	Differential scanning calorimetry
EFB	Oil palm empty fruit bunch
FAA	Federal Aviation Administration
FE-SEM	Field Emission Scanning Electron Microscopy
FIGRA	Fire growth rate index
FPI	Fire performance index
FRP	Fiber reinforced polymer
FST	Flame, smoke, and toxicity
FTIR	Fourier Transform Infrared Spectroscopy
HCN	Hydrogen cyanide
HF	Hydrogen fluoride
IFSS	Interfacial shear stress
L	Embedded length of the droplets
LOI	Limiting oxygen index
LVI	Low velocity impact

MARHE	Maximum average rate of heat emission
MLRAVG	Average mass loss rate
MWCNT	Multi-Walled Carbon Nanotubes
NaOH	Sodium hydroxide
NDF	Neutral Detergent Fiber
NDT	Non-destructive testing
Nox	Nitrogen oxides
PM	<i>Ptychosperma macarthurii</i>
SEM	Scanning Electron Microscopy
SO2	Sulfur dioxide
HCL	Hydrogen chloride
TGA	Thermogravimetric analysis
THR	Total heat release
TTI	Time to ignition
UL 94	Underwriters Laboratories
vol%	Volume percentage
wt%	Weight percentage
XRD	X-ray Diffractometry

CHAPTER 1

INTRODUCTION

1.1 Background

For over 3000 years, lignocellulosic fibers are used as reinforcing in polymeric. In 1908, researchers began investigating fiber reinforced polymeric composites, and cotton was the first reinforced polymer composite to be used in aircraft radar (Mohit & Arul Mozhi Selvan, 2018). Lignocellulosic fiber once again has received increasing research attention since the European Union legislation was introduced in 2006 (Peças, Carvalho, Salman, & Leite, 2018). This stringent regulation towards direct end-of-life automobile vehicles stipulates recycling of more than 85% of their total weight and in year of 2015, it was increased to 95%. This regulations and rules has accelerated the implementation of natural fiber reinforced polymers in automobiles for environmental considerations such as carbon emissions, embodied energy, toxicity and depletion of resources. Therefore, the automotive industry has adopted natural fiber reinforced polymer composites for most of their components, such as door panels, seat backs, and dashboards. At the same time, the Process for Advanced Management of End-of-Life Aircraft (PAMELA) aims to improve the quantity of recycled material used for aircrafts in the coming years from 70–75% up to 90% (Zhao, Verhagen, & Curran, 2020). Meanwhile, the requirement of stringent laws of Aircraft Fleet Recycling Association known as AFRA's mission to developing and promoting the safe and sustainable management of end of life aircraft and components (Mohammed, Leman, Jawaid, Ghazali, & Ishak, 2017). Thus, the exploration of the properties of lignocellulosic fibers as sustainable agro-waste materials has attracted wide interest, to support the continuous demands from the manufacturer. Therefore, the transformation from synthetic to natural fibers also inspired the aviation industry by strengthening a number of its components, especially initiate from the interior components from natural resources of fiber and matrix.

Besides agro-wastes, there are some other potential plant fibers which has not been extensively explored from the Arecaceae family, i.e., *Cyrtostachys renda* (CR) (Figure 1a) and *Ptychosperma macarthurii* (PM) (Figure 1b). CR originated in Thailand, Malaysia, Sumatra, Borneo, and Indonesia. It is a clustering palm tree which is slender multi-stemmed with a maximum height of 10 m (Loganathan et al. 2020). It has a bright red crown shaft and leaf sheath, which makes it unique from other Arecaceae species. Although PM is native to Australia and New Guinea, this plant is currently abundantly available growing well throughout the Peninsular of Malaysia as ornamental plants planted in highways, recreational areas, and housing projects. These two plants have been selected in our current study for the following reasons: (1) Their adaptability, availability, and high growth rates which enable access to large raw material stocks. (2) These plants are only used for landscaping purpose and their wastes are currently

underutilized. (3) These plants have physical similarities and are from the same family of *Areca catechu*.

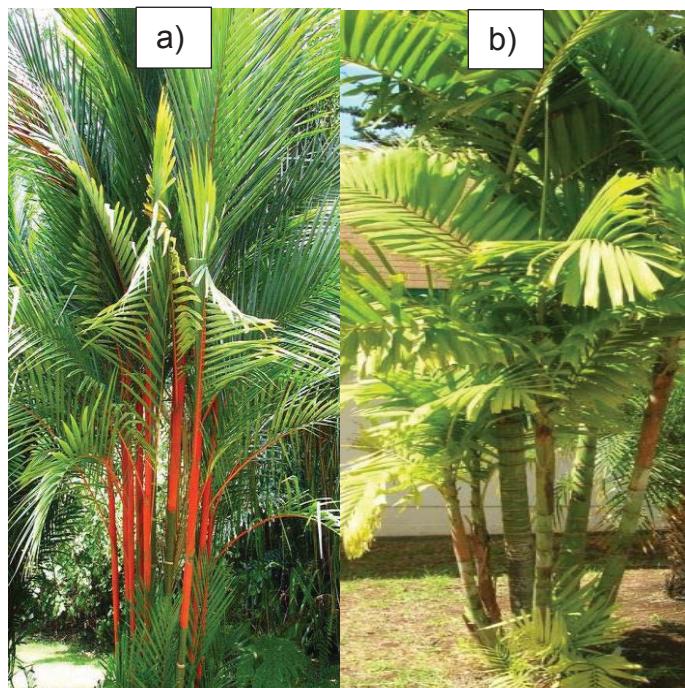


Figure 1.1: (a) *Cyrtostachys renda* (CR) and (b) *Ptychosperma macarthurii* (PM)

Based on the chemical analysis carried out on the top stem, mid stem, bottom stem, leaf stalk and frond showed that leaf stalk of CR is having highest cellulosic content. Kenaf fiber which is known as *Hibiscus cannabinus* L., is a type of bast fiber which has great properties of superior toughness, strength and stiff agro and sufficient potential to be the reinforcement in polymeric composites and high aspect ratio in comparison with other fibers (Asyraf, Rafidah, Azrina, & Razman, 2021). Kenaf is an economic crop which is grown in Malaysia and in the United States especially states like Mississippi, Texas, Florida and North Carolina (Bourguignon, Moore, Lenssen, & Baldwin, 2020). Reinforcement with kenaf is not only explored extensively in the aircraft application but also there are potential for commercialization of our nation's natural fibers to the global market and could eventually increase our economic growth. Kenaf fibers are natural sources that can contribute towards the development of eco-friendly and sustainable assets for the automotive, construction, sports industries, food packing and furniture industries (Sreenivas, Krishnamurthy, & Arpitha, 2020).

Figure 1.2 shows the Boeing 737-800 aircraft tray tables that were taken from the economic and business class seating tables. The common defects such as bulging and cracks are found on the surface of the tray tables, which may be due

to the temperature changes based on the altitudes, especially during the long layover at the remote bay when all doors are closed. Defects like bulging and crack occur due to the fabrication of polymers without the support of the reinforcement, especially fiber as the load transfer mechanism. The physical and mechanical properties of materials are altered and improved by the composite fillers and reinforcements. Fillers and reinforced products not only reduces the volume of matrix resin material costs, but also enhances composite properties in terms of thermal conductivity, electrical resistance, friction, wear, and flame retardancy. Nanoparticles are also added to the polymers to reduce the flammability in the interior component of the aircraft (Chawla, 2012; Shen & Liu, 2018).

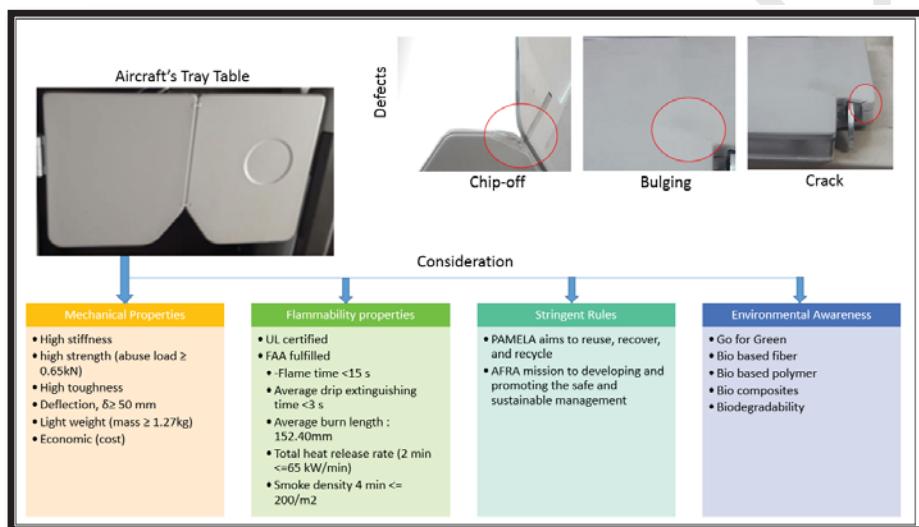


Figure 1.2: Material selection strategies for aircraft tray tables

Phenolic resin has a number of distinctive characteristics, including ease of handling, toughness, excellent flame retardance, high resistance to heat, low smoke emission, and high thermal stability (Mohammad Jawaid & Asim, 2020). Since the invention of phenolic resin, numerous uses of timber / fiber reinforced composites have been developed in various applications such as aircraft's ceiling panel and sidewalls, abrasive product, particleboard, thermal and electrical insulation. Phenolic resin is renowned for its inherent fire resistance. Nevertheless, it exhibits relatively low mechanical strength and brittleness. Therefore, low content of MWCNT as inorganic nanoparticles is used as a modifier to toughen the phenolic composites. In a previous study, it was reported that dry mixing dispersion of MWCNT in novolac type phenolic resin after 25 hours of ball milling exhibited significant improvement in flexural strength compared to wet mixing dispersion (Mathur et al., 2010). Eslami et al. stated that the flexural strength and thermal stability of phenolic composites increase with the rise in MWCNT up to 0.5 wt% (Eslami, Yazdani, & Mirzapour, 2015). The addition of nanoparticles such as MWCNT further improves the thermal

resistance of polymeric matrix. As soon as the pyrolysis reaction began, nanoparticles formed an extremely viscous melting layer and covered the residual char. Char is represented as an antioxidant and a thermal protection barrier in developing a carbon-based network. The addition of MWCNT resulted in the re-emission of large amounts of incident radiation to the gas phase in the charcoal residues, which reduced the heat transferred to the inner virgin material and reduced the pyrolysis rate (Allcorn, Natali, & Koo, 2013). To date, studies have been performed to investigate the thermal effects of MWCNT on phenolic composites (Eslami et al., 2015; J.-M. Park et al., 2014) and thermal properties of natural fibers as well as hybrid fibers on phenolic composites (M Asim, Jawaid, Nasir, & Saba, 2018; Mohd Asim et al., 2018). However, no study has been reported to examine the thermal properties of the integration of hybrid natural fibers into MWCNT/phenolic composites.

1.2 Problem statement

Fiberglass and carbon fiber reinforced polymer are abundantly used in the aerospace and automotive industry due to their superior properties on strength, high fatigue, low thermal expansion, and corrosion resistance (Rybicka, Tiwari, Alvarez Del Campo, & Howarth, 2015). The total amount of composite waste material in the world is expected to reach 50,000 metric tons by 2020 (Bledzki et al., 2020). In 2020, the global market for continuous fiber reinforced composite is forecast to reach about 95 billion dollars, which is up by 40% from 2014 (Job et al., 2016). Such a huge production growth, resulted in serious waste management completion of the life cycle of the aircraft product. The environmental impact occurs when the high loading of these non-decomposing materials accumulated in the landfills. The stringent requirement established by Directive 2008/98/EC of the European Parliament and of the Council 'On waste and revocation of a number of directives', where not more than 10% of the waste produced is permitted to be disposed, and by 2030 the norm will be reduced to 5% (Directive, 2010).

The driven momentum to introduced renewable materials in composite fabrication is generally to reduce CO₂ emission, promotes biodegradable ability, awareness on environmental issues especially aircraft dismantled components and defect manufactured components being dumping in landfills, which is harmful to the ecology and environment, besides depletion in the usage of petroleum-based resources. The selection of proper natural fibers as reinforced composite for aircraft interior is essential by considering density, cost, recycle potential, sustainability, resources requirement and the properties required to withstand with environmental load or condition to customize for the specific application. However, the lack of research studies on aircraft interior structures especially on the selection natural fibers, compared with the performance of existing manmade synthetic fiber reinforced composites. The aircraft's composite must comply with the fire retardant requirements in accordance with United States' Federal Aviation Administration (FAA), FAR 25.853a (vertical Bunsen burner test) and FAR 25.853d (OSU heat release rate) to measure

specific optical density of solid material smoke generated (Özmen, Üreyen, & Koparal, 2020).

Currently, the high-performance engineering polymer materials such as KYDEX, Royalite, PEEK and Boltran based GFRP composites has been used for aircraft tray table application. The major impediment of using these engineering polymers are that their non-biodegradability, high processing and manufacturing cost. Moreover, these polymers pollutes the environment and affects the ecosystem. Hence the selection of phenolic resin extracted from chestnut shell liquid (CNSL), is that they are naturally flame retardant and anticipated to comply with the requirements of the FAA. In addition, the fiber sources mainly from natural fiber of *Cyrtostachys renda* (CR) has never been properly explored. This research was therefore mainly carried out to fill the gap by studying the effects of hybridization of CR and kenaf reinforced MWCNT filled phenolic composites.

The goal of this study was to develop bio-composites and environmentally sustainable material with substantial improvements compared to pristine phenolic for aircraft tray table application. Also, this research has focused on evaluating the physical, mechanical, thermal and flammability properties of kenaf / CR phenolic hybrid composites with and without the presence of MWCNT. Moreover, the final product (tray table) has been tested through free fall drop test.

1.3 Objectives of the study

The main objective of this research is to develop biodegradable, green composite based natural fiber and matrix for structural application, particularly for the tray table. The specific research objectives are as follows: -

- i. To investigate the effect of NaOH treatment on the physical, chemical and thermal properties of best fiber properties selected from *Cyrtostachys renda* and *Ptychosperma macarthurii*, landscaping plants.
- ii. To evaluate the effect of size and loading of NaOH treated CR fiber from the first objective on the physical, mechanical and flammability properties of phenolic reinforced composites.
- iii. To investigate the effect of CR fiber loading on physical, mechanical and flammability properties of MWCNT/phenolic composites.
- iv. To investigate the kenaf hybridization from the optimum loading on physical, mechanical, thermal and flammability properties of CR / MWCNT filled phenolic hybrid composites.
- v. To evaluate low velocity impact and free fall drop test on the prototype of tray table from best configuration of kenaf / CR phenolic hybrid composites.

1.4 Significance of this study

These days, in response to environmental and emissions regulations, several researchers are focusing their efforts on reducing the utilization of petroleum-based resources. Synthetic fibers have profound impact on the environment and have waste management problems. The prohibition on composite landfills, led by the evacuation of aircrafts owing to the COVID-19 pandemic, is greatly stimulating the adoption of a sustainability and recycling strategy. The exploration of bio-composites generated from bio-based fibers and matrix developed from agricultural waste continues to expand in an effort to replace traditional fossil-based composites. In comparison to synthetic fiber based composites, natural or bio-based fiber composites are renewable, sustainable, exhibit low environmental impact and can be utilized in numerous applications. Therefore, hybridization of *Cyrtostachys renda* / kenaf fibers is anticipated to have greater properties of bio hybrid composites and will adversely affect the mechanical, physical and chemical in structural applications. Furthermore, the selection of bio-based matrix (Bio-phenolic produced from cashew nut shell liquid) added value to bio-degradability. Consequently, the development of food tray table with high strength to weight ratio by natural hybrid composite is a good solution for the aircraft industry to minimize the interiors maintenance issues as well as being environmentally friendly by the preservation of these natural resources. At the same time, it would also fulfil the requirements of stringent laws of Aircraft Fleet Recycling Association known as AFRA's mission of developing and promoting the safe and sustainable management of end-of-life aircraft and its components. Therefore, this study proposes the development of natural hybrid composites which is biodegradable that is expected to be a good alternative solution for aircraft interior applications.

There have been only a few studies that have postulated the use of natural fibers for aircraft interior particularly, for tray table application. Mechanical, physical, thermal, and flammability properties are the most critical factors to consider when developing the material for tray table. In the aircraft industry, fabricating tray tables from natural fiber composites will further minimize the aircraft's total weight and hence fuel usage. Furthermore, it will pave the way for further research into natural composites with applications ranging from aircrafts to automobiles, packaging, aerospace, building, agricultural, retail, maritime, recreational structures, and etc. On the other hand, MWCNT filled phenolic composites in the FRP composites has become an interesting research approach to improve the mechanical, physical, thermal and flammability properties of the nano-composites.

1.5 Scope of this study

The current research is limited to the experimental evaluation of physical, mechanical, thermal and flammability properties of hybridization of CR / kenaf fiber MWCNT filled phenolic hybrid composites. Prior to the fabrication of the composites, short CR and kenaf fiber with a length of < 0.3 mm were treated with

a 3 wt. % concentration of NaOH for an hour. The materials utilized in the study were limited to phenolic, CR fiber, kenaf, MWCNT and NaOH pallet. The random oriented composites were fabricated by hot press. 0.5 wt.% of MWCNT was used as nano-filler. The influence of adding different wt.% of CR and CR / kenaf on the physical (density, water absorption, thickness swelling), mechanical properties (tensile, flexural, impact), morphological, thermal degradation, viscoelastic and flammability properties, of the composite and hybrid composites were evaluated with presence of 0.5 wt.% of MWCNT.

1.6 Thesis outline

This thesis has been structured into 13 chapters according to alternative thesis format of Universiti Putra Malaysia (UPM) based on the publications on which each chapter (4-12) contains its introduction, materials, methods, results, discussions, and conclusions. Brief description of each chapter has been addressed in the following section.

1.6.1 Chapter 1

This chapter discusses the background of the research, the problem statements, the objectives, scope, and significance of the study, as well as the outline of the thesis.

1.6.2 Chapter 2

This chapter provides a systematic and comprehensive analysis of the literature on natural fiber composites, hybrid natural fiber composites, phenolic composites, MWCNT filled phenolic composites, the physical, mechanical, thermal, and flammability properties of natural hybrid composites, and non-destructive testing (NDT) inspection of natural composites.

1.6.3 Chapter 3

This chapter contains a comprehensive description of the study's materials, methodology, and characterization.

1.6.4 Chapter 4 (Objective 1: Article 1)

This chapter deals with the first objective supported by the first research article entitled "Characterization of new cellulosic *Cyrtostachys renda* and *Ptychosperma macarthurii* Fibers from Landscaping Plants". This research work

focused on selection of suitable plant and part of fiber (stem, leaf stalk, and frond) from *Cyrtostachys renda* (CR) and *Ptychosperma macarthurii* (PM) fibers (areca family) of landscaping plants. From the analysis, leaf stalk of CR has been chosen as a potential reinforcement in the polymeric composites for lightweight applications.

1.6.5 Chapter 5 (Objective 1: Article 2)

This chapter also presents the first objective supported by the second research article entitled “Comparative Study of Mechanical Properties of Chemically Treated and Untreated *Cyrtostachys renda* Fibers”. This study investigated the effect of sodium hydroxide (NaOH) treatment on the strength and stiffness of *Cyrtostachys renda* (CR) leaf stalk fibers, which could potentially serve as reinforcement for polymer composites. Chemical treatment was performed with NaOH concentrations of 1, 3, and 5 wt% at a soaking time of 1 and 2 hours.

1.6.6 Chapter 6 (Objective 1: Article 3)

This chapter also presents the first objective supported by the third research article entitled “Characterization of alkali treated new cellulosic fiber from *Cyrtostachys renda*”. This study investigated the effect of sodium hydroxide (NaOH) treatment on characterized in terms of density, chemical composition, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffractometry (XRD), and Thermogravimetric analysis (TGA).

1.6.7 Chapter 7 (Objective 2: Article 4)

This chapter addresses the second objective supported by the fourth research article entitled “Physico-mechanical and Flammability Properties of *Cyrtostachys renda* Fibers Reinforced Phenolic Resin Bio-composites”. This research investigated the effect of fiber length and loading on physico-mechanical and flammability properties of *Cyrtostachys renda* (CR) fiber-reinforced phenolic composites.

1.6.8 Chapter 8 (Objective 2: Article 5)

This chapter also presents the second objective supported by the fourth research article entitled “Infrared Thermographic and Ultrasonic Inspection of Randomly-Oriented Short-Natural Fiber-Reinforced Polymeric Composites”. This research work investigated the application of infrared thermographic and ultrasonic in evaluating randomly oriented short-natural-fiber-reinforced phenolic composites.

1.6.9 Chapter 9 (Objective 3: Article 6)

This objective deals with the third objective supported by the sixth research article entitled “Effect of *Cyrtostachys renda* fiber on the mechanical, morphology and flammability properties of modified multi-walled carbon nanotubes / phenolic bio-composites”. This research work investigated the effect of CR fiber loading on physical, mechanical and flammability properties of MWCNT filled phenolic composites.

1.6.10 Chapter 10 (Objective 4: Article 7)

This chapter presents the fourth objective supported by the seventh research article entitled “Physical, mechanical and morphological properties of hybrid *Cytostachys Renda* / kenaf fiber reinforced with Multi-Walled Carbon Nanotubes (MWCNT) filled phenolic composites”. This study investigated the physical, mechanical and morphological properties of different hybrid *Cytostachys Renda* (CR) / kenaf fiber (K) (10C:0K, 7C:3K, 5C:5K, 3C:7K, 0C:10K) reinforced with 0.5 wt% MWCNT filled phenolic composites.

1.6.11 Chapter 11 (Objective 4: Article 8)

This chapter also addresses the fourth objective supported by eighth research article entitled “Thermal degradation, visco-elastic and fire retardant behavior of hybrid *Cyrtostachys renda* / kenaf fiber reinforced MWCNT filled phenolic composites”. This research investigated the thermal, visco-elastic and fire-retardant properties of different hybrid *Cyrtostachys renda* (CR) / kenaf fiber (K) (10C:0K, 7C:3K, 5C:5K, 3C:7K, 0C:10K) reinforced MWCNT filled phenolic composites.

1.6.12 Chapter 12 (Objective 5: Article 9)

This chapter presents the fifth objective supported by the ninth research article entitled “Low velocity impact, free fall drop test of prototype and failure analysis of hybrid CR / kenaf reinforced MWCNT filled phenolic composites. This study focused on the damage progressions of CR / kenaf reinforced MWCNT filled phenolic composites of LVI samples and tray table investigated using non - destructive testing methods such as visual inspection, dye penetration, digital detector array radiography, and computed tomography.

1.6.13 Chapter 13

This chapter presents the Summary, General Conclusions and Recommendations for Future Research. The summary of the entire works, conclusions and recommendations for future works are presented in this chapter.



REFERENCES

- Abd El-Malak, N. (1997). Ultrasonic properties of composites (polymer-fibre glass). *Bulletin of materials science*, 20(7), 981-990.
- Abdullah, C. I., Azzahari, A. D., Rahman, N. M. M. A., Hassan, A., & Yahya, R. (2019). Optimizing Treatment of Oil Palm-Empty Fruit Bunch (OP-EFB) Fiber: Chemical, Thermal and Physical Properties of Alkalized Fibers. *Fibers and Polymers*, 20(3), 527-537.
- Abdullah, S., Zuhudi, N., Anuar, N., & Isa, M. (2018). *Mechanical and thermal characterization of alkali treated kenaf fibers*. Paper presented at the IOP Conference Series: Materials Science and Engineering.
- Abu-Abdeen, M. (2012). Static and dynamic mechanical properties of poly (vinyl chloride) loaded with aluminum oxide nanopowder. *Materials & Design*, 33, 523-528.
- Adesina, O., Jamiru, T., Sadiku, E., Ogunbiyi, O., & Beneke, L. (2019a). Mechanical evaluation of hybrid natural fibre-reinforced polymeric composites for automotive bumper beam: a review. *The International Journal of Advanced Manufacturing Technology*, 1-17.
- Adesina, O., Jamiru, T., Sadiku, E., Ogunbiyi, O., & Beneke, L. (2019b). Mechanical evaluation of hybrid natural fibre-reinforced polymeric composites for automotive bumper beam: a review. *The International Journal of Advanced Manufacturing Technology*, 103 (5-8), 1-17.
- Agrawal, P. R., Singh, N., Kumari, S., & Dhakate, S. R. (2018). Multiwall carbon nanotube embedded phenolic resin-based carbon foam for the removal of As (V) from contaminated water. *Materials Research Express*, 5(3), 035601. doi:10.1088/2053-1591/aaaf7c
- Aguilar, J., Bautista-Quijano, J., & Avilés, F. (2010). Influence of carbon nanotube clustering on the electrical conductivity of polymer composite films. *Express Polym Lett*, 4(5), 292-299.
- Ahmad, R., Hamid, R., & Osman, S. A. (2019a). Physical and Chemical Modifications of Plant Fibres for Reinforcement in Cementitious Composites. *Advances in Civil Engineering*, 2019.
- Ahmad, R., Hamid, R., & Osman, S. A. (2019b). Physical and Chemical Modifications of Plant Fibres for Reinforcement in Cementitious Composites. *Advances in Civil Engineering*, 2019, 2019.
- Aji, I. S., Zainudin, E., Khalina, A., Sapuan, S., & Khairul, M. (2011). Studying the effect of fiber size and fiber loading on the mechanical properties of hybridized kenaf/PALF-reinforced HDPE composite. *Journal of reinforced plastics and composites*, 30(6), 546-553.
- Al-Maharma, A. Y., & Al-Huniti, N. (2019). Critical review of the parameters affecting the effectiveness of moisture absorption treatments used for natural composites. *Journal of Composites Science*, 3(1), 27.

- Alawar, A., Hamed, A. M., & Al-Kaabi, K. (2009). Characterization of treated date palm tree fiber as composite reinforcement. *Composites Part B: Engineering*, 40(7), 601-606.
- Ali, A., Shaker, K., Nawab, Y., Jabbar, M., Hussain, T., Militky, J., & Baheti, V. (2018). Hydrophobic treatment of natural fibers and their composites—A review. *Journal of Industrial Textiles*, 47(8), 2153-2183.
- Aliotta, L., Gigante, V., Coltellini, M. B., Cinelli, P., & Lazzeri, A. (2019a). Evaluation of mechanical and interfacial properties of bio-composites based on poly (lactic acid) with natural cellulose fibers. *International journal of molecular sciences*, 20(4), 960.
- Aliotta, L., Gigante, V., Coltellini, M. B., Cinelli, P., & Lazzeri, A. (2019b). Evaluation of Mechanical and Interfacial Properties of Bio-Composites Based on Poly(Lactic Acid) with Natural Cellulose Fibers. *International Journal of Molecular Sciences*, 20(4), 960. Retrieved from <https://www.mdpi.com/1422-0067/20/4/960>
- Allcorn, E. K., Natali, M., & Koo, J. H. (2013). Ablation performance and characterization of thermoplastic polyurethane elastomer nanocomposites. *Composites Part A: Applied Science and Manufacturing*, 45, 109-118.
- Alomayri, T., Assaedi, H., Shaikh, F. U. A., & Low, I. M. (2014). Effect of water absorption on the mechanical properties of cotton fabric-reinforced geopolymers composites. *Journal of Asian Ceramic Societies*, 2(3), 223-230. doi:<https://doi.org/10.1016/j.jascer.2014.05.005>
- Amir, S. M. M., Sultan, M., Jawaid, M., Ariffin, A. H., Mohd, S., Salleh, K. A. M., Shah, A. U. M. (2019a). Nondestructive testing method for Kevlar and natural fiber and their hybrid composites. In *Durability and Life Prediction in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites* (pp. 367-388): Elsevier.
- Amir, S. M. M., Sultan, M. T. H., Jawaid, M., Ariffin, A. H., Mohd, S., Salleh, K. A. M., Shah, A. U. M. (2019b). 16 - Nondestructive testing method for Kevlar and natural fiber and their hybrid composites. In M. Jawaid, M. Thariq, & N. Saba, *Durability and Life Prediction in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites* (pp. 367-388): Woodhead Publishing.
- Andrew, J. J., Srinivasan, S. M., Arockiarajan, A., & Dhakal, H. N. (2019). Parameters influencing the impact response of fiber-reinforced polymer matrix composite materials: A critical review. *Composite Structures*, 224, 111007.
- Anuar, H., Ahmad, S., Rasid, R., Ahmad, A., & Busu, W. W. (2008). Mechanical properties and dynamic mechanical analysis of thermoplastic-natural-rubber-reinforced short carbon fiber and kenaf fiber hybrid composites. *Journal of Applied Polymer Science*, 107(6), 4043-4052.
- Anwar, U. M. K., Paridah, M. T., Hamdan, H., Sapuan, S. M., & Bakar, E. S. (2009). Effect of curing time on physical and mechanical properties of

- phenolic-treated bamboo strips. *Industrial crops and products*, 29(1), 214-219. doi:<https://doi.org/10.1016/j.indcrop.2008.05.003>
- Araby, S., Philips, B., Meng, Q., Ma, J., Laoui, T., & Wang, C. H. (2021). Recent advances in carbon-based nanomaterials for flame retardant polymers and composites. *Composites Part B: Engineering*, 108675.
- Aruan, & Pickering. (2014). Comparison of harakeke with hemp fibre as a potential reinforcement in composites. *Composites Part A: Applied Science and Manufacturing*, 67, 259-267. doi:<https://doi.org/10.1016/j.compositesa.2014.08.023>
- Ashori, A., & Sheshmani, S. (2010). Hybrid composites made from recycled materials: moisture absorption and thickness swelling behavior. *Bioresource technology*, 101(12), 4717-4720.
- Asim, M., Abdan, K., Jawaid, M., Nasir, M., Dashtizadeh, Z., Ishak, M., & Hoque, M. E. (2015). A review on pineapple leaves fibre and its composites. *International Journal of Polymer Science*, 2015.
- Asim, M., Jawaid, M., Abdan, K., & Ishak, M. (2017a). Dimensional stability of pineapple leaf fibre reinforced phenolic composites. Paper presented at the AIP conference proceedings.
- Asim, M., Jawaid, M., Abdan, K., & Ishak, M. (2017b). Effect of pineapple leaf fibre and kenaf fibre treatment on mechanical performance of phenolic hybrid composites. *Fibers and Polymers*, 18(5), 940-947.
- Asim, M., Jawaid, M., Abdan, K., & Ishak, M. (2018). The effect of silane treated fibre loading on mechanical properties of pineapple leaf/kenaf fibre filler phenolic composites. *Journal of Polymers and the Environment*, 26(4), 1520-1527.
- Asim, M., Jawaid, M., Abdan, K., Ishak, M., & Alothman, O. (2018). Effect of hybridization on the mechanical properties of pineapple leaf fiber/kenaf phenolic hybrid composites. *Journal of Renewable Materials*, 6(1), 38-46.
- Asim, M., Jawaid, M., Abdan, K., & Ishak, M. R. (2016). Effect of alkali and silane treatments on mechanical and fibre-matrix bond strength of kenaf and pineapple leaf fibres. *Journal of Bionic Engineering*, 13(3), 426-435.
- Asim, M., Jawaid, M., Fouad, H., & Alothman, O. Y. (2021). Effect of surface modified date palm fibre loading on mechanical, thermal properties of date palm reinforced phenolic composites. *Composite Structures*, 267, 113913. doi:<https://doi.org/10.1016/j.compstruct.2021.113913>
- Asim, M., Jawaid, M., Khan, A., Asiri, A. M., & Malik, M. A. (2020). Effects of date palm fibres loading on mechanical, and thermal properties of date palm reinforced phenolic composites. *Journal of Materials Research and Technology*, 9(3), 3614-3621.
- Asim, M., Jawaid, M., Nasir, M., & Saba, N. (2018). Effect of fiber loadings and treatment on dynamic mechanical, thermal and flammability properties of pineapple leaf fiber and kenaf phenolic composites. *Journal of Renewable Materials*, 6(4), 383-393.

- Asim, M., Jawaid, M., Paridah, M. T., Saba, N., Nasir, M., & Shahroze, R. M. (2019). Dynamic and thermo-mechanical properties of hybridized kenaf/PALF reinforced phenolic composites. *Polymer Composites*, 40(10), 3814-3822. doi:<https://doi.org/10.1002/pc.25240>
- Asim, M., Paridah, M., Jawaid, M., Nasir, M., & Saba, N. (2018). *Physical and flammability properties of kenaf and pineapple leaf fibre hybrid composites*. Paper presented at the IOP Conference Series: Materials Science and Engineering.
- Asim, M., Paridah, M., Saba, N., Jawaid, M., Alothman, O. Y., Nasir, M., & Almutairi, Z. (2018). Thermal, physical properties and flammability of silane treated kenaf/pineapple leaf fibres phenolic hybrid composites. *Composite Structures*, 202, 1330-1338.
- Asim, M., Paridah, M. T., Saba, N., Jawaid, M., Alothman, O. Y., Nasir, M., & Almutairi, Z. (2018). Thermal, physical properties and flammability of silane treated kenaf/pineapple leaf fibres phenolic hybrid composites. *Composite Structures*, 202, 1330-1338. doi:<https://doi.org/10.1016/j.compstruct.2018.06.068>
- Asim, M., Saba, N., Jawaid, M., Nasir, M., Pervaiz, M., & Alothman, O. Y. (2018). A review on phenolic resin and its composites. *Current Analytical Chemistry*, 14(3), 185-197.
- Asmatulu, E., Twomey, J., & Overcash, M. (2014). Recycling of fiber-reinforced composites and direct structural composite recycling concept. *Journal of Composite Materials*, 48(5), 593-608.
- Association, A. A. (2008). *Aviation Business Magazine*: Yaffa Publishing Group.
- ASTM C1557-03(2008). Standard Test Method For Tensile Strength And Young's Modulus Of Fibers. In. West Conshohocken, PA, USA: American Society for Testing and Materials.
- ASTM D3039-08(2008). Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. In. United States: American Society for Testing and Materials.
- ASTM D3801-10(2010). Standard Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position. In. United States: American Society for Testing and Materials.
- ASTM D2863-13(2013). Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index). In. United States: American Society for Testing and Materials
- ASTM D570-14(2014). Standard Test Method for Water Absorption of Plastics. In *Reapproved 2010*. United States: American Society for Testing and Materials.
- ASTM D7136-15(2015). Standard Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event. . In. United States: American Society for Testing and Materials.

- ASTM D7264-15(2015). Standard Test Methods For Flexural Properties of Polymer Matrix Composites Materials. In. United States: American Society for Testing and Materials
- ASTM D2734-16(2016). Standard Test Methods for Void Content of Reinforced Plastics. In. West Conshohocken, PA, USA: American Society for Testing and Materials.
- ASTM D1895-17(2017). Standard Test Methods for Apparent Density, Bulk Factor, and Pourability of Plastic Materials. In. United States: American Society for Testing and Materials.
- ASTM D256-10(2018). Standard test methods for determining the izod pendulum impact resistance of plastics. In. United States: American Society for Testing and Materials.
- ASTM D635 -18(2018). Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position. In. United States: American Society for Testing and Materials.
- ASTM D5276-19(2019). Standard Test Method for Drop Test of Loaded Containers by Free Fall. In. United States: American Society for Testing and Materials.
- ASTM E662-19(2019). Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials. In. United States: American Society for Testing and Materials ASTM.
- ASTM D4065-20(2020).Standard Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures. In. United States: American Society for Testing and Materials ASTM.
- Asyraf, M., Rafidah, M., Azrina, A., & Razman, M. (2021). Dynamic mechanical behaviour of kenaf cellulosic fibre biocomposites: A comprehensive review on chemical treatments. *Cellulose*, 1-21.
- Atiqah, A., Jawaid, M., Ishak, M., & Sapuan, S. (2018). Effect of alkali and silane treatments on mechanical and interfacial bonding strength of sugar palm fibers with thermoplastic polyurethane. *Journal of natural fibers*, 15(2), 251-261.
- Auad, M. L., Zhao, L., Shen, H., Nutt, S. R., & Sorathia, U. (2007). Flammability properties and mechanical performance of epoxy modified phenolic foams. *Journal of Applied Polymer Science*, 104(3), 1399-1407.
- Azmi, A., Sultan, M., Jawaid, M., Shah, A., Nor, A., Majid, M., .Talib, A. (2019). Impact properties of kenaf Fibre/X-ray films hybrid composites for structural applications. *Journal of Materials Research and Technology*, 8(2), 1982-1990.
- Bachtiar, D., Sapuan, S., & Hamdan, M. (2008). The effect of alkaline treatment on tensile properties of sugar palm fibre reinforced epoxy composites. *Materials & Design*, 29(7), 1285-1290.
- Bachtiar, D., Sapuan, S., Zainudin, E., Khalina, A., & Dahlan, K. (2010). *The tensile properties of single sugar palm (Arenga pinnata) fibre*. Paper

presented at the IOP Conference Series: Materials Science and Engineering.

- Bajwa, D. S., & Bhattacharjee, S. (2016). Current progress, trends and challenges in the application of biofiber composites by automotive industry. *Journal of natural fibers*, 13(6), 660-669.
- Balaji, & Nagarajan. (2017). Characterization of alkali treated and untreated new cellulosic fiber from Saharan aloe vera cactus leaves. *Carbohydrate Polymers*, 174, 200-208. doi:<https://doi.org/10.1016/j.carbpol.2017.06.065>
- Balaji, A., Karthikeyan, B., Swaminathan, J., & Raj, C. S. (2017). Mechanical behavior of short bagasse fiber reinforced cardanol-formaldehyde composites. *Fibers and Polymers*, 18(6), 1193-1199.
- Barrera, C. S., & Cornish, K. (2019). Characterization of Agricultural and Food Processing Residues for Potential Rubber Filler Applications. *Journal of Composites Science*, 3(4), 102.
- Barreto, A. C. H., Esmraldo, M. A., Rosa, D. S., Fechine, P. B. A., & Mazzetto, S. E. (2010). Cardanol biocomposites reinforced with jute fiber: Microstructure, biodegradability, and mechanical properties. *Polymer Composites*, 31(11), 1928-1937. doi:10.1002/pc.20990
- Batool, I., & Shah, G. B. (2018). Chemical Bonding of Organic Dye onto Cotton Fibers Using Silane as Coupling Agent (I). *Fibers and Polymers*, 19(4), 790-796. doi:10.1007/s12221-018-7732-z
- Bensadoun, F., Depuydt, D., Baets, J., Verpoest, I., & Van Vuure, A. W. (2017). Low velocity impact properties of flax composites. *Composite Structures*, 176, 933-944.
- Benyahia, A., Merrouche, A., Rokbi, M., & Kouadri, Z. (2013). Study the effect of alkali treatment of natural fibers on the mechanical behavior of the composite unsaturated Polyester-fiber Alfa. *composites*, 2, 3.
- Bilisik, K., Erdogan, G., & Sapancı, E. (2018). Flexural behavior of 3D para-aramid/phenolic/nano (MWCNT) composites. *RSC advances*, 8(13), 7213-7224.
- Binoj, J. S., Raj, R. E., Sreenivasan, V. S., & Thusnavis, G. R. (2016). Morphological, Physical, Mechanical, Chemical and Thermal Characterization of Sustainable Indian Areca Fruit Husk Fibers (Areca Catechu L.) as Potential Alternate for Hazardous Synthetic Fibers. *Journal of Bionic Engineering*, 13(1), 156-165. doi:[https://doi.org/10.1016/S1672-6529\(14\)60170-0](https://doi.org/10.1016/S1672-6529(14)60170-0)
- Biron, M. (2015). *Material Selection for Thermoplastic Parts: Practical and Advanced Information*: William Andrew.
- Biwa, S. (2001). Independent scattering and wave attenuation in viscoelastic composites. *Mechanics of materials*, 33(11), 635-647.
- Bledzki, A. K., Seidlitz, H., Krenz, J., Goracy, K., Urbaniak, M., & Rösch, J. J. (2020). Recycling of Carbon Fiber Reinforced Composite Polymers—

- Review—Part 2: Recovery and Application of Recycled Carbon Fibers. *Polymers*, 12(12), 3003.
- BN, R. K., & Reddy, R. S. (2017). Experimental Study of Effect of Pongomia Pod Powder as Filler on Some Mechanical, Thermal and Fire Resistant Properties of Areca Phenolic Resin Composites. *JNNCE Journal of Engineering & Management (JJEM)*, 1(1), 28.
- Bongarde, U., & Shinde, V. (2014). Review on natural fiber reinforcement polymer composites. *International Journal of Engineering Science and Innovative Technology*, 3(2), 431-436.
- Boparai, K. S., & Singh, R. (2018). Thermoplastic Composites for Fused Deposition Modeling Filament: Challenges and Applications. In *Reference Module in Materials Science and Materials Engineering*: Elsevier.
- Bose, S., Khare, R. A., & Moldenaers, P. (2010). Assessing the strengths and weaknesses of various types of pre-treatments of carbon nanotubes on the properties of polymer/carbon nanotubes composites: A critical review. *Polymer*, 51(5), 975-993.
- Botelho, E. C., Costa, M. L., Braga, C. I., Burkhart, T., & Lauke, B. (2013). Viscoelastic behavior of multiwalled carbon nanotubes into phenolic resin. *Materials Research*, 16(4), 713-720.
- Botelho, E. C., Edwards, E. R., Bittmann, B., & Burkhart, T. (2011). Dispersing carbon nanotubes in phenolic resin using an aqueous solution. *Journal of the Brazilian Chemical Society*, 22(11), 2040-2047.
- Bou-Rabee, M. Investigation of the relationship between moisture content and density of selected Malaysian biomass MNZ Moni1, SA Sulaiman1, YS Raja1, K. Karunamurthy1, M. Inayat1 and.
- Boumaaza, M., Belaadi, A., & Bourchak, M. (2020). The Effect of Alkaline Treatment on Mechanical Performance of Natural Fibers-reinforced Plaster: Optimization Using RSM. *Journal of Natural Fibers*, 1-21.
- Bourguignon, M., Moore, K. J., Brown, R. C., Kim, K. H., Baldwin, B. S., & Hintz, R. (2017). Variety trial and pyrolysis potential of kenaf grown in Midwest United States. *BioEnergy Research*, 10(1), 36-49.
- Bourguignon, M., Moore, K. J., Lenssen, A. W., & Baldwin, B. S. (2020). Agricultural practices for growing kenaf in Iowa: II. Fiber composition and quality. *Agronomy Journal*, 112(3), 1726-1736.
- Brinchi, L., Cotana, F., Fortunati, E., & Kenny, J. (2013). Production of nanocrystalline cellulose from lignocellulosic biomass: technology and applications. *Carbohydrate Polymers*, 94(1), 154-169.
- BSS 7239 (2015) Test Method for Toxic Gas Generation by Material. In. United States: Boeing.
- Cai, M., Takagi, H., Nakagaito, A. N., Katoh, M., Ueki, T., Waterhouse, G. I. N., & Li, Y. (2015). Influence of alkali treatment on internal microstructure and tensile properties of abaca fibers. *Industrial Crops and Products*, 65, 27-35. doi:<https://doi.org/10.1016/j.indcrop.2014.11.048>

- Cai, M., Takagi, H., Nakagaito, A. N., Li, Y., & Waterhouse, G. I. (2016a). Effect of alkali treatment on interfacial bonding in abaca fiber-reinforced composites. *Composites Part A: Applied Science and Manufacturing*, 90, 589-597.
- Cai, M., Takagi, H., Nakagaito, A. N., Li, Y., & Waterhouse, G. I. N. (2016b). Effect of alkali treatment on interfacial bonding in abaca fiber-reinforced composites. *Composites Part A: Applied Science and Manufacturing*, 90, 589-597. doi:<https://doi.org/10.1016/j.compositesa.2016.08.025>
- Camargo, P. H. C., Satyanarayana, K. G., & Wypych, F. (2009). Nanocomposites: synthesis, structure, properties and new application opportunities. *Materials Research*, 12(1), 1-39.
- Cao, W., Zhang, J., Sun, B., & Gu, B. (2019). X-ray tomography and numerical study on low-velocity impact damages of three-dimensional angle-interlock woven composites. *Composite Structures*, 230, 111525. doi:<https://doi.org/10.1016/j.compstruct.2019.111525>
- Cardona, F., Kin-Tak, A. L., & Fedrigo, J. (2012). Novel phenolic resins with improved mechanical and toughness properties. *Journal of Applied Polymer Science*, 123(4), 2131-2139.
- Carrillo, F., Colom, X., Sunol, J., & Saurina, J. (2004). Structural FTIR analysis and thermal characterisation of lyocell and viscose-type fibres. *European Polymer Journal*, 40(9), 2229-2234.
- Chaiwan, P., & Pumchusak, J. (2015). Wet vs. dry dispersion methods for multiwall carbon nanotubes in the high graphite content phenolic resin composites for use as bipolar plate application. *Electrochimica Acta*, 158, 1-6.
- Chaiwan, P., & Pumchusak, J. (2018). *The Synergistic Effects of Multi-Filler Addition on the Mechanical and Thermo-Mechanical Properties of Phenolic Resins*. Paper presented at the Materials Science Forum.
- Chami Khazraji, A., & Robert, S. (2013). Interaction Effects between Cellulose and Water in Nanocrystalline and Amorphous Regions: A Novel Approach Using Molecular Modeling. *Journal of Nanomaterials*, 2013, 409676. doi:10.1155/2013/409676
- Chandrasekar, M., Ishak, M., Sapuan, S., Leman, Z., & Jawaid, M. (2017). A review on the characterisation of natural fibres and their composites after alkali treatment and water absorption. *Plastics, Rubber and Composites*, 46(3), 119-136.
- Chang, H., Smith, R., Li, S., & Neumann, A. (1985). Wettability of reinforcing fibers. In *Molecular Characterization of Composite Interfaces* (pp. 413-421): Springer.
- Chapple, S., & Anandjiwala, R. (2010). Flammability of natural fiber-reinforced composites and strategies for fire retardancy: a review. *Journal of Thermoplastic Composite Materials*, 23(6), 871-893.
- Chawla, K. K. (2012). *Composite materials: science and engineering*: Springer Science & Business Media.

- Chee, S. S., Jawaid, M., Alothman, O. Y., & Yahaya, R. (2020). Thermo-oxidative stability and flammability properties of bamboo/kenaf/nanoclay/epoxy hybrid nanocomposites. *RSC Advances*, 10(37), 21686-21697.
- Chee, S. S., Jawaid, M., Sultan, M., Alothman, O. Y., & Abdullah, L. C. (2019). Thermomechanical and dynamic mechanical properties of bamboo/woven kenaf mat reinforced epoxy hybrid composites. *Composites Part B: Engineering*, 163, 165-174.
- Chee, S. S., Jawaid, M., & Sultan, M. T. (2017). Thermal stability and dynamic mechanical properties of kenaf/bamboo fibre reinforced epoxy composites. *BioResources*, 12(4), 7118-7132.
- Chee, S. S., Jawaid, M., Sultan, M. T. H., Alothman, O. Y., & Abdullah, L. C. (2019). Thermomechanical and dynamic mechanical properties of bamboo/woven kenaf mat reinforced epoxy hybrid composites. *Composites Part B: Engineering*, 163, 165-174. doi:<https://doi.org/10.1016/j.compositesb.2018.11.039>
- Chen, H., Yu, Y., Zhong, T., Wu, Y., Li, Y., Wu, Z., & Fei, B. (2017). Effect of alkali treatment on microstructure and mechanical properties of individual bamboo fibers. *Cellulose*, 24(1), 333-347.
- Chen, J., Liu, B., Gao, X., & Xu, D. (2018). A review of the interfacial characteristics of polymer nanocomposites containing carbon nanotubes. *RSC advances*, 8(49), 28048-28085.
- Chen, M., Zhong, H., Wang, H., & Zhang, M. (2020). Behaviour of recycled tyre polymer fibre reinforced concrete under dynamic splitting tension. *Cement and Concrete Composites*, 103764.
- Chen, P., Lu, C., Yu, Q., Gao, Y., Li, J., & Li, X. (2006). Influence of fiber wettability on the interfacial adhesion of continuous fiber-reinforced PPESK composite. *Journal of Applied Polymer Science*, 102(3), 2544-2551.
- Cheng, L., Zhang, T., Guo, M., & Li, X. (2014). Structural characteristics and properties of windmill palm leaf sheath fiber. *Wood and Fiber Science*, 46(2), 270-279.
- Chu, P. P., Jen, H.-P., Lo, F.-R., & Lang, C. L. (1999). Exceedingly High Lithium Conductivity in Novolac Type Phenolic Resin/PEO Blends. *Macromolecules*, 32(14), 4738-4740. doi:10.1021/ma982012z
- Colombo, C., Libonati, F., Pezzani, F., Salerno, A., & Vergani, L. (2011). *Fatigue behaviour of a GFRP laminate by thermographic measurements*. Paper presented at the 11th International Conference on the Mechanical Behavior of Materials (ICM11).
- Conley, K., Godbout, L., Whitehead, M. A., & van de Ven, T. G. (2016). Origin of the twist of cellulosic materials. *Carbohydr Polym*, 135, 285-299. doi:10.1016/j.carbpol.2015.08.029
- Correia, C. A., Oliveira, L. M. d., & Valera, T. S. (2017). The Influence of Bleached Jute Fiber Filler on the Properties of Vulcanized Natural Rubber. *Materials Research*, 20, 466-471.

- Crupi, V., Epasto, G., Guglielmino, E., Mozafari, H., & Najafian, S. (2014). Computed tomography-based reconstruction and finite element modelling of honeycomb sandwiches under low-velocity impacts. *Journal of Sandwich Structures & Materials*, 16(4), 377-397.
- Curbell Plastics (Aerospace Navigate plastic materials, certifications, and technical expertise with confidence). Retrieved January 28, 2020, from <https://www.curbellplastics.com/Shop-Materials/All-Materials/ABS/Royalite-ABS-Sheet#?Shape=CRBL.SkuSheet>.
- Dahham, O. S., Noriman, N., Hamzah, R., Al-Samarrai, M. N., Syed, S., Idrus, Z., Mohammed, M. (2018). *The influences NaOH treatment on polypropylene/Cyperus odoratus (PP/CY) composites: tensile and morphology*. Paper presented at the J Phys Conf Ser, 1st International Conference on Green and Sustainable Computing (ICoGeS) 2017 25–27 November 2017, Kuching, Sarawak, Malaysia.
- Dashtizadeh, Z., Abdan, K., Jawaid, M., & Dashtizadeh, M. (2019). Thermal and Flammability Properties of Kenaf/Recycled Carbon Filled with Cardanol Hybrid Composites. *International Journal of Polymer Science*, 2019.
- Dashtizadeh, Z., Khalina, A., Cardona, F., & Lee, C. H. (2019). Mechanical characteristics of green composites of short kenaf bast fiber reinforced in cardanol. *Advances in Materials Science and Engineering*, 2019.
- Davoodi, M., Sapuan, S., Ahmad, D., Ali, A., Khalina, A., & Jonoobi, M. (2010). Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam. *Materials & Design*, 31(10), 4927-4932.
- De Albuquerque, A., Joseph, K., de Carvalho, L. H., & d'Almeida, J. R. M. (2000). Effect of wettability and ageing conditions on the physical and mechanical properties of uniaxially oriented jute-roving-reinforced polyester composites. *Composites Science and Technology*, 60(6), 833-844.
- De Azeredo, H., Rosa, M., De Sá, M., Souza Filho, M., & Waldron, K. (2014). The use of biomass for packaging films and coatings. In *Advances in biorefineries* (pp. 819-874): Elsevier.
- De Medeiros, E. S., Agnelli, J. A. M., Joseph, K., de Carvalho, L. H., & Mattoso, L. H. C. (2005). Mechanical properties of phenolic composites reinforced with jute/cotton hybrid fabrics. *Polymer Composites*, 26(1), 1-11. doi:<https://doi.org/10.1002/pc.20063>
- De Rosa, I. M., Santulli, C., & Sarasini, F. (2009). Acoustic emission for monitoring the mechanical behaviour of natural fibre composites: A literature review. *Composites Part A: Applied Science and Manufacturing*, 40(9), 1456-1469.
- De Rosa, I. M., Santulli, C., & Sarasini, F. (2010). Mechanical and thermal characterization of epoxy composites reinforced with random and quasi-unidirectional untreated Phormium tenax leaf fibers. *Materials & Design (1980-2015)*, 31(5), 2397-2405. doi:<https://doi.org/10.1016/j.matdes.2009.11.059>

- DeBell, D. S., Singleton, R., Harrington, C. A., & Gartner, B. L. (2007). Wood density and fiber length in young *Populus* stems: relation to clone, age, growth rate, and pruning. *Wood and Fiber Science*, 34(4), 529-539.
- Dhanalakshmi, S., Ramadevi, P., & Basavaraju, B. (2015a). Areca fiber reinforced epoxy composites: Effect of chemical treatments on impact strength. *Oriental Journal of Chemistry*, 31(2), 763-769.
- Dhanalakshmi, S., Ramadevi, P., & Basavaraju, B. (2015b). Effect of chemical treatments on tensile strength of areca fiber reinforced natural rubber composites. *IOSR Journal of Applied Chemistry (IOSR-JAC)*, 8(5), 43-52.
- Dhanalakshmi, S., Ramadevi, P., & Basavaraju, B. (2015c). Influence of Chemical Treatments on Flexural Strength of Areca Fiber Reinforced Epoxy Composites. *Chemical Science*, 4(2), 409-418.
- Dhanalakshmi, S., Ramadevi, P., & Basavaraju, B. (2017). A study of the effect of chemical treatments on areca fiber reinforced polypropylene composite properties. *Science and Engineering of Composite Materials*, 24(4), 501-520.
- Di Gregorio, L., Ronchetti, S., & Onida, B. (2015). Phenolic resin emissions upon thermal degradation. In: Eurobrake.
- Dicker, M. P. M., Duckworth, P. F., Baker, A. B., Francois, G., Hazzard, M. K., & Weaver, P. M. (2014). Green composites: A review of material attributes and complementary applications. *Composites Part A: Applied Science and Manufacturing*, 56, 280-289. doi:<https://doi.org/10.1016/j.compositesa.2013.10.014>
- Directive, C. (2010). Directive 2010/75/EU of the European Parliament and of the Council. *Off. J. Eur. Union L*, 334, 17-119.
- Duskin, F. E. (1980). *Study to Develop Improved Fire Resistant Aircraft Passenger Seat Materials*.
- El-Sabbagh, A., Steuernagel, L., & Ziegmann, G. (2013). Characterisation of flax polypropylene composites using ultrasonic longitudinal sound wave technique. *Composites Part B: Engineering*, 45(1), 1164-1172. doi:<https://doi.org/10.1016/j.compositesb.2012.06.010>
- El-Sabbagh, A., Steuernagel, L., & Ziegmann, G. (2013). Ultrasonic testing of natural fibre polymer composites: effect of fibre content, humidity, stress on sound speed and comparison to glass fibre polymer composites. *Polymer bulletin*, 70(2), 371-390.
- Engel, C., Richardson, E., & Davis, E. (2002). *Reference material Kydex-100 test data message for flammability testing*. Paper presented at the Proceedings of the Fifth Aerospace Materials, Processes, and Environmental Technology Conference, Huntsville, AL.
- Engel, C. D., Richardson, E., & Davis, E. (2003). Reference Material Kydex (registered trademark)-100 Test Data Message for Flammability Testing.
- Engineers, S. o. A. (2006). *Aerospace Engineering*: Society of Automotive Engineers.

- Eslami, Z., Yazdani, F., & Mirzapour, M. A. (2015). Thermal and mechanical properties of phenolic-based composites reinforced by carbon fibres and multiwall carbon nanotubes. *Composites Part A: Applied Science and Manufacturing*, 72, 22-31.
- Etemadi, H., & Shojaei, A. (2014). Characterization of reinforcing effect of alumina nanoparticles on the novolac phenolic resin. *Polymer composites*, 35(7), 1285-1293.
- FAA, (1986). 25.853-1 - Flammability Requirements for Aircraft Seat Cushions. In ANM-110. United States: Federal Aviation Administration.
- Fatra, W., Rouhillahi, H., Helwani, Z., Zulfansyah, & Asmura, J. (2016). Effect of alkaline treatment on the properties of oil palm empty fruit bunch fiber-reinforced polypropylene composite. *International Journal of Technology*, 7(6), 1026-1034.
- Fenimore, C. P. (1975). Candle-type test for flammability of polymers. In *Flame-retardant polymeric materials* (pp. 371-397): Springer.
- Fernandes, H., Zhang, H., Ibarra-Castanedo, C., & Maldague, X. (2015). Fiber orientation assessment on randomly-oriented strand composites by means of infrared thermography. *Composites Science and Technology*, 121, 25-33. doi:<https://doi.org/10.1016/j.compscitech.2015.10.015>
- Filbert, W. C., & Bruns, E. U. (1990). Dual-ovenable food trays with textured surface. In: Google Patents.
- Friedrich, K., & Breuer, U. (2015). *Multifunctionality of polymer composites: challenges and new solutions*: William Andrew.
- Frollini, E., Silva, C., & Ramires, E. (2013). Phenolic resins as a matrix material in advanced fiber-reinforced polymer (FRP) composites. In *Advanced fibre-reinforced polymer (FRP) composites for structural applications* (pp. 7-43): Elsevier.
- Fu, T., Guo, D.-M., Chen, L., Wu, W.-S., Wang, X.-L., & Wang, Y.-Z. (2020). Fire hazards management for polymeric materials via synergy effects of pyrolysates-fixation and aromatized-charring. *Journal of hazardous materials*, 389, 122040.
- Ganesh, S., Gunda, Y., Mohan, S. R. J., Raghunathan, V., & Dhilip, J. D. J. (2020). Influence of stacking sequence on the mechanical and water absorption characteristics of areca sheath-palm leaf sheath fibers reinforced epoxy composites. *Journal of Natural Fibers*, 1-11.
- Gardner, L., Munro, T., Villarreal, E., Harris, K., Fronk, T., & Ban, H. (2018). Thermal Characterization of Alkali Treated Kenaf Fibers and Kenaf-Epoxy Composites. *Fibers and Polymers*, 19(2), 393-402. doi:10.1007/s12221-018-7796-1
- Gartner, B. L. (1995). *Plant stems: physiology and functional morphology*: Elsevier.
- Gaudenzi, P., Nardi, D., Chiappetta, I., Atek, S., Lampani, L., Pasquali, M., . . . Valente, T. (2015). Sparse sensing detection of impact-induced

- delaminations in composite laminates. *Composite Structures*, 133, 1209-1219. doi:<https://doi.org/10.1016/j.compstruct.2015.08.052>
- Gholampour, A., & Ozbakkaloglu, T. (2020). A review of natural fiber composites: Properties, modification and processing techniques, characterization, applications. *Journal of materials science*, 1-64.
- Giurgiutiu, V. (2020). Structural health monitoring (SHM) of aerospace composites. In *Polymer composites in the aerospace industry* (pp. 491-558): Elsevier.
- Gliszczyński, A. (2018). Numerical and experimental investigations of the low velocity impact in GFRP plates. *Composites Part B: Engineering*, 138, 181-193.
- Gratton, G. (2018). Environmental Impact. In *Initial Airworthiness* (pp. 337-351): Springer.
- Graupner, N. (2008). Application of lignin as natural adhesion promoter in cotton fibre-reinforced poly (lactic acid)(PLA) composites. *Journal of materials science*, 43(15), 5222-5229.
- Guadagno, L., Raimondo, M., Vertuccio, L., Naddeo, C., Barra, G., Longo, P., . . . Nobile, M. (2018). Morphological, rheological and electrical properties of composites filled with carbon nanotubes functionalized with 1-pyrenebutyric acid. *Composites Part B: Engineering*, 147, 12-21.
- Hadianfard, M., Alizadeh, M., & Moradzaman, M. (2019). Effects of chemical and mechanical functionalization of carbon nanotubes on the behavior of a CNT/Phenolic nanocomposite. *Boletín del Grupo Español del Carbón*(51), 20-25.
- Hamamousse, K., Sereir, Z., Benzidane, R., Gehring, F., Gomina, M., & Poilâne, C. (2019). Experimental and numerical studies on the low-velocity impact response of orthogrid epoxy panels reinforced with short plant fibers. *Composite Structures*, 211, 469-480.
- Hamidon, M. H., Sultan, M. T. H., Ariffin, A. H., & Shah, A. U. M. (2019). Effects of fibre treatment on mechanical properties of kenaf fibre reinforced composites: a review. *Journal of Materials Research and Technology*, 8(3), 3327-3337. doi:<https://doi.org/10.1016/j.jmrt.2019.04.012>
- Hamizol, M. S., & Megat-Yusoff, P. S. M. (2015). Tensile strength of single continuous fiber extracted from mengkuang leaves. *Jurnal Teknologi*, 76(3).
- Hanan, F., Jawaid, M., & Md Tahir, P. (2020). Mechanical performance of oil palm/kenaf fiber-reinforced epoxy-based bilayer hybrid composites. *Journal of Natural Fibers*, 17(2), 155-167.
- Hanan, F., Jawaid, M., & Tahir, P. M. (2018). Mechanical performance of oil palm/kenaf fiber-reinforced epoxy-based bilayer hybrid composites. *Journal of Natural Fibers*.
- Harizi, W., Chaki, S., Bourse, G., & Ourak, M. (2014). Mechanical damage assessment of Polymer–Matrix Composites using active infrared thermography. *Composites Part B: Engineering*, 66, 204-209.

- Hassan, A., Hau, L. Y., & Hasan, M. (2017). Effect of ammonium polyphosphate on flame retardancy, thermal stability, and mechanical properties of unsaturated polyester/phenolic/montmorillonite nanocomposites. *Advances in Polymer Technology*, 36(3), 278-283.
- Hassan, F., Zulkifli, R., Ghazali, M., & Azhari, C. (2017). Kenaf fiber composite in automotive industry: an overview. *International Journal on Advanced Science, Engineering and Information Technology*, 7(1), 315-321.
- He, H., Tay, T. E., Wang, Z., & Duan, Z. (2019). The strengthening of woven jute fiber/polylactide biocomposite without loss of ductility using rigid core-soft shell nanoparticles. *Journal of Materials Science*, 54(6), 4984-4996.
- Heimbs, S., Middendorf, P., & Maier, M. (2006). *Honeycomb sandwich material modeling for dynamic simulations of aircraft interior components*. Paper presented at the 9th international LS-DYNA users conference.
- Herlina Sari, N., Wardana, I. N. G., Irawan, Y. S., & Siswanto, E. (2018). Characterization of the Chemical, Physical, and Mechanical Properties of NaOH-treated Natural Cellulosic Fibers from Corn Husks. *Journal of Natural Fibers*, 15(4), 545-558. doi:10.1080/15440478.2017.1349707
- Hesami, M., Bagheri, R., & Masoomi, M. (2014). Flammability and thermal properties of epoxy/glass/MWNT composites. *Journal of Applied Polymer Science*, 131(4).
- Hidalgo, J. P., Torero, J. L., & Welch, S. (2018). Fire performance of charring closed-cell polymeric insulation materials: Polyisocyanurate and phenolic foam. *Fire and Materials*, 42(4), 358-373.
- Horrocks, A., & Kandola, B. K. (2005). Flammability and fire resistance of composites. In *Design and manufacture of textile composites* (pp. 330-363): Elsevier.
- Hosur, M., Maroju, H., & Jeelani, S. (2015). Comparison of effects of alkali treatment on flax fibre reinforced polyester and polyester-biopolymer blend resins. *Polymers and Polymer Composites*, 23(4), 229-242.
- Hou, T.-H., Bai, J., & Baughman, J. M. (2006). Processing and properties of a phenolic composite system. *Journal of reinforced plastics and composites*, 25(5), 495-502.
- Huang, P., Wu, F., Shen, B., Ma, X., Zhao, Y., Wu, M., Zheng, W. (2019). Bio-inspired lightweight polypropylene foams with tunable hierarchical tubular porous structure and its application for oil-water separation. *Chemical Engineering Journal*, 370, 1322-1330.
- Huzaifah, M. R. M., Sapuan, S. M., Leman, Z., & Ishak, M. R. (2019). Effect of Fibre Loading on the Physical, Mechanical and Thermal Properties of Sugar Palm Fibre Reinforced Vinyl Ester Composites. *Fibers and Polymers*, 20(5), 1077-1084. doi:10.1007/s12221-019-1040-0
- Hyness, N. R. J., Vignesh, N. J., Senthamaraiyan, P., Saravanakumar, S. S., & Sanjay, M. R. (2018). Characterization of New Natural Cellulosic Fiber from Heteropogon Contortus Plant. *Journal of Natural Fibers*, 15(1), 146-153. doi:10.1080/15440478.2017.1321516

- Ibrahim, M., Sapuan, S., & Faieza, A. (2012). Mechanical and thermal properties of composites from unsaturated polyester filled with oil palm ash. *Journal of Mechanical Engineering and Sciences*, 2, 133-147.
- Ibrahim, N., Hashim, N., Rahman, M. A., & Yunus, W. Z. W. (2011). Mechanical properties and morphology of oil palm empty fruit bunch—polypropylene composites: effect of adding engagetm 7467. *Journal of Thermoplastic Composite Materials*, 24(5), 713-732.
- 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.
- Islam, M., Pickering, K., & Foreman, N. (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. Z., & Ulven, C. A. (2020). A thermographic and energy based approach to define high cycle fatigue strength of flax fiber reinforced thermoset composites. *Composites Science and Technology*, 196, 108233. doi:<https://doi.org/10.1016/j.compscitech.2020.108233>
- Ismail, A. S., Jawaid, M., & Naveen, J. (2019). Void content, tensile, vibration and acoustic properties of kenaf/bamboo fiber reinforced epoxy hybrid composites. *Materials*, 12(13), 2094.
- Ismail, K., Sultan, M., Shah, A., Jawaid, M., & Safri, S. (2019). Low velocity impact and compression after impact properties of hybrid bio-composites modified with multi-walled carbon nanotubes. *Composites Part B: Engineering*, 163, 455-463.
- Ismail, M. F., Sultan, M. T., Hamdan, A., Shah, A. U., & Jawaid, M. (2019). Low velocity impact behaviour and post-impact characteristics of kenaf/glass hybrid composites with various weight ratios. *Journal of Materials Research and Technology*, 8(3), 2662-2673.
- ISO, I. S. O. (2002). ISO 5660-1(2002). Reaction-to-fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (cone calorimeter method). In. Geneva, Switzerland: International Organization for Standardization.
- Izani, M. N., Paridah, M., Anwar, U., Nor, M. M., & H'ng, P. (2013). Effects of fiber treatment on morphology, tensile and thermogravimetric analysis of oil palm empty fruit bunches fibers. *Composites Part B: Engineering*, 45(1), 1251-1257.
- Jabbar, A. (2017). Extraction of nanocellulose from waste jute fibers and characterization of mechanical and dynamic mechanical behavior of nanocellulose-coated jute/green epoxy composites. In *Sustainable jute-based composite materials* (pp. 71-85): Springer.
- Jahangiri, A. A., & Rostamiyan, Y. (2020). Mechanical properties of nano-silica and nano-clay composites of phenol formaldehyde short carbon fibers. *Journal of Composite Materials*, 54(10), 1339-1352.

- Jawaid, M., Abdul Khalil, H. P. S., Hassan, A., Dungani, R., & Hadiyane, A. (2013). Effect of jute fibre loading on tensile and dynamic mechanical properties of oil palm epoxy composites. *Composites Part B: Engineering*, 45(1), 619-624. doi:<https://doi.org/10.1016/j.compositesb.2012.04.068>
- Jawaid, M., Abdul Khalil, H. P. S., Noorunnisa Khanam, P., & Abu Bakar, A. (2011). Hybrid Composites Made from Oil Palm Empty Fruit Bunches/Jute Fibres: Water Absorption, Thickness Swelling and Density Behaviours. *Journal of Polymers and the Environment*, 19(1), 106-109. doi:10.1007/s10924-010-0203-2
- Jawaid, M., & Asim, M. (2020). *Phenolic Polymers Based Composite Materials*: Springer.
- Jawaid, M., & Khalil, H. A. (2011). Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. *Carbohydrate polymers*, 86(1), 1-18.
- Jawaid, M., Khalil, H. A., & Bakar, A. A. (2010). Mechanical performance of oil palm empty fruit bunches/jute fibres reinforced epoxy hybrid composites. *Materials Science and Engineering: A*, 527(29-30), 7944-7949.
- Jawaid, M., Khalil, H. A., Bakar, A. A., & Khanam, P. N. (2011). Chemical resistance, void content and tensile properties of oil palm/jute fibre reinforced polymer hybrid composites. *Materials & Design*, 32(2), 1014-1019.
- Jawaid, M., Khalil, H. A., Khanam, P. N., & Bakar, A. A. (2011). Hybrid composites made from oil palm empty fruit bunches/jute fibres: Water absorption, thickness swelling and density behaviours. *Journal of Polymers and the Environment*, 19(1), 106-109.
- Jesuarockiam, N., Jawaid, M., Zainudin, E. S., Thariq Hameed Sultan, M., & Yahaya, R. (2019). Enhanced thermal and dynamic mechanical properties of synthetic/natural hybrid composites with graphene nanoplatelets. *Polymers*, 11(7), 1085.
- Jiang, F., Zhidong, G., Zengshan, L., & Xiaodong, W. (2021). A method of predicting visual detectability of low-velocity impact damage in composite structures based on logistic regression model. *Chinese Journal of Aeronautics*, 34(1), 296-308.
- Jiang, H., Wang, J., Wu, S., Yuan, Z., Hu, Z., Wu, R., & Liu, Q. (2012). The pyrolysis mechanism of phenol formaldehyde resin. *Polymer degradation and stability*, 97(8), 1527-1533.
- Jianjun, L., & Yuxiang, O. (2019). *Theory of Flame Retardation of Polymeric Materials*: Walter de Gruyter GmbH & Co KG.
- Job, S., Leeke, G., Mativenga, P. T., Oliveux, G., Pickering, S., & Shuaib, N. A. (2016). Composites recycling: Where are we now. *Composites UK Ltd.: Berkhamsted, UK*.
- Johar, N., Ahmad, I., & Dufresne, A. (2012). Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk.

- John, M. J., Francis, B., Varughese, K., & 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, R., & Wuethrich, L. (2001). *Flammability of Automotive Child Restraint Seats for Use in Aircraft*. Retrieved from
- Joseph, P., Joseph, K., Thomas, S., Pillai, C., Prasad, V., Groeninckx, G., & Sarkissova, M. (2003). The thermal and crystallisation studies of short sisal fibre reinforced polypropylene composites. *Composites Part A: Applied Science and Manufacturing*, 34(3), 253-266.
- Joseph, S., Appukuttan, S. P., Kenny, J. M., Puglia, D., Thomas, S., & Joseph, K. (2010). Dynamic mechanical properties of oil palm microfibrill-reinforced natural rubber composites. *Journal of Applied Polymer Science*, 117(3), 1298-1308.
- Jothibasu, S., Mohanamurugan, S., Vijay, R., Lenin Singaravelu, D., Vinod, A., & Sanjay, M. (2020). Investigation on the mechanical behavior of areca sheath fibers/jute fibers/glass fabrics reinforced hybrid composite for light weight applications. *Journal of Industrial Textiles*, 49(8), 1036-1060.
- Kandola, B. K., & Deli, D. (2014). Chapter 16 - Flame-Retardant Thermoset Nanocomposites for Engineering Applications. In C. D. Papaspyrides & P. Kiliaris (Eds.), *Polymer Green Flame Retardants* (pp. 503-549). Amsterdam: Elsevier.
- Karunakaran, S., Majid, D., & Tawil, M. M. (2016). *Flammability of self-extinguishing kenaf/ABS nanoclays composite for aircraft secondary structure*. Paper presented at the IOP Conference Series: Materials Science and Engineering.
- Kashiwagi, T., Mu, M., Winey, K., Cipriano, B., Raghavan, S., Pack, S., . . . Shields, J. (2008). Relation between the viscoelastic and flammability properties of polymer nanocomposites. *Polymer*, 49(20), 4358-4368.
- Khan, A., Vijay, R., Singaravelu, D. L., Sanjay, M. R., Siengchin, S., Verpoort, F., . . . Asiri, A. M. (2020). Characterization of Natural Fibers from Cortaderia Selloana Grass (Pampas) as Reinforcement Material for the Production of the Composites. *Journal of Natural Fibers*, 1-9. doi:10.1080/15440478.2019.1709110
- Khan, T. (2020). *Characterization of Kenaf/Jute Epoxy hybrid composites for aircraft food tray*. (Characterization of Kenaf/Jute Epoxy hybrid composites for aircraft food tray). Universiti Putra Malaysia, Serdang, Malaysia.
- Khan, T., Hameed Sultan, M. T. B., & Ariffin, A. H. (2018). The challenges of natural fiber in manufacturing, material selection, and technology application: A review. *Journal of Reinforced Plastics and Composites*, 37(11), 770-779.

- Khandanlou, R., Ahmad, M. B., Shamel, K., Hussein, M. Z., Zainuddin, N., & Kalantari, K. (2014). Mechanical and thermal stability properties of modified rice straw fiber blend with polycaprolactone composite. *Journal of Nanomaterials*, 2014, 93.
- Khoathane, M. C., Sadiku, E. R., & Agwuncha, C. S. (2015). Surface Modification of natural fiber composites and their potential applications. *Surface Modification of Biopolymers*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 370-400.
- Khoshnava, S. M., Rostami, R., Ismail, M., Rahmat, A. R., & Ogunbode, B. E. (2017). Woven hybrid Biocomposite: Mechanical properties of woven kenaf bast fibre/oil palm empty fruit bunches hybrid reinforced poly hydroxybutyrate biocomposite as non-structural building materials. *Construction and Building Materials*, 154, 155-166.
- Kian, L., Saba, N., Jawaid, M., & Sultan, M. (2019). A review on processing techniques of bast fibers nanocellulose and its polylactic acid (PLA) nanocomposites. *International journal of biological macromolecules*, 121, 1314-1328.
- Kim, J. G., Yoon, S. C., & Kwon, S. T. (2011). *Analysis of Fracture Behavior in Polymer Matrix Composites by Infrared Thermography*. Paper presented at the Key Engineering Materials.
- Koo, J. H., & Pilato, L. A. (2020). Polymer Nanocomposite Ablatives– Part II. *International Journal of Energetic Materials and Chemical Propulsion*, 19(2).
- Koronis, G., Silva, A., & Fontul, M. (2013). Green composites: A review of adequate materials for automotive applications. *Composites Part B: Engineering*, 44(1), 120-127.
- Kumar, R., Ul Haq, M. I., Raina, A., & Anand, A. (2019). Industrial applications of natural fibre-reinforced polymer composites—challenges and opportunities. *International Journal of Sustainable Engineering*, 12(3), 212-220.
- Lai, W. L., Mariatti, M., & Jani S, M. (2008). The Properties of Woven Kenaf and Betel Palm (Areca catechu) Reinforced Unsaturated Polyester Composites. *Polymer-Plastics Technology and Engineering*, 47(12), 1193-1199. doi:10.1080/03602550802392035
- Lau, K.-t., Hung, P.-y., Zhu, M.-H., & Hui, D. (2018). Properties of natural fibre composites for structural engineering applications. *Composites Part B: Engineering*, 136, 222-233.
- Levință, N., Vuluga, Z., Teodorescu, M., & Corobeia, M. C. (2019). Halogen-free flame retardants for application in thermoplastics based on condensation polymers. *SN Applied Sciences*, 1(5), 422. doi:10.1007/s42452-019-0431-6
- Li, C., Wan, J., Pan, Y.-T., Zhao, P.-C., Fan, H., & Wang, D.-Y. (2016). Sustainable, biobased silicone with layered double hydroxide hybrid and their application in natural-fiber reinforced phenolic composites with

- enhanced performance. *ACS Sustainable Chemistry & Engineering*, 4(6), 3113-3121.
- Li, Q., Chen, L., Li, X., Zhang, J., Zhang, X., Zheng, K., . . . Tian, X. (2016). Effect of multi-walled carbon nanotubes on mechanical, thermal and electrical properties of phenolic foam via in-situ polymerization. *Composites Part A: Applied Science and Manufacturing*, 82, 214-225.
- Li, R., Ni, Q.-Q., Xia, H., & Natsuki, T. (2018). Analysis of individual attenuation components of ultrasonic waves in composite material considering frequency dependence. *Composites Part B: Engineering*, 140, 232-240.
- Lisle, T., Bouvet, C., Pastor, M.-L., Margueres, P., & Corral, R. P. (2013). Damage analysis and fracture toughness evaluation in a thin woven composite laminate under static tension using infrared thermography. *Composites Part A: Applied Science and Manufacturing*, 53, 75-87.
- Liu, D., Song, J., Anderson, D. P., Chang, P. R., & Hua, Y. (2012). Bamboo fiber and its reinforced composites: structure and properties. *Cellulose*, 19(5), 1449-1480.
- Liu, J., Wang, L., Zhang, W., & Han, Y. (2020). Phenolic Resin Foam Composites Reinforced by Acetylated Poplar Fiber with High Mechanical Properties, Low Pulverization Ratio, and Good Thermal Insulation and Flame Retardant Performance. *Materials*, 13(1), 148.
- Liu, T., Jing, J., Zhang, Y., & Fang, Z. (2018). Synthesis of a novel polyphosphate and its application with APP in flame retardant PLA. *RSC Advances*, 8(8), 4483-4493.
- Liu, Z., Huo, J., & Yu, Y. (2017). Water absorption behavior and thermal-mechanical properties of epoxy resins cured with cardanol-based novolac resins and their esterified ramifications. *Materials Today Communications*, 10, 80-94.
- Liu, Z., Oswald, J., & Belytschko, T. (2013). XFEM modeling of ultrasonic wave propagation in polymer matrix particulate/fibrous composites. *Wave Motion*,
- Lokensgaard, E. (2016). *Industrial plastics: theory and applications*: Cengage Learning.
- Lomonaco, D., Mele, G., & Mazzetto, S. E. (2017). Cashew nutshell liquid (CNSL): from an agro-industrial waste to a sustainable alternative to petrochemical resources. In *Cashew Nut Shell Liquid* (pp. 19-38): Springer.
- Lopes, J. P., & Lofrano, E. H. (2016). Pivot tray assembly and process of making and using the same. In: Google Patents.
- Lotfi, M., Kasiriha, S. H., & Shafiee, M. (2019). Improvement of Mechanical properties of car brake pads with phenolic/Nano clay nanocomposite. *Nashrieh Shimi va Mohandes Shimi Iran*.
- Ma, P.-C., Siddiqui, N. A., Marom, G., & Kim, J.-K. (2010). Dispersion and functionalization of carbon nanotubes for polymer-based nanocomposites: A review. *Composites Part A: Applied Science and*

- Madhu, P., Sanjay, M., Senthamaraikannan, P., Pradeep, S., Saravanakumar, S., & Yogesha, B. (2018). A review on synthesis and characterization of commercially available natural fibers: Part-I. *Journal of Natural Fibers*, 1-13.
- Madhu, P., Sanjay, M., Senthamaraikannan, P., Pradeep, S., Saravanakumar, S., & Yogesha, B. (2019). A review on synthesis and characterization of commercially available natural fibers: Part II. *Journal of Natural Fibers*, 16(1), 25-36.
- Mahajan, A., Kingon, A., Kukovecz, A., Konya, Z., & Vilarinho, P. M. (2013). Studies on the thermal decomposition of multiwall carbon nanotubes under different atmospheres. *Materials Letters*, 90, 165-168.
- Maheshwaran, M., Hyness, N. R. J., Senthamaraikannan, P., Saravanakumar, S., & Sanjay, M. (2018). Characterization of natural cellulosic fiber from epipremnum aureum stem. *Journal of Natural Fibers*, 15(6), 789-798.
- Mallick, P. K. (2007). *Fiber-reinforced composites: materials, manufacturing, and design*: CRC press.
- Malnati, P. (2016). Thermoplastic Composites Take Off in Aircraft Interiors: Extending the important role that composites already play in aircraft, reinforced thermoplastics slowly move into parts & panels. *Plastics Engineering*, 72(5), 4-8.
- Manimaran, P., Senthamaraikannan, P., Sanjay, M. R., Marichelvam, M. K., & Jawaid, M. (2018). Study on characterization of Furcraea foetida new natural fiber as composite reinforcement for lightweight applications. *Carbohydrate Polymers*, 181, 650-658.
doi:<https://doi.org/10.1016/j.carbpol.2017.11.099>
- Marliana, M., Hassan, A., Yuziah, M. N., Khalil, H. A., Inuwa, I., Syakir, M., & Haafiz, M. M. (2016). Flame retardancy, Thermal and mechanical properties of Kenaf fiber reinforced Unsaturated polyester/Phenolic composite. *Fibers and Polymers*, 17(6), 902-909.
- Martin, C., Ronda, J., & Cadiz, V. (2006). Boron-containing novolac resins as flame retardant materials. *Polymer degradation and stability*, 91(4), 747-754.
- Marzana, M., Howlader, M. I., & Hossain, M. M. (2021). Properties and Applications of Phenolic-Nanocomposites. In *Phenolic Polymers Based Composite Materials* (pp. 89-109): Springer.
- Marzuki, S. M. M. (1997). *Propagation of Sealing Wax Palm, Cyrtostachys Renda Blume, Using in Vitro Techniques*. Universiti Putra Malaysia,
- Mathur, R., Singh, B., Dhami, T., Kalra, Y., Lal, N., Rao, R., & Rao, A. (2010). Influence of carbon nanotube dispersion on the mechanical properties of phenolic resin composites. *Polymer Composites*, 31(2), 321-327.

MatWeb material property data. Retrieved from <http://www.matweb.com/search/datasheettext.aspx?matguid=4a998a49a4df4ad983e95c2100f9f8b2>. Retrieved 22/04/2020

Meenalochani, K., & Reddy, B. (2017). A review on water absorption behavior and its effect on mechanical properties of natural fibre reinforced composites. *Int. J. Innovat. Res. Adv. Eng.*, 4, 143-147.

Megiatto Jr, J. D., Silva, C. G., Rosa, D. S., & Frollini, E. (2008). Sisal chemically modified with lignins: correlation between fibers and phenolic composites properties. *Polymer Degradation and Stability*, 93(6), 1109-1121.

Mehdikhani, M., Gorbatikh, L., Verpoest, I., & Lomov, S. V. (2019). Voids in fiber-reinforced polymer composites: A review on their formation, characteristics, and effects on mechanical performance. *Journal of Composite Materials*, 53(12), 1579-1669.

Merdas, I., Thominette, F., Tcharkhtchi, A., & Verdu, J. (2002). Factors governing water absorption by composite matrices. *Composites Science and Technology*, 62(4), 487-492.

Michigan Purchasing Management. (1972). Oakland Publishing.

Mngomezulu, M. E., John, M. J., Jacobs, V., & Luyt, A. S. (2014). Review on flammability of biofibres and biocomposites. *Carbohydrate polymers*, 111, 149-182.

Mochane, M., Mokhena, T. C., Mokhothu, T., Mtibe, A., Sadiku, E., Ray, S. S., . . . Daramola, O. (2019). Recent progress on natural fiber hybrid composites for advanced applications: A review.

Moghadam, A. D., Omrani, E., Menezes, P. L., & Rohatgi, P. K. (2015). Mechanical and tribological properties of self-lubricating metal matrix nanocomposites reinforced by carbon nanotubes (CNTs) and graphene—a review. *Composites Part B: Engineering*, 77, 402-420.

Mohammed, B. R., Leman, Z., Jawaid, M., Ghazali, M. J., & Ishak, M. R. (2017). Dynamic mechanical analysis of treated and untreated sugar palm fibre-based phenolic composites. *BioResources*, 12(2), 3448-3462.

Mohanty, A. K., Misra, M., & Drzal, L. (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.

Mohit, H., & Arul Mozhi Selvan, V. (2018). A comprehensive review on surface modification, structure interface and bonding mechanism of plant cellulose fiber reinforced polymer based composites. *Composite Interfaces*, 25(5-7), 629-667.

Moniruzzaman, M. (2012). PEI/carbon as metal substitute in aircraft food tray arms. *JEC Composites*(70), 48-53.

Monteiro, S. N., Calado, V., Rodriguez, R. J. S., & Margem, F. M. (2012). Thermogravimetric behavior of natural fibers reinforced polymer

- composites—An overview. *Materials Science and Engineering: A*, 557, 17-28.
- Morán, J. I., Alvarez, V. A., Cyras, V. P., & Vázquez, A. (2008). Extraction of cellulose and preparation of nanocellulose from sisal fibers. *Cellulose*, 15(1), 149-159.
- Moreira, E., Barbosa Rabello, J., Pereira, M., Lopes, R., & Zscherpel, U. (2010). Digital Radiography Using Digital Detector Arrays Fulfills Critical Applications for Offshore Pipelines. *EURASIP Journal on Advances in Signal Processing*, 2010(1), 894643. doi:10.1155/2010/894643
- Morgan, A. B., Gagliardi, N. A., Price, W. A., & Galaska, M. L. (2009). Cone calorimeter testing of S2 glass reinforced polymer composites. *Fire and Materials: An International Journal*, 33(7), 323-344.
- Morrison, J. K., Shah, S. P., & Jenq, Y.-S. (1988). Analysis of fiber debonding and pullout in composites. *Journal of engineering mechanics*, 114(2), 277-294.
- Mostafa, N. H., Ismarrubie, Z., Sapuan, S., & Sultan, M. (2016). Effect of equibiaxially fabric prestressing on the tensile performance of woven E-glass/polyester reinforced composites. *Journal of Reinforced Plastics and Composites*, 35(14), 1093-1103.
- Mothé, C., & de Miranda, I. (2009). Characterization of sugarcane and coconut fibers by thermal analysis and FTIR. *Journal of Thermal Analysis and Calorimetry*, 97(2), 661-665.
- Muñoz, E., & García-Manrique, J. A. (2015). Water absorption behaviour and its effect on the mechanical properties of flax fibre reinforced bioepoxy composites. *International Journal of Polymer Science*, 2015.
- Mwaikambo, & Ansell. (2002). Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization. *Journal of applied polymer science*, 84(12), 2222-2234.
- Mwaikambo, & Ansell. (2006). Mechanical properties of alkali treated plant fibres and their potential as reinforcement materials. I. Hemp fibres. *Journal of materials science*, 41(8), 2483-2496.
- Mwaikambo, L., & Ansell, M. P. (1999). The effect of chemical treatment on the properties of hemp, sisal, jute and kapok for composite reinforcement. *Die angewandte makromolekulare Chemie*, 272(1), 108-116.
- Mylsamy, K., & Rajendran, I. (2011). Influence of alkali treatment and fibre length on mechanical properties of short Agave fibre reinforced epoxy composites. *Materials & Design*, 32(8-9), 4629-4640.
- Nadlene, R., Sapuan, S., Jawaid, M., Ishak, M., & Yusriah, L. (2016). A review on roselle fiber and its composites. *Journal of Natural Fibers*, 13(1), 10-41.
- Najeeb, M., Sultan, M., Andou, Y., Shah, A., Eksiler, K., Jawaid, M., & Ariffin, A. (2020). Characterization of Lignocellulosic Biomass from Malaysian's Yankee Pineapple AC6 Toward Composite Application. *Journal of Natural Fibers*, 1-13.

- Najeeb, M., Sultan, M., Shah, A., & Safri, S. (2019). *Static analysis on Malaysian Yankee's pineapple leaf fiber/epoxy composite*. Paper presented at the IOP Conference Series: Materials Science and Engineering.
- Naveen, J., Jawaid, M., Zainudin, E., Sultan, M. T., & Yahaya, R. (2019). Evaluation of ballistic performance of hybrid Kevlar®/Cocos nucifera sheath reinforced epoxy composites. *The Journal of the Textile Institute*, 110(8), 1179-1189.
- Naveen, J., Jawaid, M., Zainudin, E., Sultan, M. T., Yahaya, R., & Majid, M. A. (2019a). Thermal degradation and viscoelastic properties of Kevlar/Cocos nucifera sheath reinforced epoxy hybrid composites. *Composite Structures*.
- Naveen, J., Jawaid, M., Zainudin, E., Sultan, M. T., Yahaya, R., & Majid, M. A. (2019b). Thermal degradation and viscoelastic properties of Kevlar/Cocos nucifera sheath reinforced epoxy hybrid composites. *Composite Structures*, 219, 194-202.
- Naveen, J., Jawaid, M., Zainudin, E. S., Thariq Hameed Sultan, M., & Yahaya, R. (2019). Improved mechanical and moisture-resistant properties of woven hybrid epoxy composites by graphene nanoplatelets (GNP). *Materials*, 12(8), 1249.
- Naveen, J., Muthukumar, C., & Jawaid, M. (2020). Thermal Properties of Phenolic Composites. In *Phenolic Polymers Based Composite Materials* (pp. 191-205): Springer.
- Nayak, S., & Mohanty, J. R. (2018). Influence of chemical treatment on tensile strength, water absorption, surface morphology, and thermal analysis of areca sheath fibers. *Journal of Natural Fibers*, 1-11. doi:10.1080/15440478.2018.1430650
- Nevestenko, M., Bryuzgina, E., Tuzhikov, O., Bryuzgin, E., & Tarasova, Y. S. (2020). Study of Properties of Film Materials Based on Cellulose and Polyurethane Rubbers for Drainage of Oils. *Russian Journal of Applied Chemistry*, 93, 564-571.
- Njuguna, M. K. (2012). *Characterisation of multi wall carbon nanotube–polymer composites for strain sensing applications*. Queensland University of Technology,
- Nogueira, P., Ramirez, C., Torres, A., Abad, M., Cano, J., Lopez, J., . . . Barral, L. (2001). Effect of water sorption on the structure and mechanical properties of an epoxy resin system. *Journal of Applied Polymer Science*, 80(1), 71-80.
- Nor, A., Sultan, M., & Hamdan, A. (2017). Design and development of a food tray table for commercial aircraft using hybrid composites. *Proceedings of Mechanical Engineering Research Day*, 2017, 389-390.
- Nor, A. F. M., Sultan, M. T. H., Jawaid, M., Azmi, A. M. R., & Shah, A. U. M. (2019). Analysing impact properties of CNT filled bamboo/glass hybrid nanocomposites through drop-weight impact testing, UWPI and compression-after-impact behaviour. *Composites Part B: Engineering*, 168, 166-174.

- Nurazzi, N. M., Khalina, A., Sapuan, S. M., Ilyas, R. A., Rafiqah, S. A., & Hanafee, Z. M. (2020). Thermal properties of treated sugar palm yarn/glass fiber reinforced unsaturated polyester hybrid composites. *Journal of Materials Research and Technology*, 9(2), 1606-1618. doi:<https://doi.org/10.1016/j.jmrt.2019.11.086>
- Nurulaini, B., Romli, A. Z., & Abidin, M. H. (2013). *Tensile and flexural properties of casuarina equisetifolia unsaturated polyester composites*. Paper presented at the Advanced Materials Research.
- Ogunsona, E. O., Codou, A., Misra, M., & Mohanty, A. K. (2018). Thermally stable pyrolytic biocarbon as an effective and sustainable reinforcing filler for polyamide bio-composites fabrication. *Journal of Polymers and the Environment*, 26(9), 3574-3589.
- Omar, F. N., Mohammed, M. A. P., & Baharuddin, A. S. (2014). Effect of silica bodies on the mechanical behaviour of oil palm empty fruit bunch fibres. *BioResources*, 9(4), 7041-7058.
- Ornaghi Jr, H. L., Bolner, A. S., Fiorio, R., Zattera, A. J., & Amico, S. C. (2010). Mechanical and dynamic mechanical analysis of hybrid composites molded by resin transfer molding. *Journal of Applied Polymer Science*, 118(2), 887-896.
- Ouajai, S., & Shanks, R. (2005). Composition, structure and thermal degradation of hemp cellulose after chemical treatments. *Polymer degradation and stability*, 89(2), 327-335.
- Oushabi, A., Sair, S., Hassani, F. O., Abboud, Y., Tanane, O., & El Bouari, A. (2017). The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite. *South African Journal of Chemical Engineering*, 23, 116-123.
- Özatay, M. K. (2019). DowAksa Next Generation Advanced Composite Solutions. Retrieved from <http://www.turkchem.net/dowaksa-next-generation-advanced-composite-solutions.html>
- Ozdogan, E., Gulumser, T., & Demir, A. (2017). Surface modification of fibers and sizing operations. In *Fiber Technology for Fiber-Reinforced Composites* (pp. 81-98): Elsevier.
- Özmen, F. K., Üreyen, M. E., & Koparal, A. S. (2020). Cleaner production of flame-retardant-glass reinforced epoxy resin composite for aviation and reducing smoke toxicity. *Journal of Cleaner Production*, 276, 124065.
- 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, G., & Thostenson, E. T. (2012). Carbon nanotube-based multifunctional polymer nanocomposites. *Polymer Reviews*, 52(3), 355-416.
- Pandiselvam, R., Manikantan, M., Kothakota, A., Rajesh, G., Beegum, S., Ramesh, S., Hebbar, K. (2020). Engineering properties of five varieties

- of coconuts (*Cocos nucifera* L.) for efficient husk separation. *Journal of Natural Fibers*, 17(4), 589-597.
- Panwar, V., & Pal, K. (2017). An optimal reduction technique for rGO/ABS composites having high-end dynamic properties based on Cole-Cole plot, degree of entanglement and C-factor. *Composites Part B: Engineering*, 114, 46-57.
- Park, J.-M., Kwon, D.-J., Wang, Z.-J., Roh, J.-U., Lee, W.-I., Park, J.-K., & DeVries, K. L. (2014). Effects of carbon nanotubes and carbon fiber reinforcements on thermal conductivity and ablation properties of carbon/phenolic composites. *Composites Part B: Engineering*, 67, 22-29.
- Park, J.-M., Son, T. Q., Jung, J.-G., & Hwang, B.-S. (2006). Interfacial evaluation of single Ramie and Kenaf fiber/epoxy resin composites using micromechanical test and nondestructive acoustic emission. *Composite Interfaces*, 13(2-3), 105-129.
- Park, J.-M., Wang, Z.-J., Kwon, D.-J., Gu, G.-Y., Lee, W.-I., Park, J.-K., & Lawrence DeVries, K. (2012). Optimum dispersion conditions and interfacial modification of carbon fiber and CNT–phenolic composites by atmospheric pressure plasma treatment. *Composites Part B: Engineering*, 43(5), 2272-2278. doi:<https://doi.org/10.1016/j.compositesb.2012.01.025>
- Park, Y., Doherty, W. O., & Halley, P. J. (2008). Developing lignin-based resin coatings and composites. *Industrial crops and products*, 27(2), 163-167.
- Peças, P., Carvalho, H., Salman, H., & Leite, M. (2018). Natural fibre composites and their applications: a review. *Journal of Composites Science*, 2(4), 66.
- Pelaez-Samaniego, M. R., Yadama, V., Lowell, E., Amidon, T. E., & Chaffee, T. L. (2013). Hot water extracted wood fiber for production of wood plastic composites (WPCs). *Holzforschung*, 67(2), 193-200.
- Petroudy, S. D. (2017). Physical and mechanical properties of natural fibers. In *Advanced high strength natural fibre composites in construction* (pp. 59-83): Elsevier.
- Pickering, K. L., Efendy, M. G. 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. doi:<https://doi.org/10.1016/j.compositesa.2015.08.038>
- Pilato, L. (2010). *Phenolic resins: a century of progress* (Vol. 11): Springer.
- Plastics World. (1992). Cahners Publishing Company.
- Popineau, S., Rondeau-Mouro, C., Sulpice-Gaillet, C., & Shanahan, M. E. (2005). Free/bound water absorption in an epoxy adhesive. *Polymer*, 46(24), 10733-10740.
- Pothan, L. A., Thomas, S., & Groeninckx, G. (2006). The role of fibre/matrix interactions on the dynamic mechanical properties of chemically

- modified banana fibre/polyester composites. *Composites Part A: Applied Science and Manufacturing*, 37(9), 1260-1269.
- Prabhakar, M., Shah, A. U. R., & Song, J.-I. (2015). A review on the flammability and flame retardant properties of natural fibers and polymer matrix based composites. *Polymer*, 37, 40.
- Prade, F., Schaff, F., Senck, S., Meyer, P., Mohr, J., Kastner, J., & Pfeiffer, F. (2017). Nondestructive characterization of fiber orientation in short fiber reinforced polymer composites with X-ray vector radiography. *NDT & E International*, 86, 65-72. doi:<https://doi.org/10.1016/j.ndteint.2016.11.013>
- Prashantha, K., Soulestin, J., Lacrampe, M.-F., Krawczak, P., Dupin, G., & Claes, M. (2009). Masterbatch-based multi-walled carbon nanotube filled polypropylene nanocomposites: Assessment of rheological and mechanical properties. *Composites Science and Technology*, 69(11-12), 1756-1763.
- Pravin, J., Khan, A. A., Massimo, R., Carlo, R., & Alberto, T. (2016). Multiwalled Carbon nanotube–Strength to polymer composite. *Physical Sciences Reviews*, 1(2).
- Prime, R. B. (2005). Dynamic mechanical analysis of thermosetting materials.
- Radzi, A. M., Sapuan, S. M., Jawaid, M., & Mansor, M. R. (2019). Effect of Alkaline Treatment on Mechanical, Physical and Thermal Properties of Roselle/Sugar Palm Fiber Reinforced Thermoplastic Polyurethane Hybrid Composites. *Fibers and Polymers*, 20(4), 847-855. doi:10.1007/s12221-019-1061-8
- Raimondo, M., Naddeo, C., Vertuccio, L., Bonnaud, L., Dubois, P., Binder, W. H., Guadagno, L. (2020). Multifunctionality of structural nanohybrids: The crucial role of carbon nanotube covalent and non-covalent functionalization in enabling high thermal, mechanical and self-healing performance. *Nanotechnology*, 31(22), 225708.
- Rajak, D. K., Pagar, D. D., Menezes, P. L., & Linul, E. (2019). Fiber-reinforced polymer composites: Manufacturing, properties, and applications. *Polymers*, 11(10), 1667.
- Rajeshkumar, G., Elangovan, D., & Rajkumar, V. (2021). Natural Fibers Based Phenolic Hybrid Composites. In *Phenolic Polymers Based Composite Materials* (pp. 77-87): Springer.
- Ramesh, M. (2016). Kenaf (*Hibiscus cannabinus* L.) fibre based bio-materials: A review on processing and properties. *Progress in Materials Science*, 78, 1-92.
- Ramesh, M., & Nijanthan, S. (2016). Mechanical property analysis of kenaf–glass fibre reinforced polymer composites using finite element analysis. *Bulletin of Materials Science*, 39(1), 147-157.
- Ramires, E. C., Megiatto Jr, J. D., Gardrat, C., Castellan, A., & Frollini, E. (2010). Biobased composites from glyoxal–phenolic resins and sisal fibers. *Bioresource technology*, 101(6), 1998-2006.

- Ramlee, N. A., Jawaid, M., Zainudin, E. S., & Yamani, S. A. K. (2019a). Modification of Oil Palm Empty Fruit Bunch and Sugarcane Bagasse Biomass as Potential Reinforcement for Composites Panel and Thermal Insulation Materials. *Journal of Bionic Engineering*, 16(1), 175-188.
- Ramlee, N. A., Jawaid, M., Zainudin, E. S., & Yamani, S. A. K. (2019b). Tensile, physical and morphological properties of oil palm empty fruit bunch/sugarcane bagasse fibre reinforced phenolic hybrid composites. *Journal of Materials Research and Technology*, 8(4), 3466-3474. doi:<https://doi.org/10.1016/j.jmrt.2019.06.016>
- Ranganagowdaa, R. P. G., Kamatha, S. S., Bennehallia, B., Muddannab, A., Sampathkumar, D., & Venkateshappad, S. C. (2018). Spectral studies on chemically modified single areca fibre. *Materials Today: Proceedings*, 5(14), 28018-28025.
- Rashid, B., Leman, Z., Jawaid, M., Ghazali, M. J., & Ishak, M. (2017a). Effect of treatments on the physical and morphological properties of SPF/phenolic composites. *Journal of Natural Fibers*, 14(5), 645-657.
- Rashid, B., Leman, Z., Jawaid, M., Ghazali, M. J., & Ishak, M. R. (2016). The mechanical performance of sugar palm fibres (ijuk) reinforced phenolic composites. *International Journal of Precision Engineering and Manufacturing*, 17(8), 1001-1008.
- Rashid, B., Leman, Z., Jawaid, M., Ghazali, M. J., & Ishak, M. R. (2017b). Influence of treatments on the mechanical and thermal properties of sugar palm fibre reinforced phenolic composites. *BioResources*, 12(1), 1447-1462.
- Razali, N., Sultan, M. T. H., & Jawaid, M. (2017). A Review on Detecting and Characterizing Damage Mechanisms of Synthetic and Natural Fiber Based Composites. *BioResources*, 12(4), 9502-9519.
- Realinho, V., Haurie, L., Antunes, M., & Velasco, J. I. (2014). Thermal stability and fire behaviour of flame retardant high density rigid foams based on hydromagnesite-filled polypropylene composites. *Composites Part B: Engineering*, 58, 553-558. doi:<https://doi.org/10.1016/j.compositesb.2013.11.015>
- Reddy, N., & Yang, Y. (2006). Properties of high-quality long natural cellulose fibers from rice straw. *Journal of agricultural and food chemistry*, 54(21), 8077-8081.
- Richardson, M., & Wisheart, M. (1996). Review of low-velocity impact properties of composite materials. *Composites Part A: Applied Science and Manufacturing*, 27(12), 1123-1131.
- Ridzuan, M. J. M., Abdul Majid, M. S., Afendi, M., Aqmariah Kanafiah, S. N., Zahri, J. M., & Gibson, A. G. (2016). Characterisation of natural cellulosic fibre from *Pennisetum purpureum* stem as potential reinforcement of polymer composites. *Materials & Design*, 89, 839-847. doi:<https://doi.org/10.1016/j.matdes.2015.10.052>
- Rojo, E., Alonso, M. V., Oliet, M., Del Saz-Orozco, B., & Rodriguez, F. (2015). Effect of fiber loading on the properties of treated cellulose fiber-

- reinforced phenolic composites. *Composites Part B: Engineering*, 68, 185-192. doi:<https://doi.org/10.1016/j.compositesb.2014.08.047>
- Rokbi, M., Osmani, H., Imad, A., & Benseddiq, N. (2011). Effect of chemical treatment on flexure properties of natural fiber-reinforced polyester composite. *procedia Engineering*, 10, 2092-2097.
- Romanzini, D., Ornaghi Jr, H. L., Amico, S. C., & Zattera, A. J. (2012). Influence of fiber hybridization on the dynamic mechanical properties of glass/ramie fiber-reinforced polyester composites. *Journal of Reinforced Plastics and Composites*, 31(23), 1652-1661.
- Rosli, N. S., Harun, S., Jahim, J. M., & Othaman, R. (2017). Chemical and physical characterization of oil palm empty fruit bunch. *Malaysian Journal of Analytical Sciences*, 21(1), 188-196.
- Rozman, H., Ahmadhilmi, K., & Abubakar, A. (2004). Polyurethane (PU)—oil palm empty fruit bunch (EFB) composites: the effect of EFBG reinforcement in mat form and isocyanate treatment on the mechanical properties. *Polymer testing*, 23(5), 559-565.
- Rybicka, J., Tiwari, A., Alvarez Del Campo, P., & Howarth, J. (2015). Capturing composites manufacturing waste flows through process mapping. *Journal of Cleaner Production*, 91, 251-261. doi:<https://doi.org/10.1016/j.jclepro.2014.12.033>
- Saba, N., Paridah, M., Abdan, K., & Ibrahim, N. A. (2016). Dynamic mechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites. *Construction and Building Materials*, 124, 133-138.
- Sabaghi, M., Mascle, C., & Baptiste, P. (2016). Evaluation of products at design phase for an efficient disassembly at end-of-life. *Journal of Cleaner Production*, 116, 177-186.
- Safri, S., Sultan, M., Yidris, N., & Mustapha, F. (2014). Low velocity and high velocity impact test on composite materials—a review. *Int. J. Eng. Sci*, 3(9), 50-60.
- Safri, S. N. A., Sultan, M. T. H., Jawaid, M., & Majid, M. A. (2019). Analysis of dynamic mechanical, low-velocity impact and compression after impact behaviour of benzoyl treated sugar palm/glass/epoxy composites. *Composite Structures*, 226, 111308.
- Safri, S. N. A., Sultan, M. T. H., & Shah, A. U. M. (2020). Characterization of benzoyl treated sugar palm/glass fibre hybrid composites. *Journal of Materials Research and Technology*, 9(5), 11563-11573.
- Saha, P., Chowdhury, S., Roy, D., Adhikari, B., Kim, J. K., & Thomas, S. (2016). A brief review on the chemical modifications of lignocellulosic fibers for durable engineering composites. *Polymer Bulletin*, 73(2), 587-620. doi:10.1007/s00289-015-1489-y
- Sahari, J., Sapuan, S., Zainudin, E., & Maleque, M. (2012). Sugar palm tree: a versatile plant and novel source for biofibres, biomatrices, and biocomposites. *Polymers from Renewable Resources*, 3(2), 61-78.
- Sahi, A. K. (1990). Lid for food trays. In: Google Patents.

- Sałasińska, K., Borucka, M., Celiński, M., Gajek, A., Zatorski, W., Mizera, K., . . . Ryszkowska, J. (2018). Thermal stability, fire behavior, and fumes emission of polyethylene nanocomposites with halogen-free fire retardants. *Advances in Polymer Technology*, 37(7), 2394-2410.
- Salman, S. D., Leman, Z., Sultan, M., Ishak, M., & Cardona, F. (2017). Effect of kenaf fibers on trauma penetration depth and ballistic impact resistance for laminated composites. *Textile Research Journal*, 87(17), 2051-2065.
- Salman, S. D., Leman, Z., Sultan, M. T., Ishak, M. R., & Cardona, F. (2015). Kenaf/synthetic and Kevlar®/cellulosic fiber-reinforced hybrid composites: A review. *BioResources*, 10(4), 8580-8603.
- Salman, S. D., Leman, Z., Sultan, M. T., Ishak, M. R., & Cardona, F. (2016). The effects of orientation on the mechanical and morphological properties of woven kenaf-reinforced poly vinyl butyral film. *BioResources*, 11(1), 1176-1188.
- Salman, S. D., Leman, Z., Sultan, M. T. H., Ishak, M. R., & Cardona, F. (2016). Influence of Fiber Content on Mechanical and Morphological Properties of Woven Kenaf Reinforced PVB Film Produced Using a Hot Press Technique. *International Journal of Polymer Science*, 2016, 7828451. doi:10.1155/2016/7828451
- Sampathkumar, D., Punyamurthy, R., Bennehalli, B., & Venkateshappa, S. C. (2015). Physical characterization of natural lignocellulosic single areca fiber. *Ciência & Tecnologia dos Materiais*, 27(2), 121-135.
- Sanjay, Siengchin, S., Parameswaranpillai, J., Jawaid, M., Pruncu, C. I., & Khan, A. (2019). A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization. *Carbohydrate Polymers*, 207, 108-121. doi:<https://doi.org/10.1016/j.carbpol.2018.11.083>
- Sanjay, M., Jawaid, M., Naidu, N., & Yugesha, B. (2019). TOPSIS method for selection of best composite laminate. In *Modelling of Damage Processes in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites* (pp. 199-209): Elsevier.
- Sanjay, M., Madhu, P., Jawaid, M., Sentharamaikannan, P., Senthil, S., & Pradeep, S. (2018). Characterization and properties of natural fiber polymer composites: A comprehensive review. *Journal of Cleaner Production*, 172, 566-581.
- Sanjay, M., Siengchin, S., Parameswaranpillai, J., Jawaid, M., Pruncu, C. I., & Khan, A. (2019). A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization. *Carbohydrate polymers*, 207, 108-121.
- Sanjay, M. R., Madhu, P., Jawaid, M., Sentharamaikannan, P., Senthil, S., & Pradeep, S. (2018). Characterization and properties of natural fiber polymer composites: A comprehensive review. *Journal of Cleaner Production*, 172, 566-581. doi:<https://doi.org/10.1016/j.jclepro.2017.10.101>

- Sarasini, F., & Santulli, C. (2014). Non-destructive testing (NDT) of natural fibre composites: acoustic emission technique. In *Natural Fibre Composites* (pp. 273-302): Elsevier.
- Sawalha, S., Ma'ali, R., Joma'a, R., Salhi, Y., & Edaily, K. (2019). Tensile Modulus of Film Stacked Palm Fibers-LDPE Sheet Composites. *Journal of natural fibers*, 1-9.
- Sbordone, L., Traini, T., Caputi, S., Scarano, A., Bortolaia, C., & Piattelli, A. (2010). Scanning electron microscopy fractography analysis of fractured hollow implants. *Journal of Oral Implantology*, 36(2), 105-111.
- Searle, O., & Pfeiffer, R. (1985). Victrex® poly (ethersulfone)(PES) and Victrex® poly (etheretherketone)(PEEK). *Polymer Engineering & Science*, 25(8), 474-476.
- Seemann, R. (2019). *A Virtual Testing Approach for Honeycomb Sandwich Panel Joints in Aircraft Interior* (Vol. 16): Springer.
- Segal, L., Creely, J. J., Martin, A. E., & Conrad, C. M. (1959). An Empirical Method for Estimating the Degree of Crystallinity of Native Cellulose Using the X-Ray Diffractometer. *Textile Research Journal*, 29(10), 786-794. doi:10.1177/004051755902901003
- Selamat, M. Z., Ahadlin, M. D., YAAKOB, M. Y., Azma, P., & Sivakumar, D. M. (2016). Mechanical properties of polypropylene composites reinforced with alkaline treated pineapple leaf fibre from Josapine cultivar. *International Journal of Automotive and Mechanical Engineering (IJAME)*, 13(1), 3157-3167.
- Selmi, S., Habibi, M., Laperrière, L., & Kelouwani, S. (2020). Characterisation of Natural Flax Fibers Honeycomb: Compression Damage Analysis Using Acoustic Emission. *Journal of Natural Fibers*, 1-10. doi:10.1080/15440478.2020.1789531
- Senthamarai Kannan, P., & Kathiresan, M. (2018). Characterization of raw and alkali treated new natural cellulosic fiber from *Coccinia grandis*.L. *Carbohydrate Polymers*, 186, 332-343. doi:<https://doi.org/10.1016/j.carbpol.2018.01.072>
- Seviaryna, I., Bueno, H. G., Maeva, E., & Tjong, J. (2014). *Characterization of natural fibre-reinforced composites with advanced ultrasonic techniques*. Paper presented at the 2014 IEEE International Ultrasonics Symposium.
- Shah, A. U. M., Sultan, M. T. H., & Safri, S. N. A. (2020). Experimental Evaluation of Low Velocity Impact Properties and Damage Progression on Bamboo/Glass Hybrid Composites Subjected to Different Impact Energy Levels. *Polymers*, 12(6), 1288.
- Shanmugasundaram, Rajendran, & Ramkumar. (2018). Characterization of untreated and alkali treated new cellulosic fiber from an Areca palm leaf stalk as potential reinforcement in polymer composites. *Carbohydrate Polymers*, 195, 566-575. doi:<https://doi.org/10.1016/j.carbpol.2018.04.127>

- Sharba, M. J., Leman, Z., Sultan, M., Ishak, M. R., & Hanim, M. (2016). Tensile and compressive properties of woven kenaf/glass sandwich hybrid composites. *International Journal of Polymer Science*, 2016.
- Shen, H., & Liu, Y. (2018). One-step synthesis of hydrophobic magnesium hydroxide nanoparticles and their application in flame-retardant polypropylene composites. *Chinese Journal of Chemical Engineering*, 26(10), 2199-2205.
- Shibata, S., Cao, Y., & Fukumoto, I. (2005). Effect of bagasse fiber on the flexural properties of biodegradable composites. *Polymer composites*, 26(5), 689-694.
- Shokrieh, M. M., Saeedi, A., & Chitsazzadeh, M. (2013). Mechanical properties of multi-walled carbon nanotube/polyester nanocomposites. *Journal of Nanostructure in Chemistry*, 3(1), 20. doi:10.1186/2193-8865-3-20
- Sinha, E., & Rout, S. K. (2009). Influence of fibre-surface treatment on structural, thermal and mechanical properties of jute fibre and its composite. *Bulletin of Materials Science*, 32(1), 65. doi:10.1007/s12034-009-0010-3
- Sreenivas, H., Krishnamurthy, N., & Arpitha, G. (2020). A comprehensive review on light weight kenaf fiber for automobiles. *International Journal of Lightweight Materials and Manufacture*, 3(4), 328-337.
- Sreenivasan, S., Iyer, P. B., & Iyer, K. K. (1996). Influence of delignification and alkali treatment on the fine structure of coir fibres (*Cocos nucifera*). *Journal of Materials Science*, 31(3), 721-726.
- Sreenivasan, S., Sulaiman, S., Ariffin, M. K. A. M., Baharudin, B. H. T., & Abdan, K. (2018). Physical properties of novel kenaf short fiber reinforced bulk molding compounds (bmc) for compression moulding. *Materials Today: Proceedings*, 5(1), 1226-1232.
- Srikanth, I., Padmavathi, N., Kumar, S., Ghosal, P., Kumar, A., & Subrahmanyam, C. (2013). Mechanical, thermal and ablative properties of zirconia, CNT modified carbon/phenolic composites. *Composites Science and Technology*, 80, 1-7.
- Starkova, O., Buschhorn, S. T., Mannov, E., Schulte, K., & Aniskevich, A. (2013). Water transport in epoxy/MWCNT composites. *European Polymer Journal*, 49(8), 2138-2148.
- Sudiyani, Y., Styarini, D., Triwahyuni, E., Sudiyarmanto, Sembiring, K. C., Aristiawan, Y., . . . Han, M. H. (2013). Utilization of Biomass Waste Empty Fruit Bunch Fiber of Palm Oil for Bioethanol Production Using Pilot-Scale Unit. *Energy Procedia*, 32, 31-38. doi:<https://doi.org/10.1016/j.egypro.2013.05.005>
- Sultan, M., Worden, K., Staszewski, W., Pierce, S., Dulieu-Barton, J., & Hodzic, A. (2009a). Impact damage detection and quantification in CFRP laminates; a precursor to machine learning.
- Sultan, M., Worden, K., Staszewski, W., Pierce, S., Dulieu-Barton, J., & Hodzic, A. (2009b). *Impact damage detection and quantification in CFRP*

- laminates; a precursor to machine learning.* Paper presented at the 7th International Workshop on Structural Health Monitoring.
- Swain, S. K., & Jena, I. (2010). Polymer/carbon nanotube nanocomposites: a novel material. *Asian Journal of Chemistry*, 22(1), 1.
- Swoger, J., Verveer, P., Greger, K., Huiskens, J., & Stelzer, E. H. (2007). Multi-view image fusion improves resolution in three-dimensional microscopy. *Optics express*, 15(13), 8029-8042.
- Symington, M. C., Banks, W. M., West, O. D., & Pethrick, R. (2009). Tensile testing of cellulose based natural fibers for structural composite applications. *Journal of composite materials*, 43(9), 1083-1108.
- Symington, M. C., David-West, O. S., Banks, W. M., Pethrick, R. A., & Thomason, J. (2008). *The effect of alkali on the mechanical properties of natural fibres.* Paper presented at the 13th European Conference on Composite Materials (ECCM 13).
- Taherian, R., Moradzaman, M., Hadianfard, M. J., & Golikand, A. N. (2011). *The Optimization of Ball Milling Method in Preparation of Phenolic/Functionalized Multi-wall Carbon Nanotube Composite and Comparison with Wet Method.* Paper presented at the International Journal of Engineering Research in Africa.
- Tahermansouri, H., Dehghan, Z., & Kiani, F. (2015). Phenol adsorption from aqueous solutions by functionalized multiwalled carbon nanotubes with a pyrazoline derivative in the presence of ultrasound. *RSC advances*, 5(55), 44263-44273.
- Taib, M. N. A. M., & Julkapli, N. M. (2019). Dimensional stability of natural fiber-based and hybrid composites. In *Mechanical and Physical Testing of Biocomposites, Fibre-Reinforced Composites and Hybrid Composites* (pp. 61-79): Elsevier.
- Taimur-Al-Mobarak, Mina, M. F., Gafur, M. A., Ahmed, A. N., & Dhar, S. A. (2018). Effect of Chemical Modifications on Surface Morphological, Structural, Mechanical, and Thermal Properties of Sponge-gourd Natural Fiber. *Fibers and Polymers*, 19(1), 31-40. doi:10.1007/s12221-018-7199-3
- Tamunaidu, P., & Saka, S. (2011). Chemical characterization of various parts of nipa palm (*Nypa fruticans*). *Industrial Crops and Products*, 34(3), 1423-1428.
- Tang, Q., Fang, L., & Guo, W. (2019). Effects of bamboo fiber length and loading on mechanical, thermal and pulverization properties of phenolic foam composites. *Journal of Bioresources and Bioproducts*, 4(1), 51-59.
- Tang, X., & Yan, X. (2020). A review on the damping properties of fiber reinforced polymer composites. *Journal of Industrial Textiles*, 49(6), 693-721.
- Techinal brief: Kydex thermoplastics *FAR 25.853a and FAR 25.853d*.
- Technical data sheets aircraft grades Boltaron® 9815 Extruded. Retrieved 20/04/2020, from SIMONA Boltaron

- Testing, A. S. f., & Materials. (2007). *ASTM D3822-07 Standard Test Method for Tensile Properties of Single Textile Fibers*.
- Thakur, V. K., Thakur, M. K., & Kessler, M. R. (2017). *Handbook of Composites from Renewable Materials, Biodegradable Materials* (Vol. 5): John Wiley & Sons.
- Thomas, S., Paul, S., Pothan, L., & Deepa, B. (2011). Natural fibres: structure, properties and applications. In *Cellulose fibers: bio-and nano-polymer composites* (pp. 3-42): Springer.
- Thygesen, A., Thomsen, A. B., Daniel, G., & Lilholt, H. (2007). Comparison of composites made from fungal defibrated hemp with composites of traditional hemp yarn. *Industrial Crops and Products*, 25(2), 147-159. doi:<https://doi.org/10.1016/j.indcrop.2006.08.002>
- Toldy, A., Szébenyi, G., Molnár, K., Tóth, L. F., Magyar, B., Hliva, V., . . . Szolnoki, B. (2019). The effect of multilevel carbon reinforcements on the fire performance, conductivity, and mechanical properties of epoxy composites. *Polymers*, 11(2), 303.
- Tran, L., Yuan, X., Bhattacharyya, D., Fuentes, C., Van Vuure, A. W., & Verpoest, I. (2015). Fiber-matrix interfacial adhesion in natural fiber composites. *International Journal of Modern Physics B*, 29(10n11), 1540018.
- Trindade, W. G., Hoareau, W., Razera, I. A., Ruggiero, R., Frollini, E., & Castellan, A. (2004). Phenolic thermoset matrix reinforced with sugar cane bagasse fibers: attempt to develop a new fiber surface chemical modification involving formation of quinones followed by reaction with furfuryl alcohol. *Macromolecular Materials and Engineering*, 289(8), 728-736.
- Vahabi, H., Kandola, B. K., & Saeb, M. R. (2019). Flame retardancy index for thermoplastic composites. *Polymers*, 11(3), 407.
- Vaidya, U. K. (2011). Impact response of laminated and sandwich composites. In *Impact engineering of composite structures* (pp. 97-191): Springer.
- Van de Weyenberg, I., Ivens, J., De Coster, A., Kino, B., Baetens, E., & Verpoest, I. (2003). Influence of processing and chemical treatment of flax fibres on their composites. *Composites Science and Technology*, 63(9), 1241-1246.
- Van Soest, P., & Wine, R. (1968). Determination of lignin and cellulose in acid-detergent fiber with permanganate. *Journal of the association of official analytical chemists*, 51, 780-785.
- Venkatachalam, N., Navaneethakrishnan, P., Rajsekhar, R., & Shankar, S. (2016). Effect of pretreatment methods on properties of natural fiber composites: a review. *Polymers and Polymer Composites*, 24(7), 555-566.
- Venkataraman, S., Bhuvaneswari, B., Athijayamani, A., & Sekar, S. (2019). Effect of addition of areca fine fibers on the mechanical properties of Calotropis Gigantea fiber/phenol formaldehyde biocomposites. *Vacuum*, 166, 6-10.

- Verma, D., Jain, S., Zhang, X., & Gope, P. C. (2016). *Green approaches to biocomposite materials science and engineering*: IGI Global.
- Vicovaro, M. (2014). Intuitive physics of free fall: an information integration approach to the mass-speed belief. *Psicológica*, 35(3), 463-477.
- Vijay, R., Lenin Singaravelu, D., Vinod, A., Sanjay, M. R., Siengchin, S., Jawaid, M., Parameswaranpillai, J. (2019). Characterization of raw and alkali treated new natural cellulosic fibers from *Tridax procumbens*. *International Journal of Biological Macromolecules*, 125, 99-108. doi:<https://doi.org/10.1016/j.ijbiomac.2018.12.056>
- Vijay, R., Vinod, A., Kathiravan, R., Siengchin, S., & Singaravelu, D. L. (2018). Evaluation of *Azadirachta indica* seed/spent *Camellia sinensis* bio-filler based jute fabrics–epoxy composites: experimental and numerical studies. *Journal of Industrial Textiles*, 1528083718811086.
- Vilaseca, F., Serra-Parareda, F., Espinosa, E., Rodríguez, A., Mutjé, P., & Delgado-Aguilar, M. (2020). Valorization of Hemp Core Residues: Impact of NaOH Treatment on the Flexural Strength of PP Composites and Intrinsic Flexural Strength of Hemp Core Fibers. *Biomolecules*, 10(6), 823.
- Wagner, H., Lourie, O., Feldman, Y., & Tenne, R. (1998). Stress-induced fragmentation of multiwall carbon nanotubes in a polymer matrix. *Applied physics letters*, 72(2), 188-190.
- 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, B., Zhong, S., Lee, T.-L., Fancey, K. S., & Mi, J. (2020). Non-destructive testing and evaluation of composite materials/structures: A state-of-the-art review. *Advances in mechanical engineering*, 12(4), 1687814020913761.
- Wang, H., Hassan, E., Memon, H., Elagib, T., & Abad Allaldris, F. (2019). Characterization of natural composites fabricated from *Abutilon*-fiber-reinforced Poly (Lactic Acid). *Processes*, 7(9), 583.
- Wang, H., Yang, L., Guo, H., Zhao, Y., & Zhao, J. (2019). Mechanical and Thermodynamic Properties of Unidirectional Flax Fiber Reinforced CNT Modified Epoxy Composites. *Fibers and Polymers*, 20(6), 1266-1276. doi:10.1007/s12221-019-8836-9
- Wang, Z., Li, J., Barford, J. P., Hellgradt, K., & McKay, G. (2016). A comparison of chemical treatment methods for the preparation of rice husk cellulosic fibers. *International Journal of Environmental & Agriculture Research*, 2(1), 67-77.
- Weaver, J. C., Milliron, G. W., Miserez, A., Evans-Lutterodt, K., Herrera, S., Gallana, I., DiMasi, E. (2012). The stomatopod dactyl club: a formidable damage-tolerant biological hammer. *Science*, 336(6086), 1275-1280.
- Widyatmoko, D., Burgman, M. A., Guhardja, E., Mogea, J. P., Walujo, E. B., & Setiadi, D. (2005). Population status, demography and habitat

- preferences of the threatened lipstick palm *Cyrtostachys renda* Blume in Kerumutan Reserve, Sumatra. *Acta Oecologica*, 28(2), 107-118. doi:<https://doi.org/10.1016/j.actao.2005.03.003>
- Wiley-VCH. (2016). *Ullmann's Polymers and Plastics, 4 Volume Set: Products and Processes* (Vol. 1): John Wiley & Sons.
- Wong, Yousif, & Low. (2010). The effects of alkali treatment on the interfacial adhesion of bamboo fibres. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, 224(3), 139-148.
- Wong, K., Ahsan, Q., Putra, A., Subramonian, S., & Nor, M. J. M. (2017). Preliminary study on the sound absorption behavior of spent tea leaves filled with natural rubber latex binder. *Jurnal Teknologi*, 79(5-2).
- Wong, K., Yousif, B., & Low, K. (2010). The effects of alkali treatment on the interfacial adhesion of bamboo fibres. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, 224(3), 139-148.
- Wong, S., Shanks, R., & Hodzic, A. (2004). Interfacial improvements in poly (3-hydroxybutyrate)-flax fibre composites with hydrogen bonding additives. *Composites science and technology*, 64(9), 1321-1330.
- Wyman, C. E., Decker, S. R., Himmel, M. E., Brady, J. W., Skopec, C. E., & Viikari, L. (2005). Hydrolysis of cellulose and hemicellulose. *Polysaccharides: Structural diversity and functional versatility*, 1, 1023-1062.
- Xia, L., Zhang, C., Wang, A., Wang, Y., & Xu, W. (2020). Morphologies and properties of *Juncus effusus* fiber after alkali treatment. *Cellulose*, 27(4), 1909-1920.
- Yaghoobi, H., & Fereidoon, A. (2018). Evaluation of viscoelastic, thermal, morphological, and biodegradation properties of polypropylene nano-biococomposites using natural fiber and multi-walled carbon nanotubes. *Polymer Composites*, 39, E592-E600.
- Yaghoobi, H., & Fereidoon, A. (2019). Preparation and characterization of short kenaf fiber-based biocomposites reinforced with multi-walled carbon nanotubes. *Composites Part B: Engineering*, 162, 314-322.
- Yang, G., Wang, Y., Xu, H., Zhou, S., Jia, S., & Zang, J. (2018). Preparation and properties of three dimensional graphene/phenolic resin composites via in-situ polymerization in graphene hydrogels. *Applied Surface Science*, 447, 837-844.
- Yang, H., Yan, R., Chen, H., Lee, D. H., & Zheng, C. (2007). Characteristics of hemicellulose, cellulose and lignin pyrolysis. *Fuel*, 86(12-13), 1781-1788.
- Yang, S.-Y., Lin, W.-N., Huang, Y.-L., Tien, H.-W., Wang, J.-Y., Ma, C.-C. M., ... Wang, Y.-S. (2011). Synergetic effects of graphene platelets and carbon nanotubes on the mechanical and thermal properties of epoxy composites. *Carbon*, 49(3), 793-803.

- Yang, W., & Li, Y. (2012). Sound absorption performance of natural fibers and their composites. *Science China Technological Sciences*, 55(8), 2278-2283.
- Yang, Y., Boom, R., Irion, B., van Heerden, D.-J., Kuiper, P., & de Wit, H. (2012). Recycling of composite materials. *Chemical Engineering and Processing: Process Intensification*, 51, 53-68. doi:<https://doi.org/10.1016/j.cep.2011.09.007>
- Yeh, M.-K., Tai, N.-H., & Lin, Y.-J. (2008). Mechanical properties of phenolic-based nanocomposites reinforced by multi-walled carbon nanotubes and carbon fibers. *Composites Part A: Applied Science and Manufacturing*, 39(4), 677-684.
- Yetgin, S. H. (2019). Effect of multi walled carbon nanotube on mechanical, thermal and rheological properties of polypropylene. *Journal of Materials Research and Technology*, 8(5), 4725-4735.
- Yi, X.-S., Zhang, X., Ding, F., & Tong, J. (2018). Development of bio-sourced epoxies for bio-composites. *Aerospace*, 5(2), 65.
- Yusof, N., Sapuan, S., Sultan, M., & Jawaid, M. (2020). Conceptual design of oil palm fibre reinforced polymer hybrid composite automotive crash box using integrated approach. *Journal of Central South University*, 27(1), 64-75.
- Yusoff, M. Z. M., Salit, M. S., Ismail, N., & Wirawan, R. (2010). Mechanical properties of short random oil palm fibre reinforced epoxy composites. *Sains Malaysiana*, 39(1), 87-92.
- Yusuff, I., Sarifuddin, N., & Ali, A. M. (2021). A review on kenaf fiber hybrid composites: Mechanical properties, potentials, and challenges in engineering applications. *Progress in Rubber, Plastics and Recycling Technology*, 37(1), 66-83.
- Zakaria, M. R., Kudus, M. H. A., Akil, H. M., & Thirmizir, M. Z. M. (2017). Comparative study of graphene nanoparticle and multiwall carbon nanotube filled epoxy nanocomposites based on mechanical, thermal and dielectric properties. *Composites Part B: Engineering*, 119, 57-66.
- Zakikhani, P., Zahari, R., Sultan, M. T. b. H. H., & Majid, D. L. A. A. (2017). Morphological, mechanical, and physical properties of four bamboo species. *BioResources*, 12(2), 2479-2495.
- Zakikhani, P., Zahari, R., Sultan, M. T. H., & Majid, D. L. A. A. (2016). Thermal degradation of four bamboo species. *BioResources*, 11(1), 414-425.
- Zare, Y. (2016). Study of nanoparticles aggregation/agglomeration in polymer particulate nanocomposites by mechanical properties. *Composites Part A: Applied Science and Manufacturing*, 84, 158-164. doi:<https://doi.org/10.1016/j.compositesa.2016.01.020>
- Zhang, C., Rao, Y., & Li, W. (2020). Low-velocity impact behavior of intralayer hybrid composites based on carbon and glass non-crimp fabric. *Composite Structures*, 234, 111713.

- Zhang, L., Sun, Z., Liang, D., Lin, J., & Xiao, W. (2017). Preparation and Performance Evaluation of PLA/Coir Fibre Biocomposites. *BioResources*, 12(4), 7349-7362.
- Zhang, T., Guo, M., Cheng, L., & Li, X. (2015). Investigations on the structure and properties of palm leaf sheath fiber. *Cellulose*, 22(2), 1039-1051. doi:10.1007/s10570-015-0570-x
- Zhang, Y., Xiang-Ming, W., Feng, M., Brunette, G., Cheng, F., & Simard, B. (2014). Phenol-formaldehyde polymer with carbon nanotubes, a method of producing same, and products derived therefrom. In: Google Patents.
- Zhao, X., Verhagen, W. J. C., & Curran, R. (2020). Disposal and Recycle Economic Assessment for Aircraft and Engine End of Life Solution Evaluation. *Applied Sciences*, 10(2), 522. Retrieved from <https://www.mdpi.com/2076-3417/10/2/522>
- Zhou, A., Qiu, Q., Chow, C. L., & Lau, D. (2020). Interfacial performance of aramid, basalt and carbon fiber reinforced polymer bonded concrete exposed to high temperature. *Composites Part A: Applied Science and Manufacturing*, 131, 105802.
- Zhou, J., & Lucas, J. P. (1999). Hygrothermal effects of epoxy resin. Part I: the nature of water in epoxy. *Polymer*, 40(20), 5505-5512.
- Zhou, J., Yao, Z., Chen, Y., Wei, D., Wu, Y., & Xu, T. (2013). Mechanical and thermal properties of graphene oxide/phenolic resin composite. *Polymer Composites*, 34(8), 1245-1249.
- Zhou, R., Li, W., Mu, J., Ding, Y., & Jiang, J. (2020). Synergistic effects of aluminum diethylphosphinate and melamine on improving the flame retardancy of phenolic resin. *Materials*, 13(1), 158.
- Živković, I., Fragassa, C., Pavlović, A., & Brugo, T. (2017). Influence of moisture absorption on the impact properties of flax, basalt and hybrid flax/basalt fiber reinforced green composites. *Composites Part B: Engineering*, 111, 148-164.
- Zorthian, J. (2017, August 7, 2017). 5 of the Filthiest Places to Avoid on Airplanes. *Time*
- Zulfli, N. M., Bakar, A. A., & Chow, W. (2013). Mechanical and water absorption behaviors of carbon nanotube reinforced epoxy/glass fiber laminates. *Journal of Reinforced Plastics and Composites*, 32(22), 1715-1721.