PINEAPPLE LEAF FIBER EXTRACTION AND ITS APPLICATION AS KRAFT PAPER

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ABSTRACT

Cultivation of pineapple in Malaysia produces wastes such as leaf and crown where these wastes are discarded or left in the field. A systematic pineapple leaf fiber (PALF) extraction method was designed to maximally utilized this waste and make pineapple plantation more sustainable. Therefore, these four-parts of studies were conducted in order to develop an effective fiber extraction method. In Part 1 (method selection), PALF from Josapine cultivar was successfully extracted via manual retting (combing), water retting, chemical extraction or mechanical-chemical extraction methods. The mechanical-chemical method was found to be the best method to produce the whitish pulp while larger yield (4.0 wt%) of fine and clean fibrils of PALF was obtained using 3 wt% of sodium hydroxide (NaOH). In Part 2, (extraction parameter), the PALF extraction was done by cooking the PALF in NaOH at 1 wt% to 11 wt% NaOH concentrations for 30 to 180 minutes. Scanning electron microscopy images showed that the structure of fibre was starting to deteriorate when the concentration of NaOH was more than 10 wt%. Thermogravimetric analysis revealed that at the concentration of less than 3 wt% NaOH was insufficient to remove the hemicellulose layer from the fiber. It was also found that the amount of lignin removal was constant at 7 wt% NaOH onwards, as revealed by the value of Kappa number. Fourier transform infrared spectroscopy shows that at 3 wt% NaOH was sufficient to remove the hemicellulose and lignin from the PALF. In conclusion, 3 wt% NaOH concentration, 90 minutes of cooking time at 90 °C were identified as the optimum parameter to be used in the delignification process. Further discovery revealed that the NaOH solution can be reused one time only for the extraction process without significantly affected the extracted PALF’s properties. In Part 3 (kraft paper production), kraft papers produced using the PALF extracted at different NaOH concentrations (1, 3, 5, 7, 9, and 11 wt%) and NaOH solution recycle were characterized in terms of tensile strength, tear strength and water absorption properties. It was found that the average tearing force of the kraft paper reached its maximum (216604.8 mN) at the NaOH concentration of 9 wt% while the tensile strength was at its maximum (13 MPa) at 3 wt% NaOH. It was also observed that by recycling 3 wt% NaOH solution led to the reduction of PALF paper tensile strength from 12.6 MPa (fresh NaOH) to 11 MPa (1^{st} recycle) and 6.5 MPa (2^{nd} recycle). At 3 wt% NaOH concentration and only one time of NaOH recycling were good processing parameters for obtaining PALF kraft papers with balance properties. In Part 4, the kraft paper prepared at the selective parameter (3 wt% NaOH, 90 minutes cooking time at 90 ^{0}C) was used as a reinforcing layer in the epoxy resin. The kraft paper/epoxy composites were prepared at different number of layers i.e. 1, 2 and 3 layers. The properties of the composites were measured via tensile test and Izod impact test. Results showed that the insertion of the papers' layers made of NaOH extraction into the epoxy resin had reduced the density and the tensile properties of the composites. However, the impact properties of the composites improved corresponding to the fiber pull out as a result of weak fiber-matrix bonding. In contrast, the composite that used the papers made of manual retted PALF have weak impact strength due to the stronger fiber-matrix adhesion.

ABSTRAK

Penanaman nanas di Malaysia menghasilkan sisa seperti daun dan jambul di mana sisa ini dibuang atau pun dibiarkan di ladang. Kaedah pengekstrakan gentian daun nanas (PALF) yang sistematik telah direkabentuk bagi memaksimakan penggunaan sisa ini dan menjadikan penanaman nanas lebih lestari. Maka, kajian yang terdiri daripada empat bahagian ini telah dijalankan untuk membangunkan satu kaedah pengekstrakan yang efektif. Di bahagian 1 (pemilihan kaedah), PALF daripada kultivar *Josapine* telah berjaya diekstrak dengan kaedah rautan manual (sikatan), rendaman air, pengekstrakan kimia atau pengekstrakan mekanikal-kimia. Kaedah pengekstrakan mekanikal-kimia didapati merupakan kaedah terbaik bagi menghasilkan pulpa yang keputihan serta hasil yang banyak (4.0 wt%) dan gentian PALF yang halus dan bersih diperolehi menggunakan 3 wt% NaOH. Di bahagian 2, (parameter pengekstrakan), pengekstrakan PALF dilakukan dengan memasak PALF pada kepekatan NaOH antara 1 hingga 11 wt% selama 30 hingga 180 minit. Imej mikroskop elekton imbasan menunjukkan bahawa gentian mula merosot pada kepekatan NaOH melebihi 10 wt%. Analisis termogravimetrik menunjukkan bahawa kepekatan NaOH kurang dari 3 wt% tidak cukup untuk mengalihkan lapisan hemiselulosa daripada gentian nanas. Didapati bahawa jumlah penyingkiran lignin adalah malar pada 7 wt% dan ke atas, seperti yang telah ditunjukkan oleh nilai nombor Kappa. Spektroskopi inframerah jelmaan Fourier menunjukkan pada 3 wt% NaOH cukup untuk menyingkirkan hemiselulosa dan lignin daripada PALF. Kesimpulannya, 3 wt% kepekatan NaOH, 90 minit masa memasak pada 90 °C telah dikenalpasti sebagai parameter optima untuk digunakan dalam proses delignifikasi. Penemuan selanjutnya menunjukkan bahawa larutan NaOH boleh dikitar semula hanya sekali tanpa menjejaskan sifat-sifat PALF yang diekstrak. Di bahagian 3 (penghasilan kertas kraf), kertas kraf yang terhasil daripada PALF yang diekstrak pada kepekatan NaOH (1, 3, 5, 7, 9 dan 11 wt%) dan kitar semula larutan NaOH telah dikaji berdasarkan sifat kekuatan tegangan, kekuatan koyakan dan penyerapan air. Didapati bahawa purata daya koyakan kertas kraf mencapai tahap maksima (216604.8 mN) pada kepekatan 9 wt% NaOH manakala kekuatan tegangan maksima (13 MPa) tercapai pada 3 wt% NaOH. Juga diperhatikan bahawa kitar semula pada 3 wt% larutan NaOH menyebabkan penurunan pada kekuatan tegangan kertas PALF daripada 12.6 MPa (NaOH segar) kepada 11 MPa (kitar semula sekali) dan 6.5 MPa (kitar semula kali kedua). Maka, 3 wt% kepekatan NaOH dan penggunaan semula larutan NaOH kali pertama adalah parameter pemprosesan yang baik untuk mendapatkan kertas PALF dengan sifat yang seimbang. Di bahagian 4, kertas kraf telah disediakan pada parameter yang telah dipilih (3 wt% NaOH, 90 minit masa memasak pada 90 °C) telah digunakan sebagai lapisan penetulang dalam resin epoksi. Komposit kertas kraf/epoksi telah disediakan pada jumlah lapisan yang berbeza iaitu 1, 2 dan 3 lapisan. Sifat-sifat komposit telah diukur melalui ujian tegangan dan hentaman Izod. Keputusan menunjukkan bahawa penyelitan helaian kertas yang diperbuat secara pengekstrakan NaOH telah mengurangkan ketumpatan komposit dan sifat tegangan. Bagaimanapun, sifat hentaman komposit bertambah baik kerana kejadian tarik keluar gentian disebabkan kelemahan ikatan gentian-matriks. Sebaliknya, komposit yang menggunakan kertas yang dihasilkan melalui kaedah rautan manual mempunyai sifat hentaman yang lemah disebabkan oleh kekuatan rekatan gentian-matriks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AQ	-	anthraquinone
DEG	-	diethylene glycol
DMF	-	dimethylformamide
DSC	-	differential scanning calorimetry
EDTA	-	ethylene diamine tetra acetic acid
FAO	-	Food and Agriculture Organization
FTIR	-	Fourier Transform Infrared
MPIB	-	Malaysian Pineapple Industry Board
M	-	manual retted
MC	-	mechanical-chemical retted
NFC	-	nanofibrillated cellulose
OCC	-	old corrugated container
OPEFB	-	oil palm empty fruit bunch
PAL	-	pineapple leaf
PALF	-	pineapple leaf fiber
PANI	-	polyaniline
TCF	-	totally chlorine free
$CaCO_3$	-	calcium carbonate
H_2O_2	-	hydrogen peroxide
Na_2S	-	sodium sulphide

LIST OF SYMBOLS

K	-	Kappa number
f	-	factor correction to a 50% permanganate consumption, dependent on the value of *p*
w	-	weight of moisture free pulp in the specimen, g
p	-	amount of 0.1 permanganate actually consumed by the test specimen, ml
b	-	amount of thiosulfate consumed in the blank determination, ml
a	-	amount of thiosulfate consumed by the test specimen, ml
N	-	normality of thiosulfate
X	-	mass of the PALF obtained from the extraction process, g
Y	-	initial mass of PAL used in the extraction process, g
m_1	-	wet weight, g
m_2	-	conditioned weight, g
ρ_c	-	calculated density of solid, g/cm^3
A	-	weight of the solid in the air, g
B	-	weight of the solid in the auxiliary liquid (distilled water), g
ρ_0	-	density of the auxiliary liquid at the given temperature, g/cm^3

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Increasing global industrialization led to significant consumption of paper especially for the purpose of packaging, which accounts for over 41 % of paper usage globally (Beckline, Yujun, Eric et al., 2016). According to the pulp and paper capacities survey 2013 – 2018 by the Food and Agriculture Organization of the United Nations (FAO, 2014), the global paper consumption will increase to 500 million tons in year 2025 which corresponds to an annual paper consumption growth of 1.6 %. The intensive paper consumption leads to significant depletion in natural resources especially wood due to rapid deforestation. Conventionally, paper was produced from the hardwood pulp which caused the deforestation to occur as these sources of hardwood took up several years before mature. Hence, research has been conducted continuously to search different source of suitable pulp for paper especially for packaging purposes.

Much efforts have been invested to study different non-wood alternatives as potential candidates for paper production. One of the potential replacements of wood in paper pulp production is pineapple leaf fiber (PALF), which is abundantly available in Malaysia (Daud, Hatta, Kassim et al., 2013; Yusof, Ahmad and Wahab., 2012). There are many attempts and researches that have been done on the utilization of PALF as cellulosic materials either for pulp production or as reinforcement in the natural fiber based polymer composites.

Researchers utilized pineapple biomass especially pineapple leaves to produce PALF/polypropylene (PP) composites (Arib, Sapuan, Ahmad et al., 2006), PALF/glass vinyl ester (VE) hybrid biocomposites (Zin, Abdan, Mazlan et al., 2019), PALF/polyester composites (Senthilkumar, Saba, Chandrasekar et al., 2019), silane treated kenaf/PALF phenolic hybrid biocomposites (Asim, Jawaid, Abdan et al., 2016), PALF, napier and hemp fibres filled scratch resistant epoxy composites (Ridzuan, Abdul Majid, Khasrib et al., 2019), sound adsorption material (Putra, Or, Selamat et al., 2018) and soil cover (Sarah, Rahman, Majid et al., 2018).

Pineapple leaf (PAL) serves as an attractive option for pulp making as pineapple plant can produce up to 1.5 kg of leaves per plant which is left in the field after cultivation (Sibaly and Jeetah, 2017). Furthermore, PALF possesses high cellulose content (66.2%) and low lignin content (4.2%) which resulted in good mechanical properties against the potential abrasion and tear when it is used as a packaging material (Mohamed, Sapuan, Shahjahan et al., 2009; Daud et al., 2013). Thus far, PALF has been used as the raw materials for pulping by Wutisatwongkul and co-workers (2016) where varies soda-pulping conditions were studied. Daud et al. (2013) studied on the suitability of napier grass and PALF for papermaking production where the study stated that both fibres exhibited great potential as substitute for pulp production.

1.2 Problem Statement

In Malaysia especially in the state of Johor, pineapple cultivation has contributed much to the income for the country. According to Malaysian Pineapple Industry Board (MPIB), there are more than 10 types of pineapple cultivators that are widely cultivated in the country, Josapine, Moris, Sarawak, MD2 and N36, to name a few. The main parts of a pineapple plant include the fruit, crown, stem and leaves. However, there is almost 50 % of the pineapple parts are covered by the leaves which are left unwanted during the harvest. During harvest, the unwanted by-products of pineapple are usually thrown away or burnt in the field as shown in Figure 1.1 hence generated wastes and air pollution (Sarah et al., 2018; Kasim, Selamat, Aznan et al., 2015 and Hazarika, Gogoi, Jose et al., 2017) as this burning can take up to 2 to 3 days for completion. Open burning at the field was found to be the cheapest way to get rid of the wastes before next plantation as it does not acquire much labour. Thousand tons of PAL were produced and discarded every year yet only a small amount of it was used as feed stock for energy production (Asim, Khalina and Jawaid et al., 2015). In order to reduce the negative impact of the generated wastes, research works have been done to convert them into value-added products, as mentioned in the introduction.

Figure 1.1 Open burning of pineapple field in Pontian (a) Before cultivation (b) After cultivation

Effective fiber extraction method must be established in order to enhance the feasibility of PAL usage as a non-wood alternative for pulp production (Daud et al., 2013; Yusof et al., 2012). The conventional extraction method often falls into three categories namely, mechanical method, chemical method and mechanical-chemical method. So far, reports on the results obtained by utilizing separate, different methods are available (Uddin, Miah, Jalil et al., 2018; Sarah et al., 2018; Laftah and Rahman., 2015 and Munawar, Umemura, Tanaka et al., 2008) but a systematic study which covers the comparison of all the aforementioned methods and the selection of the best processing parameters is still a gap in the field that needs to be filled.

On the other hand, the black liquor produced from the delignification process which consists mainly of sodium hydroxide (NaOH) was regarded as pulping discharged. There were attempts to recover portion of this black liquor for energy generation purpose (Vakkilainen and Välimäki, 2014; Tran and Vakkilainen, 2016). The black liquor was recovered to obtain the pulping chemicals such as NaOH, sodium sulphide (Na_2S) and calcium carbonate ($CaCO_3$) where the chemicals were returned to the digester for reuse in pulping and serve as a fuel for steam production to generate energy. However, the recovery process was only applicable to big scale pulp production and it could be quite expensive due to the machineries involved. Therefore, recycling of NaOH solution in the extraction process can be an interesting topic to be focused on.

Natural fiber has been used in producing reinforced epoxy composites; for instance, Sand, Oliveira and Cândido et al. (2019) used bamboo/woven kenaf mat to produce epoxy hybrid composites. Others include sugar palm/epoxy composites (Bachtiar, Sapuan and Hamdan, 2008), abaca/epoxy laminated composites (Sinha, Narang and Bhattacharya, 2018), laminates of napier grass fiber/polyester (Haameem, Majid and Afendi et al., 2015), and jute/PALF/glass fiber reinforced epoxy composites (Reddy, Kumar and Rama et al., 2018). However, application of PALF paper as reinforcing material for epoxy has not been found. This justifies the need for the related studies.

This study was conducted so that the selection of PALF extraction method and determination of the best PALF extraction parameters can be done systematically. Four commonly used PALF extraction methods were screened through based on the PALF yields and morphology. After that, effects of processing parameters such as NaOH concentration and cooking time on the PALF yield and morphology were studied. Besides, effects of utilizing recycled NaOH was also investigated.

The extracted PALF was then used to produce kraft paper via conventional papermaking method. The kraft paper was then incorporated into epoxy resin to produce PAL/epoxy composites in order to study its effectiveness as reinforcing material.

1.3 Objectives of the Study

The aim of this study was to identify the most suitable extraction method and processing conditions for PALF extraction which was used for the production of kraft paper and epoxy composites. This aim is subdivided into the following objectives:

(a) To determine the best PALF extraction method based on dry pulp yield and fiber morphology.

(b) To study the effects of NaOH concentrations, cooking time as well as NaOH solution recycling on the dry pulp yield, morphological and thermal properties of the extracted PALF.

(c) To characterize the PALF kraft paper produced at different NaOH concentrations and NaOH recycling level in terms of their water absorption, tear and tensile properties.

(d) To study the effects of PALF kraft paper incorporation on density, tensile, impact and morphological properties of epoxy composites.

1.4 Scope of the Study

The whole study was divided into four parts which are PALF extraction method selection, extraction parameters studies, PALF paper characterizations and PALF/epoxy composites characterizations. Josapine cultivator was used as the source of PALF.

Four extraction methods namely, manual retting, water retting, chemical extraction and mechanical-chemical extraction were investigated. The extraction parameters studied were NaOH solution concentrations (1 to 11 wt%) and cooking time (from 30 to 180 minutes). Selections of the most suitable method and extraction parameters were done based on the percentage of dry pulp yield, morphological and thermal properties. In the study of the effects of NaOH solution recycling, the NaOH solutions were recycled up to 2 times only.

PALF paper was produced by using conventional papermaking process where 16 g of pulp was used to produce each sheet. Characterizations and properties of paper were determined based on tearing properties, percentage of water absorption and tensile properties.

Move on to the next part, PALF/epoxy composites were produced by hand lay-up process. Epoxy and hardener were kept at 2:1 for each formulation. PALF paper produced from manual retting (without NaOH) and chemical-mechanical (with NaOH) were used and each composite consists of 1, 2 or 3 plies of PALF paper. Properties of the PALF/epoxy composites were determined based on density measurement, physical and morphological properties.

Testing involved in each part of the study are as follows:

(i) Extraction method selection
- Percentage of dry pulp yield
- Morphological properties (SEM)

(ii) Fiber extraction parameter selection
- Percentage of dry pulp yield
- Morphological properties (SEM)
- Functional groups identification (FTIR)
- Kappa number determinations
- Thermal properties (TGA)

(iii) Paper production and characterizations

- Tearing test
- Water absorption test
- Tensile properties

(iv) PALF Paper/epoxy composites performance testing

- Density measurement
- Tensile properties
- Impact properties
- Morphological properties (SEM)

REFERENCES

Adeyi, A. J., Adeyi, O., Oke, E. O., Olalere, O. A., Oyelami, S., and Ogunsola, A. D. (2021). Effect of varied fiber alkali treatments on the tensile strength of Ampelocissus cavicaulis reinforced polyester composites: Prediction, optimization, uncertainty and sensitivity analysis. *Advanced Industrial and Engineering Polymer Research*, *4*(1), 29–40. https://doi.org/10.1016/j.aiepr.2020.12.002

Agrawal, R., Saxena, N. S., Sharma, K. B., Thomas, S., and Sreekala, M. S. (2000). Activation energy and crystallization kinetics of untreated and treated oil palm fibre reinforced phenol formaldehyde composites. *Materials Science and Engineering A277*, *277*, 77–82.

Akash, Venkatesha Gupta, N. S., and Sreenivas Rao, K. V. (2018). An experimental study on sisal/hemp fiber reinforced hybrid composites. *Materials Today: Proceedings*, *5*(2), 7383–7387. https://doi.org/10.1016/j.matpr.2017.11.408

Ardina, V., Irawan, B., and Prajitno, D. H. and Roesyadi, A. (2018). Active alkali charge effect on kraft pulping process of acacia mangium and eucalyptus pellita active alkali charge effect on kraft pulping process of acacia mangium and eucalyptus pellita. *AIP Conference Proceedings 2014*, *020036* (September).

Ariawan, D., Rivai, T. S., Surojo, E., Hidayatulloh, S., Akbar, H. I., and Prabowo, A. R. (2020). Effect of alkali treatment of Salacca Zalacca fiber (SZF) on mechanical properties of HDPE composite reinforced with SZF. *Alexandria Engineering Journal*, *59*(5), 3981–3989. https://doi.org/10.1016/j.aej.2020.07.005

Arib, R. M. N., Sapuan, S. M., Ahmad, M. M. H. M., Paridah, M. T. and Khairul Zaman, H. M. D. (2006). Mechanical properties of pineapple leaf fibre reinforced polypropylene composites. *Materials and Design, 27*, 391-396.

Ariffin, A. and Yusof, Y. (2017). Effect of extraction process and surface treatment on the mechanical properties in pineapple leaf fibre. *MATEC Web of Conferences, 135*, 00042

Aristri, M. A., Lubis, M. A. R., Yadav, S. M., Antov, P., Papadopoulos, A. N., Pizzi, A., Fatriasari, W., Ismayanti, M. and Iswanto, A. H. (2021). Recent developments in lignin- and tannin-based non-isocyanate polyurethane resins for wood adhesives—a review. *Applied Sciences (Switzerland)*, *11*(9), 1–29. https://doi.org/10.3390/app11094242

Asim, M., Khalina, A., Jawaid, M., Nasir, M., Zahra, D., Ishak, M. R., and Hoque, M. E. (2015). A review on pineapple leaves fibre and its composites. *International Journal of Polymeric Science*, *2015*, 1–16.

Asim, M., Jawaid, M., Abdan, K., and 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., Abdan, K., and Nasir, M. (2017). Effect of alkali treatments on physical and mechanical strength of pineapple leaf fibres. *IOP Conf. Series: Materials Science and Engineering*, *290*, 2–7.

Athijayamani, A., Thiruchitrambalam, M., Natarajan, U. and Pazhanivel, B. (2009). Effect of moisture absorption on the mechanical properties of randomly oriented natural fibers/ polyester hybrid composite. *Material Science and Engineering A. 517*, 344-353.

Azeez, M. A. (2018). Pulping of Non-Woody Biomass. In S. N. Kazi (Ed.), *Pulp and Paper Processing* (pp. 1–32). https://doi.org/10.5772/intechopen.79749

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

Balaji, A. N., and Nagarajan, K. J. (2017). Characterization of alkali treated and untreated new cellulosic fiber from Saharan aloe vera cactus leaves. *Carbohydrate Polymers*, *174*, 200–208.

Banerjee, R., Chintagunta, A. D., and Ray, S. (2017). A cleaner and eco-friendly bioprocess for enhancing reducing sugar production from pineapple leaf waste. *Journal of Cleaner Production*, *149*, 387–395.

Beckline, M., Yujun, S., Eric, Z., and Kato, M. S. (2016). Paper consumption and environmental impact in an emerging economy. *Journal of Energy, Environmental and Chemical Engineering*, *1*(1), 13-18.

Benyahia, A., Merrouche, A., Rokbi, M., and Kouadri, Z. (2013). Study the effect of alkali treatment of natural fibers on the mechanical behavior of the composite unsaturated polyester-fiber Alfa. *21ème Congrès Français de Mécanique*, *21*, 1–6.

Bhardwaj, N. K., Kaur, D., Chaudhry, S., Sharma, M., and Arya, S. (2019). Approaches for converting sugarcane trash, a promising agro residue, into pulp and paper using soda pulping and elemental chlorine-free bleaching. *Journal of Cleaner Production*, *217*, 225–233. https://doi.org/10.1016/j.jclepro.2019.01.223

Bidin, N., Zakaria, M. H., Bujang, J. S., and Abdul Aziz, N. A. (2015). Suitability of aquatic plant fibers for handmade papermaking. *International Journal of Polymer Science*, 1–9.

Boix, E., Georgi, F., and Navard, P. (2016). Influence of alkali and Si-based treatments on the physical and chemical characteristics of miscanthus stem fragments. *Industrial Crops & Products*, *91*, 6–14.

Boussehel, H., Mazouzi, D. E., Belghar, N., Guerira, B., and Lachi, M. (2019). Effect of chemicals treatments on the morphological, mechanical, thermal and water uptake properties of polyvinyl chloride/ palm fibers composites. *Revue Des Composites et Des Materiaux Avances*, *29*(1), 1–8. https://doi.org/10.18280/rcma.290101

Brodowsky, H. M., Hennig, A., Müller, M. T., Werner, A., Zhandarov, S., and Gohs, U. (2020). Laccase-enzyme treated flax fibre for use in natural fibre epoxy composites. *Materials*, *13*(20), 1–14. https://doi.org/10.3390/ma13204529

Chandra Sekhar, V., Sreedhar, C., and Rajesh, P. (2018). Effect of fiber loading and fiber length on tensile properties of fiber reinforced epoxy composites. *Materials Today: Proceedings*, *5*(13), 27149–27154. https://doi.org/10.1016/j.matpr.2018.09.024

Cherian, B. M., Leão, A. L., de Souza S. F., Thomas, S., Pothan, L. A., and Kottaisamy, M. (2010). Isolation of nanocellulose from pineapple leaf fibres by steam explosion. *Carbohydrate Polymer*, *81*, 720–725.

Chintagunta, A. D., Ray, S., and Banerjee, R. (2017). An integrated bioprocess for bioethanol and biomanure production from pineapple leaf waste. *Journal of Cleaner Production*, *165*, 1508–1516.

Costa, U. O., Fabio, L., Nascimento, C., Garcia, J. M., Bruno, W., Bezerra, A., and Monteiro, S. N. (2019). Evaluation of Izod impact and bend properties of epoxy composites reinforced with mallow fibers. *Integrative Medicine Research, 9*(1), 373–382. https://doi.org/10.1016/j.jmrt.2019.10.066

Członka, S., Strakowska, A., Pospiech, P., and Strzelec, K. (2020). Effects of chemically treated eucalyptus fibers on mechanical, thermal and insulating properties of polyurethane composite foams. *Materials*, *13*(7), 1-22. https://doi.org/10.3390/MA13071781

Daud, Z., Mohd Hatta, M. Z., Mohd Kassim, A. S., and Mohd Aripin, A. (2013). Suitability of Malaysia's pineapple leaf and napier grass as a fiber substitution for paper making industry. *EnCon 2013, 6th Engineering Conference, "Energy and Environment,"* 2–5. Kuching, Sarawak.

Deesoruth, A., and Ramasawmy, H. (2014). Investigation into the use of alkali treated screwpine (Pandanus Utilis) fibres as reinforcement in epoxy matrix. 18 (December), 263–279.

del Rey, R., Serrat, R., Alba, J., Perez, I., Mutje, P., and Espinach, F. X. (2017). Effect of sodium hydroxide treatments on the tensile strength and the interphase quality of hemp core fiber-reinforced polypropylene composites. *Polymers, 9*(8). https://doi.org/10.3390/polym9080377

De Prez, J., Van Vuure, A. W., Ivens, J., Aerts, G., and Van de Voorde, I. (2019). Flax treatment with strategic enzyme combinations: Effect on chemical fiber composition and ease of fiber extraction. *Biotechnology Reports*, *23*, e00358. https://doi.org/10.1016/j.btre.2019.e00358

Diaz, M. J., Garcia, M. M., Eugenio, M. E., Tapias, R., Fernandez, M., and Lopez, F. (2007). Variations in fiber length and some pulp chemical properties of Leucaena varieties. *Industrial Crops & Products*, *26*, 142–150.

Dutt, D., Upadhyaya, J. S., Malik, R. S., and Tyagi, C. H. (2004). Studies on pulp and paper - making characteristics of some Indian non-woody fibrous raw materials: Part 1. *Journal of Scientific & Industrial Research*, *63*(2004), 48–57.

Edson, T., Segura, S., and Sarto, C. (2016). Effect of Kappa number variation on modified pulping of eucalyptus. *BioResources. 11*(4), 9842–9855.

Ekhtera, M. H., Azadfallah, M., Bahrami, M., and Mohammadi-Rovshandeh, J. (2009). Comparative study of pulp and paper properties of canola stalks prepared by using dimethyl formamide or diethylene glycol. *BioResources*, *4*(1), 214–233.

Fabio, L., Nascimento, C., Monteiro, S. N., Henrique, L., Louro, L., Santos, F., dos Santos, J. L., Braga, F. D. O. and Marcal, R. L. S. B. (2018). Charpy impact test of epoxy composites reinforced with untreated and mercerized mallow fibers. *Journal of Material Resources and Technology*. *7*(4), 520–527.

Fahmi, I., Abdul Majid, M., Afendi, M., Helmi, E. A., and Haameem, M. J. A. (2016). Low-velocity impact responses of Napier fibre/polyester composites. *International Journal of Automotive and Mechanical Engineering*, *13*(1), 3226–3237.

Fang, G., and Shen, K. (2018). Wheat straw pulping for paper and paperboard production production. In S. Fahad & A. Basir (Eds.), *Global Wheat Production* (pp. 223–239).

FAO, 2014. Pulp and paper capacities survey 2013-2018. Rome.

Feng, Z. and Alén, R. (2001). Soda-AQ pulping of reed canary grass. *Industrial Crops and Products, 14*(1), 31-39.

Ferreira, A. C. H., Rodriguez, N. M., Neiva, J. N. M., Pimentel, P. G., Gomes, S. P., Campos, and W. E., Moreira, G. R. (2016). In situ degradability of elephant grass ensiled with increasing levels of pineapple agro-industrial byproduct. *Ciências Agrárias*, *37*(4–1), 2807–2818.

Ferreira, D. P., Cruz, J., and Fangueiro, R. (2018). Surface modification of natural fibers in polymer composites. In G. Koronis & A. Silva (Eds.), *Green Composites for Automotive Applications*. https://doi.org/10.1016/B978-0-08-102177-4.00001-X

Fitriasari, W., Supriyanto, and Ispriyanto, A. H. (2015). The Kraft pulp and paper properties of sweet sorghum bagasse (sorghum the kraft pulp and paper properties of sweet sorghum bagasse (Sorghum Bicolor L Moench). *Journal of Engineering and Technological Science*, (June), 149–159.

Ghosh, S. R., Kalita, D., and Saikia, C. N. (2003). Studies on pulping and paper making characteristics of some common reeds. *Journal of Indian Pulp and Paper Technical Association*, *15*(1), 59–63.

Gonzalo, A., Bimbela, F., Sanchez, J. L., Labidi, J., Marín, F., and Arauzo, J. (2017). Evaluation of different agricultural residues as raw materials for pulp and paper production using a semichemical process. *Journal of Cleaner Production*, *156*, 184–193. https://doi.org/10.1016/j.jclepro.2017.04.036

Haameem, M. J. A., Abdul Majid, M. S., Afendi, M., Haslan Fadli, M., Helmi, E. A., and Fahmi, I. (2015). Tensile and flexural strength of untreated Napier grass fibre/polyester composites. *Material Science Forum*, *819*, 295–300. https://doi.org/10.4028/www.scientific.net/MSF.819.295

Haameem, M. J. A., Abdul Majid, M. S., Afendi, M., Marzuki, H. F. A., Fahmi, I., and Gibson, A. G. (2016). Mechanical properties of Napier grass fibre/polyester composites. *Composite Structure*, *136*, 1–10.

Hafizhah, R., Juwono, A. I., and Roseno, S. (2017). Study of tensile properties and deflection temperature of polypropylene/Subang pineapple leaf fiber composites. *IOP Conf. Series: Materials Science and Engineering*, *196*, 1–4.

Hashim, M. Y., Roslan, M. N., Mohd Zin, S. M., Ariffin, S. (2013). Determination of alkali treatment conditions effects which influence the variability of kenaf fiber mean cross sectional area. *International Journal of Mechanical and Mechatronics Engineering, 7*(10).

Hassan, A., Othman, Z., & Siriphanich, J. (2011). Pineapple (Ananas comosus L. Merr.). In *Postharvest Biology and Technology of Tropical and Subtropical Fruits* (Vol. 4). https://doi.org/10.1533/9780857092618.194

Hazarika, D., Gogoi, N., Jose, S., Das, R., and Basu, G. (2017). Exploration of future prospects of Indian pineapple leaf, an agro waste for textile application. *Journal of Cleaner Production*, *141*, 580–586.

Hedjazi, S., Kordsachia, O., Patt, R., Latibari, A. J., and Tschirner, U. (2009). Alkaline sulfite-anthraquinone (AS/AQ) pulping of wheat straw and totally chlorine free (TCF) bleaching of pulps. *Industrial Crops & Products*, *29*(1), 27–36.

Hoang, V. T., Pham, T. N., & Yum, Y. J. (2020). Mechanical properties of coconut trunk particle/polyester composite based on alkali treatment. *Advanced Composites Letters*, *29*, 1–6. https://doi.org/10.1177/2633366X20935891

Hossain, S. I., Hasan, M., Hasan, M. N., and Hassan, A. (2013). Effect of chemical treatment on physical, mechanical and thermal properties of ladies finger natural fiber. *Advances in Materials Science and Engineering*, *2013*, 1–6.

Hubbe, M. A., Alén, R., Paleologou, M., Kannangara, M., and Kihlman, J. (2019). Lignin recovery from spent alkaline pulping liquors using acidification, membrane separation, and related processing steps: A review. *BioResources.Com*, *14*(1), 1–52.

Hurter, B. R. W. (2001). Nonwood Plant Fiber Uses in Papermaking. *TAPPI 1997 Nonwood Fibers Short Course Notes*, (August), 1–6.

Ilvessalo-Pfäffli, M.-S. (1995). Descriptions of Nonwood Plant Fibers. In M.-S. Ilvessalo-Pfäffli (Ed.), *Fiber Atlas: Identification of Papermaking Fibers* (1st ed., pp. 307–359). https://doi.org/https://doi.org/10.1007/978-3-662-07212-7

Jahan, M. S., Al-Maruf, A., and Quaiyyum, M. A. (2007). Comparative Studies of Pulping of Jute Fiber, Jute Cutting and Jute Caddis. *Bangladesh Journal of Scientific and Industrial Research*, *42*(4), 425–434.

Jain, J., Jain, S., and Sinha, S. (2018). Characterization and thermal kinetic analysis of pineapple leaf fibers and their reinforcement in epoxy. *Journal of Elastomers and Plastics*, 1–21. https://doi.org/10.1177/0095244318783024

Jain, J., Sinha, S., and Jain, S. (2021). Compendious characterization of chemically treated natural fiber from pineapple leaves for reinforcement in polymer composites. *Journal of Natural Fibers*, *18*(6), 845–856. https://doi.org/10.1080/15440478.2019.1658256

Jaramillo, N., Hoyos, D., and Santa, J. F. (2016). Composites with pineapple-leaf fibers manufactured by layered compression molding Compuestos de fibra de hoja de piña fabricados mediante. *Ingeniería y Competitividad*, *18*(July), 151–162.

Jean-francis, B., Imtiaz, A., Raphael, P., and Sabine, R. du R. (2013). Papers as functional green materials. *Advanced Materials Research*, *747*, 715–718.

Jiang, W., Song, Y., Liu, S., Ben, H., Zhang, Y., Zhou, C., Han, G., and Ragauskas, A. J. (2018). A green degumming process of ramie. *Industrial Crops and Products*, *120*(308), 131–134. https://doi.org/10.1016/j.indcrop.2018.04.045

Jimenez, L., Ramos, E., Rodriguez, A., De la Torre, M. J., and Ferrer, J. L. (2005). Optimization of pulping conditions of abaca. An alternative raw material for producing cellulose pulp. *Bioresource Technology*, *96*, 977–983.

Juwono, A. L., and Subawi, H. (2014). The treated rice straw as potentially feedstock of wood and rice straw fiber blend for pulp and paper making industry. *Advanced Materials Research*, *896*, 318–321.

Kaewpirom, S., and Worrarat, C. (2014). Preparation and properties of pineapple leaf fiber reinforced poly (lactic acid) green composites. *Fibers and Polymers*, *15*(7), 1469–1477.

Kalapakdee, A., and Amornsakchai, T. (2014). Mechanical properties of preferentially aligned short pineapple leaf fiber reinforced thermoplastic elastomer: Effects of fiber content and matrix orientation. *Polymer Testing*, *37*, 36–44.

Kathirselvam, M., Kumaravel, A., Arthanarieswaran, V. P., and Saravanakumar, S. S. (2019). Characterization of cellulose fibers in thespesia populnea barks: Influence of alkali treatment. *Carbohydrate Polymer, 217*, 178–189.

Kasim, A. N., Selamat, M. Z., Aznan, N., Sahadan, S. N., Mohd Daud, M. A., Jumaidin, R., and Salleh, S. (2015). Effect of pineapple leaf fiber loading on the mechanical properties of pineapple leaf fiber – polypropylene composite. *Jurnal Teknologi*, *77*(21), 117–123.

Kasim, A. N., Selamat, M. Z., Daud, M. A. M., Yaakob, M. Y., Putra, A., and Sivakumar, D. (2016). Mechanical properties of polypropylene composites reinforced with alkaline treated pineapple leaf fibre from Josapine cultivar. *International Journal of Automotive and Mechanical Engineering*, *13*(1), 3157–3167.

Kengkhetkit, N., and Amornsakchai, T. (2012). Utilisation of pineapple leaf waste for plastic reinforcement: 1. A novel extraction method for short pineapple leaf fiber. *Industrial Crops & Products*, *40*, 55–61.

Kengkhetkit, N., and Amornsakchai, T. (2014). A new approach to '"Greening"' plastic composites using pineapple leaf waste for performance and cost effectiveness. *Materials and Design*, *55*, 292–299.

Khalil, H. P. S. A., Yusra, A. F. I., Bhat, A. H., and Jawaid, M. (2010). Cell wall ultrastructure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. *Industrial Crops and Products. 31*, 113–121.

Kim, S., Park, J. M., Seo, J., and Kim, C. H. (2012). Sequential acid-/alkali-pretreatment of empty palm fruit bunch fiber. *Bioresource Technology*, *109*, 229–233.

Kojima, Y., Kato, Y., Akazawa, M., Yoon, S.-L., and Lee, M.-K. (2015). Pyrolysis characteristic of kenaf studied with separated tissues, alkali pulp, and alkali lignin. *Biofuel Research Journal*, *2*(4), 317–323.

Kumar, D.S. and Marimuthu, P. (2012). Sweet sorghum stalks-an alternate agro based raw material for paper making. *IPPTA Journal*, *24*(3), 47-50.

Kumar, A., Singh, B. P., Jain, R. K., and Sharma, A. K. (2013). The use of alternate ligno-cellulosic raw materials banana (Musa sapientum) Ankara (Calotropis procera) and pineapple (Ananas comosus) in handmade paper and their blending with waste paper. *American Journal of Engineering Research*, *2*(9), 171–189.

Laftah, W. A., and Rahman, W. A. W. A. (2015). Chemical pulping of waste pineapple leaves fiber for kraft paper production. *Journal of Materials Research and Technology*, *4*(3), 254–261.

Laftah, W. A., and Wan Abdul Rahman, W. A. (2016). Pulping process and the potential of using non-wood pineapple leaves fiber for pulp and paper production: A review. *Journal of Natural Fibers*, *13*(1), 85–102.

Lai, J. C., Rahman, W. A. W. A., and Toh, W. Y. (2013). Characterisation of sago pith waste and its composites. *Industrial Crops & Products*, *45*, 319–326.

Lasikun, Ariawan, D., Surojo, E., and Triyono, J. (2018). Effect of fiber orientation on tensile and impact properties of Zalacca Midrib fiber- HDPE composites by compression molding Effect of Fiber Orientation on Tensile and Impact Properties of Zalacca Midrib Fiber-HDPE Composites by Compression. *AIP Conference Proceedings*, *030060*(February), 1–6.

Latibari, A. J., and Pourali, K. (2019). Effect of alkaline pre-hydrolysis on soda pulping. *Cellulose Chemistry and Technology*, *53*, 79–85.

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

Liu, Z., Huimei, W., and Lanfeng, H. (2018). Pulping and Papermaking of Non-Wood Fibers. In S. N. Kazi (Ed.), *Pulp and Paper Processing* (1st ed., p. 30). https://doi.org/10.5772/intechopen.79017

Lopattananon, N., Panawarangkul, K., Sahakaro, K., and Ellis, B. (2006). Performance of pineapple leaf fiber-natural rubber composites: The effect of fiber surface treatments. *Journal of Applied Polymer Science*, *102*(2), 1974–1984.

Lopattananon, N., Payae, Y., and Seadan, M. (2008). Influence of Fiber modification on interfacial adhesion and mechanical properties of pineapple leaf fiber-epoxy composites. *Journal of Applied Polymer Science, 110,* 433–443. https://doi.org/10.1002/app

Low, J. H., Ghanbari, T., Rahman, W. A. W. A. and Majid, R. A. (2018). Preparation and characterization of kenaf papers reinforced with tapioca starch: physicomechanical and morphological properties. *Journal of Natural Fibers, 15*(2), 191-203.

Low, J. H., Xun, L. Z., Yoon, L. W., Pang, M. M. and Wong, S. (2019). Exploration of tree pruning waste for papermaking. *AIP Conference Proceedings, 2137*, 020008.

Madakadze, I. C., Radiotis, T., Li, J., Goel, K., and Smith, D. L. (1999). Kraft pulping characteristics and pulp properties of warm season grasses. *Bioresource Technology*, *69*, 75–85

Maharana, S. M., Samal, P., Dehury, J., and Mohanty, P. P. (2019). Effect of fiber content and orientation on mechanical properties of epoxy composites reinforced with jute and Kevlar. *Materials Today: Proceedings*, *26*(September 2020), 273–277. https://doi.org/10.1016/j.matpr.2019.11.239

Main, N. M., Talib, R. A., Ibrahim, R., Rahman, R. A., and Mohamed, A. Z. (2014). Suitability of coir fibers as pulp and paper. *Agricultural and Agricultural Science Procedia*, *2,* 304–311.

Majid, R. A., Mohamad, Z., Rusman, R., Zulkornain, A. A., Halim, N. A., Abdullah, M., Low, J. H. (2018). Development of tea waste/kapok fiber composite paper. *Chemical Engineering Transactions*, *63*, 457-462.

Malenab, R. A. J., Ngo, J. P. S., and Promentilla, M. A. B. (2017). Chemical treatment of waste abaca for natural fiber-reinforced geopolymer composite. *Materials*, *10*(6), 1–19.

Malik, S., Rana, V., Joshi, G., Gupta, P. K., and Sharma, A. (2020). Valorization of Wheat Straw for the Paper Industry: Pre-extraction of Reducing Sugars and Its Effect on Pulping and Papermaking Properties. *ACS Omega*, *5*(47), 30704–30715. https://doi.org/10.1021/acsomega.0c04883

Manalo, A. C., Wani, E., Zulkarnain, N. A., and Karunasena, W. (2015). Effects of alkali treatment and elevated temperature on the mechanical properties of bamboo fibre-polyester composites. *Composites Part B, 80,* 73–83.

Manohar, S., Samal, P., Dehury, J. and Paramita, P. (2019). Effect of fiber content and orientation on mechanical properties of epoxy composites reinforced with jute and Kevlar. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2019.11.239

Marques, G., Rencoret, J., Gutiérrez, A., and Del Río, J. C. (2010). Evaluation of the chemical composition of different non-woody plant fibers used for pulp and paper manufacturing. *The Open Agriculture Journal*, *4*, 93–101.

Miletzky, A., Fischer, W. J., Czibula, C., Teichert, C., Bauer, W., and Schennach, R. (2015). How xylan effects the breaking load of individual fiber – fiber joints and the single fiber tensile strength. *Cellulose*, *22*, 849–859.

Minmunin, J., Limpitipanich, P., and Promwungkwa, A. (2018). Delignification of bana grass using sodium hydroxide and ozone. *Waste and Biomass Valorization*, *9*(11), 2099–2105. https://doi.org/10.1007/s12649-017-0002-2

Mohamed, A. R., Sapuan, S. M., Shahjahan, M., and Khalina, A. (2009). Characterization of pineapple leaf fibers from selected Malaysian cultivars. *Journal of Food, Agriculture and Environment*, *7*(1), 235–240.

Mohamed, A. R., Sapuan, S. M., and Khalina, A. (2014). Mechanical and thermal properties of josapine pineapple leaf fiber (PALF) and PALF-reinforced vinyl ester composites. *Fiber and Polymers*, *15*(5), 1035–1041.

Mohammed, I. Y., Abakr, Y. A., Kazi, F. K., Yusup, S., Alshareef, I., and Chin, S. A. (2015). Comprehensive characterization of napier grass as a feedstock for thermochemical conversion. *Energies*, *8*(5), 3403–3417.

Mohieldin, S. D. (2014). Pretreatment approaches to non-wood plant for pulp and paper production. *Journal of Forest Products & Industries*, *3*(2), 84–88.

Mohapatra, S., Dandapat, S. J., and Thatoi, H. (2017). Physicochemical characterization, modelling and optimization of ultrasono-assisted acid pretreatment of two Pennisetum sp. using Taguchi and artificial neural networking for enhanced delignification. *Journal of Environmental Management*, *187*, 537–549.

Moli, T., Thariq, M., Sultan, H., and Ahsan, Q. (2020). Characterization of alkali treated new cellulosic fibre from Cyrtostachys renda. *Integrative Medicine Research*, *9*(3), 3537–3546. https://doi.org/10.1016/j.jmrt.2020.01.091

Mousavi, S. M. M., Hosseini, S. Z., Resalati, H., Mahdavi, S., and Garmaroody, E. R. (2013). Papermaking potential of rapeseed straw, a new agricultural-based fiber source. *Journal of Cleaner Production*, *52*, 420–424.

Munawar, S. S., Umemura, K., Tanaka, F. and Kawai, S. (2008). Effects of alkali, mild steam, and chitosan treatments on the properties of pineapple, ramie, and sansevieria fiber bundles. *Journal of Wood Science*, *54*, 28-35.

Mydin, M. A. O., Zamzani, N. M., and Ghani, A. N. A. (2018). Effect of alkali-activated sodium hydroxide treatment of coconut fiber on mechanical properties of lightweight foamed concrete. *AIP Conference Proceedings*, *2016*(September). https://doi.org/10.1063/1.5055510

Mylsamy, B., Chinnasamy, V., Palaniappan, S. K., Subramani, S. P., and Gopalsamy, C. (2020). Effect of surface treatment on the tribological properties of Coccinia Indica cellulosic fiber reinforced polymer composites. *Journal of Materials Research and Technology*, *9*(6), 16423–16434. https://doi.org/10.1016/j.jmrt.2020.11.100

Mwaikambo, L. Y., and Ansell, M. P. (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. https://doi.org/10.1007/s10853-006-5098-x

Nagarajan, T. T., Babu, A. S., Palanivelu, K., and Nayak, S. K. (2016). Mechanical and thermal properties of PALF reinforced epoxy composites. *Macromolecular Symposia*, *361*, 57–63.

Nagieb, Z. A., Abd-El-Sayed, E. S., E-l-Sakhawy, M., and Khalil, E. M. (2019). Hydrogen peroxide alkaline pulping of bagasse. *Quarterly Journal of Indian Pulp and Paper Technical Association*, *12*(Sept 2000), 1999–2001.

Nascimento, L. F. C., Monteiro, S. N., Louro, L. H. L., Luz, F. S. Da, Santos, J. L. Dos, Braga, F. D. O., and Marçal, R. L. S. B. (2018). Charpy impact test of epoxy composites reinforced with untreated and mercerized mallow fibers. *Journal of Materials Research and Technology*, *7*(4), 520–527. https://doi.org/10.1016/j.jmrt.2018.03.008

Nasser, R. A., Hiziroglu, S., Abdel-Aal, M. A., and Al-Mefarrej, H. A. (2015). Measurement of some properties of pulp and paper made from date palm midribs and wheat straw by soda-AQ pulping process. *Measurement*, *62*, 179–186.

Nasrullah, A., Bhat, A. H., Khan, A. S., and Ajab, H. (2017). Comprehensive approach on the structure, production, processing, and application of lignin. In M. Jawaid, P. M. Tahir, and N. Saba (Eds.), *Lignocellulosic Fibre and Biomass-Based Composite Materials* (pp. 165–178). https://doi.org/10.1016/B978-0-08-100959-8.00009-3

Oladele, I. O., Michael, O. S., Adediran, A. A., Balogun, O. P., and Ajagbe, F. O. (2020). Acetylation treatment for the batch processing of natural fibers: Effects on constituents, tensile properties and surface morphology of selected plant stem fibers. *Fibers*, *8*(12), 1–19. https://doi.org/10.3390/fib8120073

Oliveira, G., Carolina, M., Teles, A., Perissé, F., and Lopes, D. (2017). Tensile strength of polyester composites reinforced with PALF. *Integrative Medicine Research*, (September), 6–11. https://doi.org/10.1016/j.jmrt.2017.08.006

Padzil, F. N. M., Ainun, Z. M. A., Naziratulasikin A. K., S. H. L., Lee, C. H., Ariffin, H., and Zainudin, E. S. (2020). Pineapple leaf fibers processing, properties and applications. In M. Jawaid, M. Asim, P. M. Tahir, and N. Mohammed (Eds.), *Green Energy and Technology* (1st ed., pp. 71–90). Singapore: Springer Nature.

Pandit, P., Pandey, R., Singha, K., Shrivastava, S., Gupta, V., and Jose, S. (2020). Pineapple leaf fibers processing, properties and applications. In M. Jawaid, M. Asim, P. M. Tahir, and N. Mohammed (Eds.), *Green Energy and Technology* (1st ed., pp. 1–20). Singapore: Springer Nature.

Panyasart, K., Chaiyut, N., and Amornsakchai, T. (2014). Effect of surface treatment on the properties of pineapple leaf fibers reinforced polyamide 6 composites. *Energy Procedia*, *56*, 406–413.

Parasuram, K. V., Reddy, K. O., Shukla, M., and Marwala, T. (2013). Morphological, structural and thermal characterization of acetic acid modified and unmodified napier grass fiber strands. *IEEE Xplore*, *7*, 506–510.

Parre, A., Karthikeyan, B., Balaji, A., and Udhayasankar, R. (2020). Investigation of chemical, thermal and morphological properties of untreated and NaOH treated banana fiber. *Materials Today: Proceedings*, *22*(July), 347–352. https://doi.org/10.1016/j.matpr.2019.06.655

Patil, J.V., Chari, A., Rao, S.V., Mathur, R.M., Vimelesh, B. and Lal, P.S. (2011). High bio-mass sorghum (sorghum bicolor): an alternate raw material for pulp and paper making in India. *IPPTA Journal*, *23*(2), 161-165.

Peng, S. W., An, Y. X., Chen, C., Fei, B., Zhuang, Y. G., and Dong, L. S. (2003). Miscibility and crystallization behavior of poly(3-hydroxyvalerate-co-3-hydroxyvalerate)/poly(propylene carbonate) blends. *Applied Polymer Science*, *90*, 4054-4060.

Phitsuwan, P., Charupongrat, S., Klednark, R., and Ratanakhanokchai, K. (2015). Structural features and enzymatic digestibility of Napier grass fibre treated with aqueous ammonia. *Journal of Industrial and Engineering Chemistry*, *32*, 360–364.

Phitsuwan, P., Sakka, K., and Ratanakhanokchai, K. (2016). Structural changes and enzymatic response of Napier grass (Pennisetum purpureum) stem induced by alkaline pretreatment. *Bioresource Technology*, *218*, 247–256.

Pickering, K. L., Efendy, M. G. A., and Le, T. M. (2016). A review of recent developments in natural fibre composites and their mechanical performance. *Composites : Part A*, *83*, 98–112. https://doi.org/10.1016/j.compositesa.2015.08.038

Pittayavinai, P., Thanawan, S., and Amornsakchai, T. (2016). Manipulation of mechanical properties of short pineapple leaf fiber reinforced natural rubber composites through variations in cross-link density and carbon black loading. *Polymer Testing*, *54*, 84–89.

Putra, A., Or, K. H., Selamat, M. Z., Mohd Nor, M. J., Hassan, M. H., and Iwan, P. (2018). Sound absorption of extracted pineapple-leaf fibres. *Applied Acoustics*, *136*, 9–15.

Rafiqah, A., Abdan, K., Nasir, M., and Asim, M. (2020). Pineapple leaf fibers processing, properties and applications. In M. Jawaid, M. Asim, P. M. Tahir, and N. Mohammed (Eds.), *Green Energy and Technology* (1st ed., pp. 39–53). Singapore: Springer Nature.

Rahman, A. (2011). Study on modified pineapple leaf fiber. *Journal of Textile and Apparel, Technology and Management*, *7*(2), 1–16.

Rajesh, G., Siripurapu, G., and Lella, A. (2018). Evaluating tensile properties of successive alkali treated continuous pineapple leaf fiber reinforced polyester composites. *Materials Today: Proceedings*, *5*(5), 13146–13151. https://doi.org/10.1016/j.matpr.2018.02.304

Ramly, S. N. R., Md. Fadzullah, S. H. S., and Mustafa, Z. (2016). The effect of alkaline treatment and fiber length on pineapple leaf fiber reinforced lactic acid. *Jurnal Teknologi*, *79*(4–2), 111–115.

Ravindran, L., Sreekala, M. S., and Thomas, S. (2019). Novel processing parameters for the extraction of cellulose nanofibers (CNF) from environmentally benign pineapple leaf fibres (PALF): Structure-property relationships. *International Journal of Biological Mocromolecules. 131*, 858–870.

Reddy, N., and Yang, Y. (2009). Natural cellulose fibers from soybean straw. *Bioresource Technology*, *100*(14), 3593–3598.

Reddy, M. I., Kumar, M. A., Rama, C., and Raju, B. (2018). Tensile and flexural properties of jute, pineapple leaf and glass fiber reinforced polymer matrix hybrid composites. *Materials Today: Proceedings*, *5*(1), 458–462.

Renugadevi, K., Devan, P. K., Chandra Sekhara, R. M., Karthik, P., andThomas, T. (2020). Optimization of surface treatment in Calotropis Gigantea (CG)-fibre yarn by simple techniques and characterization of CG fibre yarn reinforced laminate. *Journal of Materials Research and Technology*, *9*(6), 12187–12200. https://doi.org/10.1016/j.jmrt.2020.08.058

Revati, R., Majid, M. S. A., Ridzuan, M. J. M., Basaruddin, K. S., Rahman, M. N. Y., Cheng, E. M., and Gibson, A. G. (2017). In vitro degradation of a 3D porous Pennisetum purpureum/PLA biocomposite scaffold. *Journal of the Mechanical Behavior of Biomedical Materials*, *74*, 383–391.

Rezayati-Charani, P., Mohammadi-Rovshandeh, J., Hashemi, S. J. and Kazemi-Najafi, S. (2006). Influence of dimethyl formamide pulping of bagasse on pulp properties. *Bioresources Technology, 97*(18), 2435-2442.

Ridzuan, M. J. M., Majid, M. S. A., Afendi, M., Kana, S. N. A., Zahri, J. M., & Gibson, A. G. (2016). Characterisation of natural cellulosic fibre from Pennisetum purpureum stem as potential reinforcement of polymer composites. *Materials and Design*, *89*, 839–847. https://doi.org/10.1016/j.matdes.2015.10.052

Ridzuan, M. J. M., Abdul Majid, M. S., Khasrib, A., Gan, E. H. D., Razlan, Z. M. and Syahrullail, S. (2019). Effect of pineapple leaf (PALF), napier, and hemp fibres as filler on the scratch resistance of epoxy composites. *Journal of Materials Research and Technology 8*(6), 5384-5395.

Rodríguez, A., Serrano, L., Moral, A., Pérez, A., and Jiménez, L. (2008a). Use of high-boiling point organic solvents for pulping oil palm empty fruit bunches. *Bioresources Technology, 99*(6), 1743-1749.

Rodríguez, A., Serrano, L., Moral, A., and Jiménez, L. (2008b). Pulping of rice straw with high-boiling point organosolv solvents. *Biochemical Engineering Journal*, *42*(3), 243–247.

Rousu, P., Rousu, P., and Juha, A. (2002). Sustainable pulp production from agricultural waste. *Resources, Conservation and Recycling*, *35*, 85–103.

Saad, M. B. W., Oliveira, L. R. M., Cândido, R. G., Quintana, G., Rocha, G. J. M., and Gonçalves, A. R. (2008). Preliminary studies on fungal treatment of sugarcane straw for organosolv pulping. *Enzyme and Microbial Technology, 43*(2), 220–225.

Sabarinathan, P., Rajkumar, K., Annamalai, V. E., and Vishal, K. (2020). Characterization on chemical and mechanical properties of silane treated fish tail palm fibres. *International Journal of Biological Macromolecules*, *163,* 2457–2464. https://doi.org/10.1016/j.ijbiomac.2020.09.159

Sahu, P., and Gupta, M. K. (2020). A review on the properties of natural fibres and its bio-composites: Effect of alkali treatment. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications, 234*(1), 198–217. https://doi.org/10.1177/1464420719875163

Salgado, P. R., Schmidt, V. C., Ortiz, S. E. M., Mauri, A. N., and Laurindo, J. B. (2008). Biodegradable foams based on cassava starch, sunflower proteins and cellulose fibers obtained by a baking process. *Journal of Food Engineering, 85*, 435-443.

Sand, S., Jawaid, M., Sultan, M. T. H., Alothman, O. Y., and Chuah, L. (2019). Thermomechanical and dynamic mechanical properties of bamboo / woven kenaf mat reinforced epoxy hybrid composites. *Composites Part B, 163*(August 2018), 165–174.

Safdari, V., Reza, M., Sigarody, N., and Ahmed, M. (2011). Identification of fibers of woody and non-woody plant species in pulp and papers. *Pakistan Journal of Botany*, *43*(4), 2127–2133.

Saiful Izwan, A. R., Noor Fadzliana, A. S., and Nadirul Hasraf, M. N. (2014). Electrically conductive paper of polyaniline modified pineapple leaf fiber. *Fiber and Polymers*, *15*(6), 1107–1111.

Sara, L. S., Monteiro, S. N., and Drelich, J. W. (2016). A novel method for contact angle measurements on natural fi bers. *Materials Letters*, *164*, 599–604. https://doi.org/10.1016/j.matlet.2015.11.039

Sarah, S., Rahman, W. A. W. A., Majid, R. A., Yahya, W. J., Adrus, N., Hasannuddin, A. K. and Low, J. H. (2018). Optimization of pineapple leaf fibre extraction methods and their biodegradabilities for soil cover application. *Journal of Environmental Degradation, 26*(1), 319–32.

Saravanan, P., and Devaraju, A. (2018). Improving mechanical properties of palm sheath composites using sodium hydroxide [NaOH] treatment. *Materials Today: Proceedings*, *5*(6), 14355–14361. https://doi.org/10.1016/j.matpr.2018.03.019

Schall, B. N., Krüger, E., Blum, R., and Basf, M. R. (2009). Soda-AQ pulping of wheat straw and its blending effect on old corrugated cardboard (OCC) pulp properties. (March), 35–39.

Sedelnik, N. (2004). Properties of hemp fibre cottonised by biological modification of hemp hackling noils. *Fibres and Textiles in Eastern Europe*, *12*(1), 58–60.

Seghini, M. C., Tirillò, J., Bracciale, M. P., Touchard, F., Chocinski-Arnault, L., Zuorro, A., Lavecchia, R and Sarasini, F. (2020). Surface modification of flax yarns by enzymatic treatment and their interfacial adhesion with thermoset matrices. *Applied Sciences (Switzerland)*, *10*(8), 1–17. https://doi.org/10.3390/APP10082910

Sena, A. R., Araujo, M. A. M., Souza, F. V. D., Mattoso, L. H. C., and Marconcini, J. M. (2013). Characterization and comparative evaluation of thermal, structural, chemical, mechanical and morphological properties of six pineapple leaf fiber varieties for use in composites. *Industrial Crops and Products*, *43*, 529–537.

Sena, A. R., Araujo, M. A. M., Barboza, R. M. P., Fonseca, A. S., Tonoli, G. H. D., Souza, F. V. D., Mattoso, L. H. C. and Marconcini, J. M. (2015). Comparative study of 12 pineapple leaf fiber varieties for use as mechanical reinforcement in polymer composites. *Industrial Crops and Products*, *64*, 68–78. https://doi.org/10.1016/j.indcrop.2014.10.042

Senthilkumar, K., Saba, N., Chandrasekar, M., Jawaid, M., Rajini, N., Alothman, O. Y. and Siengchin, S. (2019). Evaluation of mechanical and free vibration properties of the pineapple leaf fibre reinforced polyester composites. *Construction and Building Materials, 195*, 423-432.

Sgriccia, N., Hawley, M.C. and Misra, M. (2008). Characterization of natural fiber surfaces and natural fiber composites. *Composites: Part A. 39*, 1632–1637

Shanmugasundram, N., Rajendran, I., and Ramkumar, T. (2019). Characterization of untreated and alkali treated new cellulosic fiber from an Areca palm leaf stalk as potential reinforcement in polymer composites. *Carbohydrate Polymers, 217*, 178–189

Siakeng, R., Jawaid, M., and Sapuan, S. M. (2017). Physical properties of coir and pineapple leaf fibre reinforced polylactic acid hybrid composites. *IOP Conf. Series: Materials Science and Engineering*, *290*(012031).

Siakeng, R., Jawaid, M., Tahir, P. M., Siengchin, S., and Asim, M. (2020). Pineapple leaf fibers processing, properties and applications. In M. Jawaid, M. Asim, P. M. Tahir, and N. Mohammed (Eds.), *Green Energy and Technology* (1st ed., pp. 54–71). Singapore: Springer Nature.

Sibaly, S., and Jeetah, P. (2017). Production of paper from pineapple leaves. *Journal of Environmental Chemical Engineering*, *5*(6), 5978–5986.

Sinha, A. K., Narang, H. K., and Bhattacharya, S. (2018). Tensile strength of abaca epoxy laminated composites. *Materials Today: Proceedings, 5*(14), 27861–27864.

Singha, K., Pandit, P., and Shrivastava, S. (2020). Pineapple leaf fibers processing, properties and applications. In M. Jawaid, M. Asim, P. M. Tahir, and N. Mohammed (Eds.), *Green Energy and Technology* (1st ed., pp. 21–38). Singapore: Springer Nature.

Siregar, J.P., Sapuan, S. M., Rahman, M. Z. A. and Zaman, H. M. D. K. (2010). The effect of alkali treatment on the mechanical properties of short pineapple leaf fibre (PALF) reinforced high impact polystyrene (HIPS) composites. *Journal of Food, Agriculture & Environment, 8* (2), 1103-1108.

Sofyan, S., Kenji, M., and Fumio, U. (2008). Effects of alkali, mild steam, and chitosan treatments on the properties of pineapple, ramie, and sansevieria fi ber bundles. *Journal of Wood Science, 54*, 28–35.

Souza, K. D., and Aparecida, M. (2015). Characterization of fibers from pineapple's crown, rice husks and cotton textile residues. *Materials Research, 18*(3), 530–537.

Surip, S. N., Abdul Aziz, F. M., Bonnia, N. N., and Sekak, K. A. (2017). Effect of pineapple leaf fibers (PALF) concentration on nanofibers formation by electrospinning. *IOP Conf. Series: Materials Science and Engineering*, *290*(012003).

Suwanruji, P., Tuechart, T., Smitthipong, W., and Chollakup, R. (2017). Modification of pineapple leaf fiber surfaces with silane and isocyanate for reinforcing thermoplastic. *Journal of Thermoplastic Composite*, *30*(10), 1344–1360.

Threepopnatkul, P., Kaerkitcha, N., and Athipongarporn, N. (2009). Effect of surface treatment on performance of pineapple leaf fiber – polycarbonate composites. *Composites Part B*, *40*(7), 628–632. https://doi.org/10.1016/j.compositesb.2009.04.008

Tran, H. and Vakkilainen, E. K. (2016). The kraft chemical recovery process. ResearchGate. *Jan 2015*, 1-8.

Uddin, N., Miah, S., Jalil, M. A., Islam, M., and Siddika, A. (2017). A review on extraction, characterization and application of pineapple leaf fiber (PALF) in textiles and other fields. *International Journal of Advanced Research*, *5*(4), 112–116.

Vakkilainen, E. K. and Välimäki, E. (2009). Effect of lignin separation to black liquor and recovery boiler operation. *TAPPI EPE 2009*, 1-18.

Valls, C., Javier, P. F. I., Blanca, R. M., Vidal, T., Diaz, P., Martínez, J., and Valenzuela, S. V. (2019). Assessing the enzymatic effects of cellulases and LPMO in improving mechanical fibrillation of cotton linters. *Biotechnology for Biofuels*, *12*, 1–14. https://doi.org/10.1186/s13068-019-1502-z

Vijay, R., Lenin, S. D., Vinod, A., Sanjay, M. R., Siengchin, S., Jawaid, M., Khan, A., and Parameswaranpillai, J. (2019). Characterization of raw and alkali treated new natural cellulosic fibers from Tridax procumbens. *International Journal of Biological Macromolecules*, *125*, 99–108. https://doi.org/10.1016/j.ijbiomac.2018.12.056

Wang, X., Hu, J., and Zeng, J. (2012). Steam explosion pulping of oil palm empty fruit bunch fiber. *BioResources.Com*, *7*(1), 1008–1015.

Wang, J., Deng, Y., Qian, Y., Qiu, X., Ren, Y., and Yang, D. (2016). Reduction of lignin color via one-step UV irradiation. *Green Chemisry*. *18*(3), 695–699.

Wan Nadirah, W. O., Jawaid, M., Al Masri, A. A., Abdul Khalil, H. P. S., Suhaily, S. S., and Mohamed, A. R. (2012). Cell wall morphology, chemical and thermal analysis of cultivated pineapple leaf fibres for industrial applications. *Journal of Polymer Environment, 20*, 404–411.

Wan Rosli, W. D., Mazlan, I., and Law, K. N. (2009). Effects of kraft pulping variables on pulp and paper properties of acacia mangium kraft pulp. *Cellulose Chemistry and Technology, 43*(1–3), 9–15.

Wan Rosli, W. D., Mazlan, I., Law, K. N., and Nasrullah, R. (2011). Influences of the operating variables of acetosolv pulping on pulp properties of oil palm frond fibres. *Maderas. Ciencia y Tecnología*, *13*(2), 193–202.

Wetaka, C., Githinji, D. N., Namango, S., and Starovoytova, D. (2016). Combined effect of water retting and sodium hydroxide concentration on properties of luffa cylindrica fibres. *American Journal of Engineering Research (AJER), 5*(11), 339-345.

Wutisatwongkul, J., Thavarungkul, N., Tiansuwan, J., and Termsuksawad, P. (2016). Influence of soda pulping variables on properties of pineapple (Ananas comosus Merr.) leaf pulp and paper studied by face-centered composite experimental design. *Advances in Materials Science and Engineering, 2016*.

Yang, H. (2007). Characteristics of hemicellulose, cellulose and lignin pyrolysis. *Fuel,86*, 1781–1788.

Yuliasmi, S., Nerdy, and Husnita, A. (2017). Characterization of microcrystalline from pineapple leaf (Ananas comosus L. Merr). *IOP Conf. Series: Materials Science and Engineering, 180*, 3–9.

Yusof, Y., Ahmad, M. R., and Wahab, S. (2012). Producing paper using pineapple leaf fiber. *Advanced Materials Research, 383–390*(January), 3382–3386.

Yusof, Y., Asia, S., and Adam, A. (2015). Novel technology for sustainable pineapple leaf fibers productions. *Procedia CIRP, 26*, 756–760.

Zawawi, D., Mohd Zainuri, M. H., Angzzas Sari, M. K., Halizah, A., and Ashuvila, M. A. (2014). Exploring of agro waste (pineapple leaf, corn stalk, and napier grass) by chemical composition and morphological study. *Bioresources.Com, 9*(1), 872–880.

Zin, M. H., Abdan, K., Mazlan, N., Zainuddin, E. S., Liew, K. E. and Norizan, M. N. (2019). Automated spray up process for pineapple leaf fibre hybrid biocomposites. *Composites Part B, 177*, 107306.

Zwane, P. E., Ndlovu, T., Mkhonta, T. T., Masarirambi, M. T., and Thwala, J. M. (2019). Effects of enzymatic treatment of sisal fibres on tensile strength and morphology. *Scientific African*, *6*, e00136. https://doi.org/10.1016/j.sciaf.2019.e00136

LIST OF PUBLICATIONS

Indexed Journal

1. **Munthoub, D. I.,** Abdul Rahman, W. A. W., Lew, J. H., A. Majid, R. and Lai, J. C. (2020). Effects and extraction method on dry pulp yield and morphological properties of pineapple leaf fibre. *Malaysian Journal of Fundamental and Applied Sciences. 16*(3), 378-383. **(Indexed by SCOPUS)**