CHARACTERIZATION OF OIL PALM LEAF PAPER WITH STARCH AS BINDER

Sabrina Soloi[1*], Adib Afifi Mohammad[1]

[1]Fakulti Sains dan Sumber Alam, Universiti Malaysia Sabah,
88400 Kota Kinabalu, Sabah.
*Corresponding author: sabrinas@ums.edu.my

ABSTRACT. *The utilization of agro-based fibre in replacing the wood fibre for pulp and paper making has been the subject of interest due to the abundance of this agro-based fibre as well as to reduce the usage of wood pulp. The presence of cellulose and hemicellulose in acceptable amount for pulp paper makes this agro based fibre an alternative in paper making industry. Previous study has shown that oil palm leaf fibre can be moulded into paper sheet without any binding agent, however, the physical properties of the paper were very low compare to other non-wood paper. In this study, the oil palm leaf paper was prepared using 5,8,11 and 14% sodium hydroxide (NaOH) with the addition of 5% starch as the binding agent. The incorporation of starch increases the smoothness of the paper. The tear strength of the paper increases with increasing concentration of sodium hydroxide. At higher concentration of sodium hydroxide, the paper tear index falls within the range of commercial paper tear index. This study proves that the oil palm leaf has the potential to be developed in paper making industry.*

KEYWORDS. Agro-based pulp; Oil palm leaf paper; Soda pulping; Binding agent; Surface morphology

INTRODUCTION

Paper is a thin layer material produced from the fibre of cellulose pulp that made from mechanical and chemical pulping of lignocellulosic biomass which is generally used for writing, cleaning, printing and packaging. For a little more than a century, wood species have been the primary raw materials for producing cellulose pulp; in fact, 90–95% of all pulp has been obtained from such materials. World wood pulp production in 2003 amounted to 170,358,000 tons, whereas non-wood pulp production was only 18,695,000 tons (Rodríguez *et al*., 2008). It was also reported in 2004 that the annual paper consumption is 52.45 kg per person and was 16.32% greater than in 1991 (Rodríguez *et al*., 2008). The tree, as the source of paper manufacturing, has been used since 200 years ago. This long term use of tree consequently increasing the area of deforestation that will contribute to global warming and other environmental problem. Due to this reason, researchers have found other alternatives for the production of lignocellulosic pulp from non-wood resources (Laftah & Abdul Rahaman, 2015; Ververis *et al*., 2004).

Agro-based fibre resources have the potential to complement conventional wood supplies because, they are abundant, have short cycles and rapid regeneration, and are of comparatively low price. Wheat straw (Hedjazi *et al*., 2009), rice straw (Rodríguez *et al*., 2008), sugarcane straw (Rezende *et al*., 2011), reeds (Saad *et al*., 2008), bamboo (Vu *et al*., 2004), bagasse (Khristova *et al*., 2006), kenaf (Farsheh *et al*., 2011), palm oil (Rodríguez *et al*., 2008b) and jute (Sahin, 2003) were among the non-wood fibre resources available for paper production. In addition, increasing the usage of the non-wood fibres may bring significant effect in reduction of wood consumption and could allow preserving the forestry resources as well as a positive impact on the environmental problems.

Abundant biomass generated by the palm oil industry in Malaysia drives the exploration of this biomass for others application. Production of pulp from oil palm fronds has been demonstrated by (Wanrosli *et al*., 2007) for papermaking. In this study, the palm leaf was used as it is considered as a potential non-wood lignocellulosic compound for paper production since it contains 43.8% cellulose (Mohd Kassim *et al*., 2016) within the acceptable range of wood fibre (40-45%) (Rowell *et al*., 2000).

Meanwhile, the lignin content of oil palm leaves was reported around 19% and falls in the low range of those in wood resources (18 - 25%) (Mohd Kassim *et al.*, 2016). Low lignin content is important in the pulp industry since good quality of paper can be achieved with low lignin content (Laftah & Abdul Rahaman, 2015). Previous study by Soloi & Hao (2019) has shown that oil palm leaf fibre can be moulded into paper sheet without any processing aid such as starch solution as a binder. The tensile strength of the paper was low. Still, the tear index was found to be comparable with commercial paper tear index, which indicates that with some modification and improvements, the physical properties of oil palm leaf paper can be improved.

In order to increase the tensile strength of a paper, the binder usually applied during the manufacturing process (Flory *et al.*, 2013). These binders usually made of acryl-amide, acetaldehyde, urea-formaldehyde and vinyl acetate. However, due to environmental concern, a renewable binder has been developed as an alternative to synthetic binders. One of the most abundant renewable binder is starch in which can be obtained in large quantity with lower cost (Flory *et al.*, 2013). Thus, the aim of this study was to determine the feasibility of using non-wood plants as raw material for the pulp and paper industry. The effectiveness of lignin removal was monitored using fourier-transform infrared (FTIR), while the physical properties was monitored using universal testing machine and the surface morphology of the paper was observed using scanning electron microscope (SEM).

MATERIAL AND METHODS

Soda Pulping

The preparation of the paper was conducted based on a previous study (Hao, 2017) with some modification. The fresh green leaves were washed to remove any unwanted residue prior to chemical pulping. After washing with the running water, the leaves were cut into smaller sizes (3 cm – 5 cm) then it was grinding before soaking with sodium hydroxide (NaOH) for delignification process using various concentration of NaOH ranging from 5% to 14% for 2 hours with temperature around 80 ^{o}C to investigate the effectiveness of lignin removal for good fibre production. Once the delignification process was completed, the liquor was washing several times with running water and the obtained fibre was then undergoes bleaching process with 30% hydrogen peroxide (H_2O_2) for 15 minutes in temperature range of 50-60^{o}C. After that, the fibre was wash again with running water to removes the H_2O_2 residue. Then, the fibre obtained was soaked in 5% starch solution for 10-15 minutes prior to being moulded using mould and deckle. The paper was then dried in the oven until dried.

Characterization of the Paper

The paper sample was subject to fourier-transform infrared (FTIR) analysis to identify the presence of cellulose and lignin functional group in the fibre before and after treatment. FTIR was performed using Perkin Elmer Spectrum 100 FTIR Spectrometer. Then, scanning electron microscope (SEM) analysis was done to obtain the surface morphology image of the paper. The SEM was conducted using JEOL JSM-5610LV machine. The image was captured at 100 × and 500× magnification at 20kV accelerating voltage. Tensile testing and tearing resistance were done to identify the mechanical properties of the paper using GOTECH/AI-700 electronic tensile machine and DC-SLY13K tearing tester respectively.

RESULT AND DISCUSSION

Fourier Transform Infra-Red (FTIR)

The effect of chemical treatment on lignin removal from the palm oil leaves was investigated in this study. Lignin is usually considered as a polyphenolic material having an amorphous structure which consists of three different phenylpropane building block namely *p*-coumaryl, sinapyl and coniferyl. Paper quality was identified by the good strength, bleach ability, high cellulose and hemicellulose content and low lignin content. Therefore, it is desirable to have a pulp process that gave the highest delignification efficiency and good quality of cellulose and hemicellulose (Laftah & Abdul Rahaman, 2015). The decomposition of lignin and the appearance of cellulose peak can be detected using FTIR analysis. Lignin decomposition during soda pulping is usually attributed to the cleavage of the α-aryl ether bonds from its phenylpropane monomers (Liu *et al.*, 2014; McDonough, 1992; Rezende *et al.*, 2011). Hao (2017) found that the ether and phenylpropane of lignin in the oil palm leaf appear in the band around 1100 cm^{-1} and 1246 cm^{-1}. Based on the FTIR spectra in Figure 1, no peak was detected at this region proved that at all concentrations of NaOH, the lignin has successfully removes during the pulping. Meanwhile, the prominent signal at around 3300 cm^{-1} was attributed to the -OH functional group of cellulose from the pulp and the starch.

Morphology Analysis

The oil palm leaf fibre looks coarse and consists of elementary fibre and technical fibre. The surface morphology of the paper in Figure 3 – Figure 6 shows that after two hours of pulping, the fibrillar structure was clearly observed after removal of lignin (Sreekala *et al.*, 2000) and it increased the mechanical interlocking at the interface that makes the fibre mouldable into a sheet of paper. As the NaOH concentration increased, the fibre becomes curly and soft upon alkali treatment and the fibre bundle being oriented in various orientations in the paper sheet. Separation of fibre bundle into elementary fibre with increasing NaOH concentration was observed as shown in Figure 5, Figure 6 and Figure 7. The presence of starch can be seen in Figure 4 and 5 in which the starch fills some of the void that presence among the fibre. The physical appearance of the paper produced in this study also has better smoothness compared to a previous study (Hao, 2017) as shown in Figure 8. This is due to the presence of starch as the binder.

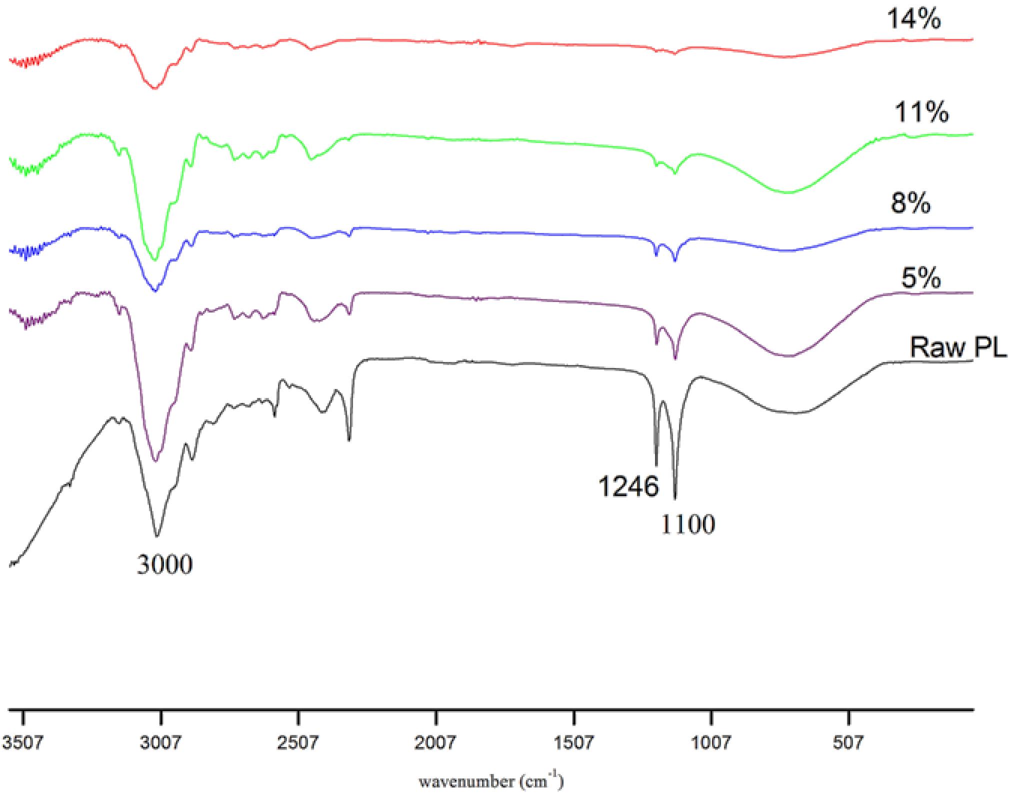

Figure 1 : Fourier Transform Infra-Red spectra of oil palm leaf paper at various concentration

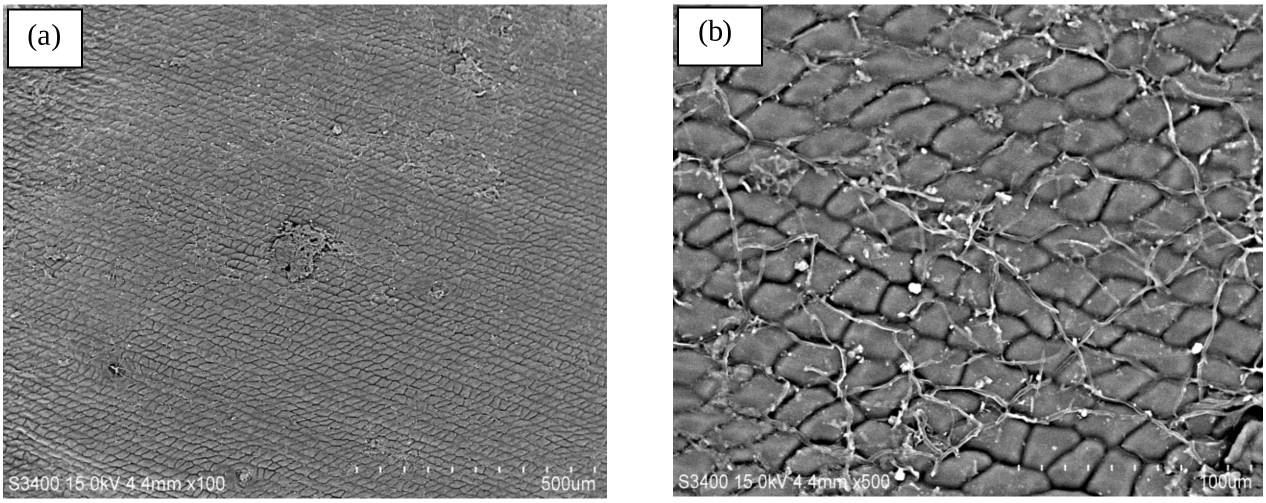

Figure 1 : SEM image of untreated oil palm leaf at magnification (a) 100× ; (b) 500×.

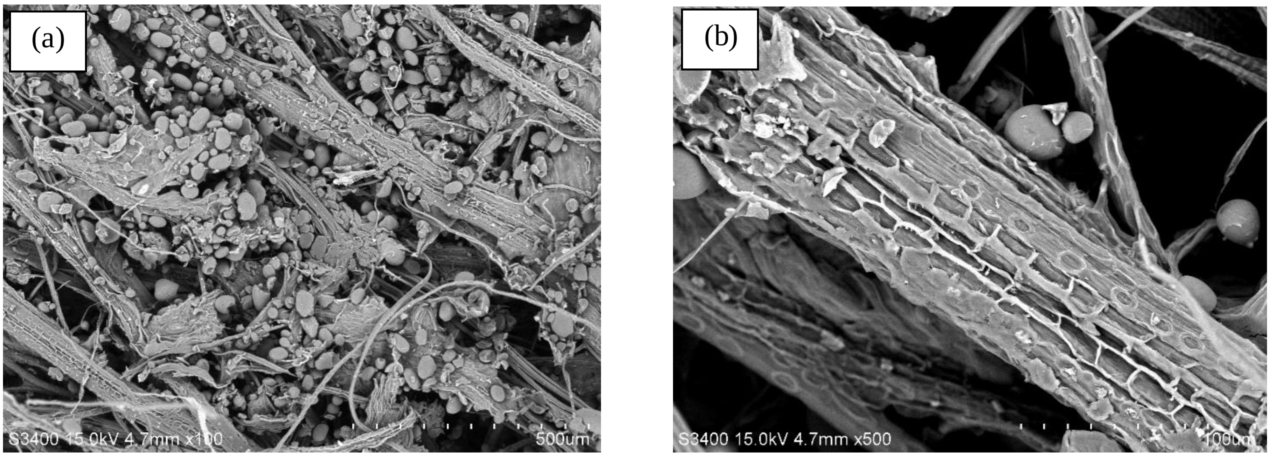

Figure 2 : SEM image of oil palm leaf fibre treated with 5% NaOH at magnification (a) 100× ; (b) 500×.

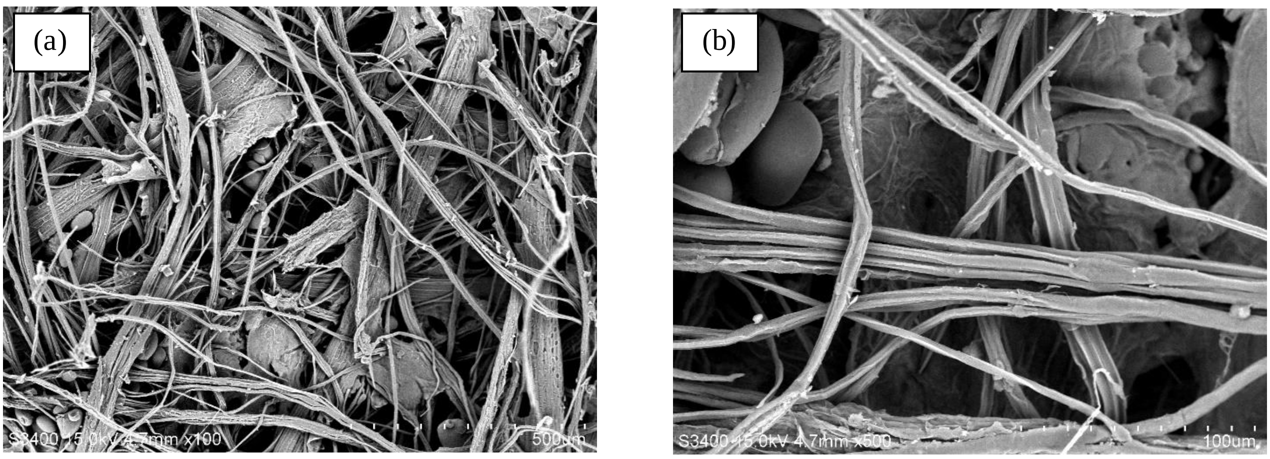

Figure 3 : SEM image of oil palm leaf fibre treated with 8% NaOH at magnification (a) 100× ; (b) 500×.

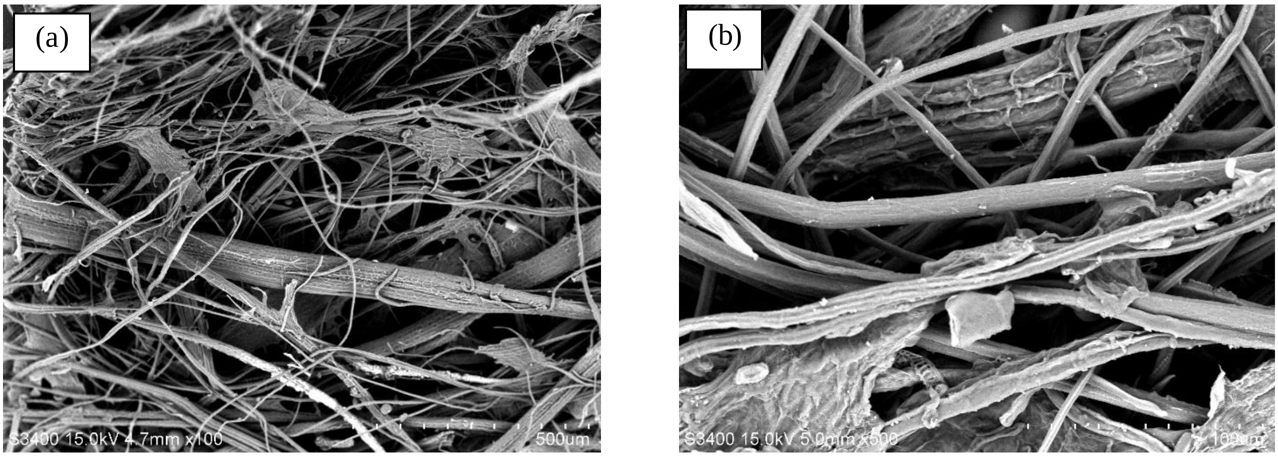

Figure 4 : SEM image of oil palm leaf fibre treated with 11% NaOH at magnification (a) 100× ; (b) 500×.

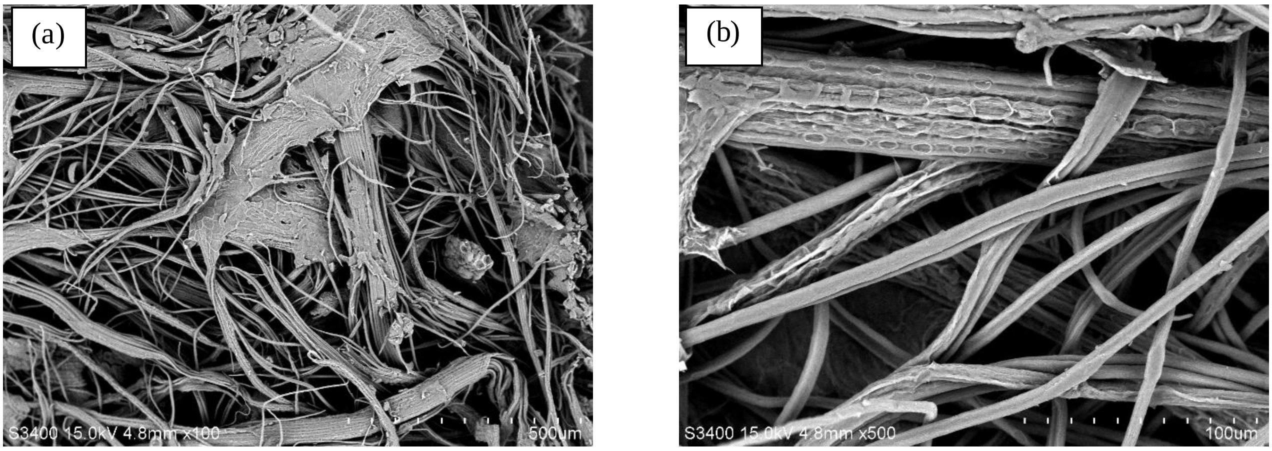

Figure 5 : SEM image of oil palm leaf fibre treated with 14% NaOH at magnification (a) 100× ; (b) 500×.

Figure 6 : Physical appearance of oil palm leaf paper processed using starch (a) and without starch (b)

Mechanical Strength

The tensile and tear index of the paper were shown in figure 9. The tensile strength of the paper are comparable to other agro-based paper-like pineapple leaf (Aremu *et al.*, 2015) but lower than wood paper probably due to weak fibre bonding and fibre strength (Mohd Kassim *et al.*, 2016). The tensile strength of a paper highly influences by the arrangement of the fibre in the paper. As in this study, the handmade technique during the moulding step affects the non-uniformity on the orientation of the fibre and it might give low value of tensile index. As the NaOH concentration increased, the decrease in tensile strength might be due to the degradation of cellulose fibre at higher concentration of NaOH. Even though lignin was effectively removed at this concentration, it might cause cellulose degradation and fibre rupture (Asim *et al.*, 2018). Meanwhile, the tear index of the paper was in the range of commercial paper tear index (Yamauchi & Tanaka, 2002) and showed increasing value as the NaOH concentration increased. This might be due to hydrogen bonding interaction among the cellulose material (Fiserova & Gigac, 2011) and hence increased the strength of the paper sheet.

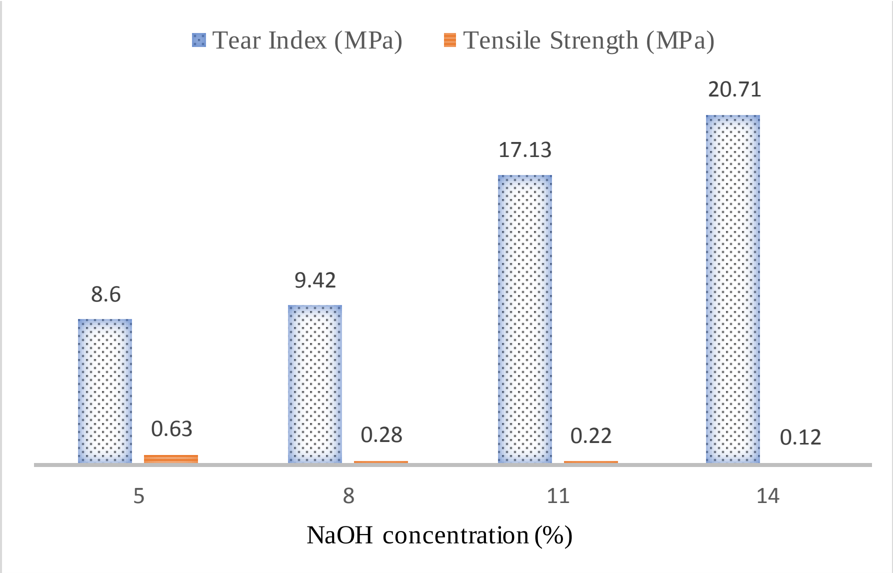

Figure 7 Tensile strength and tear index of oil palm leaf paper at different concentration of NaOH.

CONCLUSION

This study shows that oil palm leaf fibre has a huge potential to be developed for non-wood pulp since the tensile strength of the paper were comparable to that of commercial paper. The lignin was successfully removed at 5% NaOH. With the incorporation of starch as binder, the physical properties of oil palm leaf paper were increased to the level that comparable to wood paper. The presence of starch also increased the smoothness of the paper surface. This study also remarks that non-wood pulp can be further explored in order to maintain the sustainability of our environment.

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REFERENCES

Aremu, M. O., Rafiu, M. A., & Adedeji, K. K. (2015). Pulp and Paper Production from Nigerian Pineapple Leaves and Corn Straw as Substitute to Wood Source. *International Research Journal of Engineering and Technology*.

Asim, M., Jawaid, M., Abdan, K., & Nasir, M. (2018). Effect of Alkali treatments on physical and Mechanical strength of Pineapple leaf fibres. *IOP Conference Series: Materials Science and Engineering*, *290*(1). https://doi.org/10.1088/1757-899X/290/1/012030

Farsheh, A. T., Firouzabadi, M. D., & Mahdavi, S. (2011). Properties of kenaf(hibiscus cannabinus L.) bast fibre reinforced bagasse soda pulp in comparison to long fiber. *World Applied Sciences Journal*, *14*(6), 906–909.

Fiserova, M., Gigac, J. (2011). Comparison of hardwood kraft pulp fibre characteristics and tensile strength. *Cellulose Chemicstry and Technology*, *45*(9–10), 627–631.

Flory., A. ., Requesens, D. V., Dvaiah, S. P., Teoh, K. T., Mansfield, S. D., & Hood, E. E. (2013). Development of green binder for paper products. *BMC Biotechnology*, *13*(28). Retrieved from http://www.lignocellulose.ir/ojs/index.php/lignocellulose/article/view/66

Hao, E. K. Z. (2017). *The Effect of Cooking Time in Paper Made from Oil Palm Leaves*. Universiti Malaysia Sabah.

Hedjazi, S., Kordsachia, O., Patt, R., Latibari, A. J., & Tschirner, U. (2009). Alkaline sulfite–anthraquinone (AS/AQ) pulping of wheat straw and totally chlorine free (TCF) bleaching of pulps. *Industrial Crops and Products*, *29*(1), 27–36. https://doi.org/10.1016/j.indcrop.2008.03.013

Khristova, P., Kordsachia, O., Patt, R., Karar, I., & Khider, T. (2006). Environmentally friendly pulping and bleaching of bagasse. *Industrial Crops and Products*, *23*(2), 131–139. https://doi.org/10.1016/j.indcrop.2005.05.002

Laftah, W. A., & Abdul Rahaman, W. A. W. (2015). Chemical pulping of waste pineapple leaves fiber for kraft paper production. *Journal of Materials Research and Technology*, *4*(3), 254–261. https://doi.org/10.1016/j.jmrt.2014.12.006

Liu, Y., Hu, T., Wu, Z., Zeng, G., Huang, D., Shen, Y., … He, Y. (2014). Study on biodegradation process of lignin by FTIR and DSC. *Environmental Science and Pollution Research*, *21*(24), 14004–14013. https://doi.org/10.1007/s11356-014-3342-5

McDonough, T. (1992). The chemistry of organosolv delignification. *IPST Technical Paper Series*.

Mohd Kassim, A. S., Aripin, A. M., Ishak, N., Zainulabidin, M. H., & Abang Zaidel, D. N. F. (2016). Oil palm leaf fibre and its suitability for paper-based products. *ARPN Journal of Engineering and Applied Sciences*, *11*(11), 7364–7369.

Rezende, C., de Lima, M., Maziero, P., deAzevedo, E., Garcia, W., & Polikarpov, I. (2011). Chemical and morphological characterization of sugarcane bagasse submitted to a delignification process for enhanced enzymatic digestibility. *Biotechnology for Biofuels*, *4*(1), 54. https://doi.org/10.1186/1754-6834-4-54

Rodríguez, A., Serrano, L., Moral, A., & Jiménez, L. (2008). Pulping of rice straw with high-boiling point organosolv solvents. *Biochemical Engineering Journal*, *42*(3), 243–247. https://doi.org/10.1016/j.bej.2008.07.001

Rodríguez, Alejandro, Serrano, L., Moral, A., Pérez, A., & Jiménez, L. (2008). Use of high-boiling point organic solvents for pulping oil palm empty fruit bunches. *Bioresource Technology*, *99*(6), 1743–1749. https://doi.org/10.1016/j.biortech.2007.03.050

Rowell, R. M., Han, J. S., & Rowell, J. S. (2000). Characterization and Factors Effecting Fiber Properties. *Natural Polymers an Agrofibers Composites*, 115–134.

Saad, M. B. W., Oliveira, L. R. M., Cândido, R. G., Quintana, G., Rocha, G. J. M., & Gonçalves, A. R. (2008). Preliminary studies on fungal treatment of sugarcane straw for organosolv pulping. *Enzyme and Microbial Technology*, *43*(2), 220–225. https://doi.org/10.1016/j.enzmictec.2008.03.006

Sahin, H. T. (2003). Base-catalyzed organosolv pulping of jute. *Journal of Chemical Technology & Biotechnology*, *78*(12), 1267–1273. https://doi.org/10.1002/jctb.931

Soloi, S., & Hao, E. K. Z. (2019). The Potential of Oil Palm Leaf Fibre in Paper-making Industry The Potential of Oil Palm Leaf Fibre in Paper-making Industry. https://doi.org/10.1088/1742-6596/1358/1/012005

Sreekala, M. ., Kumaran, M. ., Joseph, S., & Jacob, M. (2000). Oil palm fiber reinforced phenol formaldehyde composites: Influence of fiber surface modifications on mechanical properties. *Applied Composite Materials*, *7*(5–6), 295–329.

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., & Santas, R. (2004). Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production. *Industrial Crops and Products*, *19*(3), 245–254. https://doi.org/10.1016/j.indcrop.2003.10.006

Vu, T. H. M., Pakkanen, H., & Alén, R. (2004). Delignification of bamboo (Bambusa procera acher) Part 1. Kraft pulping and the subsequent oxygen delignification to pulp with a low kappa number. *Industrial Crops and Products*, *19*(1). https://doi.org/10.1016/j.indcrop.2003.07.001

Wanrosli, W. D., Zainuddin, Z., Law, K. N., & Asro, R. (2007). Pulp from oil palm fronds by chemical processes. *Industrial Crops and Products*, *25*(1), 89–94. https://doi.org/10.1016/j.indcrop.2006.07.005

Yamauchi, T., & Tanaka, A. (2002). Tearing test for paper using a tensile tester. *Journal of Wood Science*, *48*(April 1995), 532–535. https://doi.org/10.1007/BF00766652