Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

January 2025. Vol. 13, No. 1
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 76-83

Fabrication and Characterization of Pineapple Leaf Fiber (PALF) as Candidate of Composite Reinforcing Material

Wulan Ratia Ratulangi, *Rosnalia Widyan, Adriyan Suhada, Rahmad Dani
Program Studi D3 Farmasi, Politeknik Medica Farma Husada Mataram, Jl. Medica Farma No. 1, Baturinggit Selatan, Mataram, Indonesia. Postal code: 83125

*Corresponding Author e-mail: rosnalia.widyan17@gmail.com

Received: November 2024; Revised: December 2024; Published: January 2025

Abstract

Pineapple leaf is a waste product of pineapple cultivation which may leads to environmental issues. Pineapple leaf fibre (PALF) is an important natural fibre with high cellulose content that exhibits high mechanical properties which is high specific strength and stiffness which may vary for each cultivar. Besides, isolation of cellulose from lignocellulosic fibre become more crucial. In this study, isolation of cellulose were undergo by alkaline treatment In that order, concentration of NaOH 0.5% at 121oC for 60 min and bleaching teatment using NaClO 10% at 121oC for 30. The PALF and treated fiber were characterized using Tensilon, Scanning Electron Microscopy, Fourier Transmission Infrared Spectroscopy. Based on results, 5% NaOH (60 min) and bleaching process by using 10% NaClO (30 min) in autoclave succeed to remove pektin, lignin, and unwanted components. The surface morphology showed high surface area, however still remaining small amaount of pektin and lignin was confirmed from FTIR and SEM images.

Keywords: Characterization, Pineapple leaf fiber, Composite

How to Cite: Ratulangi, W., Widyan, R., Suhada, A., & Dani, R. (2025). Fabrication and Characterization of Pineapple Leaf Fiber (PALF) as Candidate of Composite Reinforcing Material. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *13*(1), 76-83. doi:https://doi.org/10.33394/j-ps.v13i1.13563

https://doi.org/10.33394/j-ps.v13i1.13563

INTRODUCTION

Pineapple leaf fiber (PALF) is one type of fiber obtained from pineapple leaves by combination of mechanical and chemical process. Pineapple plants (Ananas comosus) are fruit plants that have been widely known by the public. Pineapple plants can grow well especially in tropical countries. The availability of pineapple leaves which is quite abundant in Indonesia has not been utilized optimally by farmers due to the lack of knowledge about post-harvest pineapple leaf processing techniques to make products with high economic value (Soeprijanto et al., 2021). One alternative for utilizing this waste is to process it into natural fiber by utilizing leaf fibers into staple fiber (long fibers). Staple fiber has several broad application in the automotive, textile, composite material and other fields.

PALF consist of about 80% cellulose, 6-12 % hemicellulose, 5-12% lignin (Fan et al., 2022; Gaba et al., 2021). Cellulose is the largest component in PALF, exist in two distinct forms; the crystalline and amorphous phases. In the crystallin phase, there are bundle of microfibrils, made of assemblies of (1-4) β-D-glucan chains that are strongly hydrogen-bonded (Cozier, 2014). The amorphous phase concist of randomly arranged cellulose and hemicelloce that contribute insignificantly to the structural and mechanical stifness of fiber.previous study reported that removal of amorphous phase through hydrolsis leading a higher degree of ordered crystalline regions with ultimate goal of enhancing the cellulose isolation (Gaba et al., 2021).

Previous study shown that the chemical treatment of natural fibers can not only enhance their surface morphology but improve the mechanical properties of the fiber (Gholampour & Ozbakkaloglu, 2020). The PALF chemical treatement are developed by the process of steam treatment correlated with alkali tretament. Steam treatment is hydrothermal process of biomass tretament, involving of the application of steam high pressure, and which can be performed by batch or continous reactor. The biomass is expossed to saturated steam (180-230oC) for 20-40 min. Generally the steaming method results in hydrolysis of glycosidic bond in the hemisellulose and, to lesser extend in the cellulose (Cherian et al., 2011). The microfiber from PALF has a high surface area and porosity, morphological properties of the fiber, better mechanical properties compare to macrofiber, and has an abilty of heat resistant (Barhoum et al., 2019). It would makes this natural fiber have wide applications, one of which is as a reinforce for composite.

Composite is a material formed from a combination of two or more materials with different mechanical properties of the forming materials, where one material is a filler (matrix) and the other is a reinforcing phase (reinforcement) (Lalhmangaihzuali et al., 2019). Natural fibers are crucial materials in developing eco-friendly, biodegradable composites to address pressing environmental issues. These composites offer a promising solution due to their excellent mechanical properties, low density, affordability, high toughness, reasonable specific strength, recyclability, biodegradability, renewability (Gnanasekaran et al., 2021). Therefore PALF is suitable for reinforcing canditate material.

Recent studies have been explored the development of eco-friendly composites reinforced with pineapple leaf fiber (PALF). The mechanical properties of PALF-reinforced polyethylene composites, emphasizing factors such as fiber size, loading percentage, and orientation. It notes that PALF-LDPE composites are eco-friendly and demonstrate superior performance compared to other cellulose-fiber-reinforced LDPE systems (Sethupathi, Murugan, Khumalo, Mandla, Skosana, Sifiso, Muniyasamy, 2023). (Duangsuwan et al., 2023) reported that low-carbon composites using biobased poly(butylene succinate) (PBS) reinforced with well-aligned PALF. The study highlights the potential of PALF as a reinforcing fiber to improve composite mechanical properties while reducing environmental impact and production costs. While green composite used of recycled plastic bags combined with pineapple fibers to create green composites. The research emphasizes the mechanical properties of these composites, suggesting potential applications in various industries (Gandara M, Zanini NC, Mulinari DR, Saron C, 2022). The recent advancements in PALF-reinforced polymer composites, discussing their properties and potential applications in sustainable materials. These studies underscore the growing interest in utilizing PALF for developing sustainable, eco-friendly composite materials with enhanced mechanical properties (Xiao Hanyue, Mohamed Thariq Hameed Sultan, Muhammad Imran Najeeb, 2024).

The pineapple leaf fiber (PALF) as a sustainable and eco-friendly natural fiber for composite reinforcement by isolating microscale cellulose from PALF, the study leverages its superior characteristic to develop advanced composites. The aim of this study, to produce microscale cellulose produce as candidate of reinforcing material for composite. The resulting microcellulose were characterized by TENSILON to identify the tensile strength, Scanning Electron Microscopy (SEM), and Fourier Transmission Infrared Spectroscopy (FTIR).

METHOD

Materials

The pineapple fiber were purchased from farmer in Subang, Indonesia. The reagents used for chemical process were NaOH (pa) and Sodium Hipocloryte. Distilled water used for all the process. The apparatus for pretreatment of pineapple fiber was an Autoclave. The characterization were carried out using the Transmission Electron Microscope (JEOL JCM-

7000 Neoscope), Fourier Transmission Infrared (Perkin Elmer L1600300 Spectrum Two Lita), and Tensilon (RTG-1310).

Chemical Treatment

Pinepple leave fiber were treated by adding 5% NaOH at 121°C for 60 min in autoclave. The bleaching process was carried out by adding NaClO 10% at 121°C for 30 min in autoclave then washed until neutral pH and dried at room temperature. The dried were cut into small pieces using cutter and mechanical blender. The treated fiber will undergo further characterization.

Characterization

Chacarterization of pineapple fiber, fisrt by using Tensilon to measure the tensile strength, second by using Fourier Transform Spectroscopy, The powder sample were pelleted and mixed with KBR and recorded the spectrum range 400 cm^{-1} to 4000 cm^{-1} . and the last is Scanning Electron Microscopy used to analzed the morphology of fiber.

RESULTS AND DISCUSSION

Effect of Alkaline Treatment

PALF was extracted through the mechanical and chemical treatment, each affecting the fiber's surface characteristics and mechanical performance. The chemical treatment of PALF was undergo under alkaline treatment by degumming and bleaching process. degumming process is carried out by soaking the PALF in a solution of Sodium hydroxide (NaOH) 5% at 121°C for 60 min in autoclave (Fig 2). This process aims to remove hydrophilic components such as pectin, lignin, hemicellulose and other unwanted contents from the surface of fiber. The mechanism of alkaline treatment is correlated to saponification of intermolecular ester bond closs-linking lignin and part of hemicellulose. The reduction of this cross-linking would increase the porosity of PALF, the used of 5% of NaOH was the suitable concentration to the alkaline treatment (Amirulhakim et al., 2021) for removing these components.

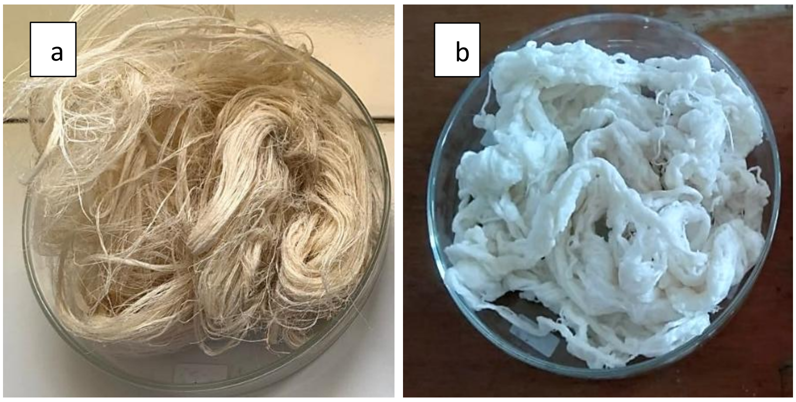

Figure 1. The Untreated PALF (a) Treated PALF (b)

Furthermore, the bleaching process or known as oxidative delignification by using Sodium Hypoklorite 10% NaClO. The PALF was soaked in 10% NaClO (sodium hypochlorite) solution then placing it in an autoclave for 30 minutes at a temperature of 121°C and the final stage is washing and drying. Sodium hypochlorite (NaClO) is used for bleaching. The indication of this process visually is the color alteration from brown to white (Fig 2). The mechanism reaction is Sodium Hypoklorit may react with the side chain of carbonyl and carbon-carbon double bond lignin to further oxidative degradation, which leading to lignin removal and unwanted components on the surface (Septevani et al., 2018)(Gnanasekaran et al., 2021). This is further supported by the pH value being close to 7, indicating that sodium hydroxide was released along with the impurities (Table 1)

Table 1. pH of PALF After Degumming and Bleaching Process

No	Sample	pH
1	Degumming	7.4
2	Bleaching	7.1

PALF Analysis by Using FTIR

The FTIR analysis used to identify the functional group of treated and untreated PALF. Based on the IR spectra (Fig. 2). The FTIR results of PALF examine the changes in the chemical bonds of PALF before and after surface modification. Identified functional groups in the chemical structure included alkanes, alcohols, aromatics, and esters. The infrared absorption peaks at 1370 cm^{-1} and 1730 cm^{-1} are linked to the benzene ring (C=C) in lignin and the acetyl group (C=O) in hemicellulose, respectively. Additionally, the sharp peak at 1070 cm^{-1} is attributed to the pyranose ring structure (C–O–C) or the β-glycosidic bonds in celluloses. In untreated PALF, these three peaks were clearly visible. However, the peaks at 1370 cm^{-1} and 1730 cm^{-1} diminished significantly in treated fibers, while the peak at 1070 cm^{-1} remained prominent. The strong 1070 cm^{-1} peak observed treated fibers confirms that the used of NaOH for 60 minutes, retained a higher cellulose content compared to untreated PALF. This indicates that the process effectively removed lignin and hemicellulose (Gnanasekaran et al., 2021). Infrared absorption stretching in the range of 3000–3700 cm^{-1} was observed, corresponding to the hydroxyl (O–H) groups of carboxylic acids and alcohols present in lignin (Yudhanto et al., 2021).

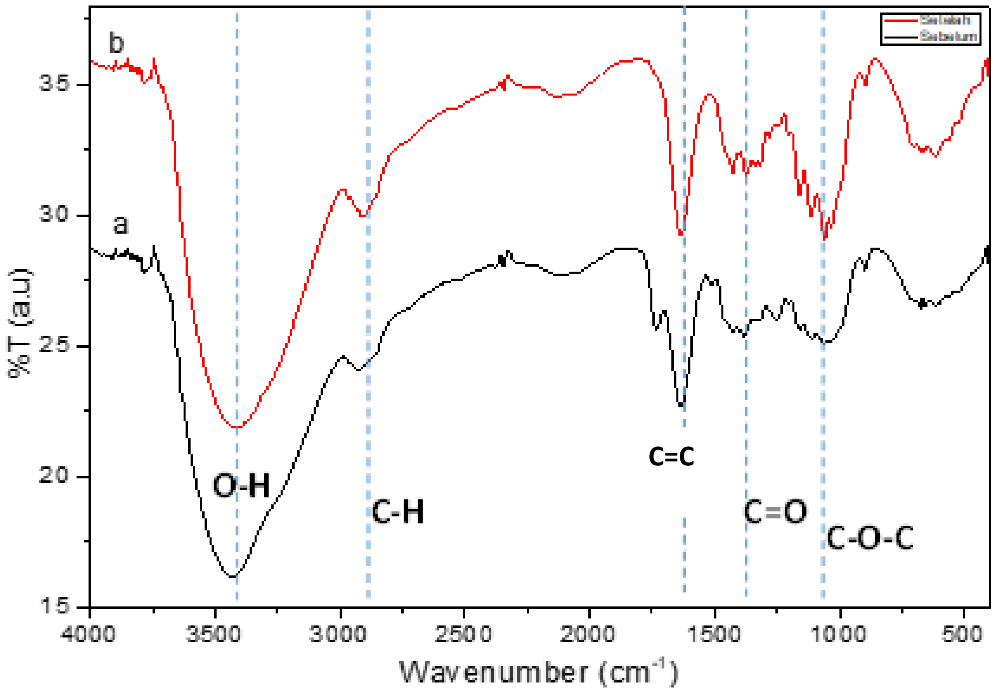

Figure 2. FTIR Spectra of Treated and Untreated PALF

However, while the content of lignin and hemicellulose was nearly eliminated, the cellulose content may have degraded, as indicated by the intensity of certain peaks. The C-H peak intensity was low in the range of 2800–2900 cm^{-1}, suggesting the loss of alkyl groups due to cellulose degradation. Additionally, the low intensity of the C=O stretching in carboxyl groups (1730–1750 cm^{-1}) indicates partial degradation of cellulose. This peak, often associated with hemicellulose, can diminish, signaling degradation or removal. The intensity ratio between the peaks at 1375 cm^{-1} and 1335 cm^{-1} may also reflect a loss of crystallinity in cellulose, which is typically associated with its degradation.

Scanning Electron Microscopy (SEM)

In the SEM analysis of pineapple leaf fiber (PALF), both long fibers and microfibers display distinct characteristics that provide insight into their potential applications, particularly in composite materials. The SEM images (Fig 2) of long PALF show a relatively smooth and elongated structure, which is typical of natural fibers. These fibers retain their bundle form, but the presence of impurities such as lignin, pectin, and hemicellulose can be observed along the surface. These impurities contribute to a rough texture and might hinder the fiber's ability to bond with matrices in composite materials. However, the long fibers are beneficial in terms of mechanical reinforcement due to their large length, which can enhance the strength and stiffness of composites when properly treated and incorporated (Gaba et al., 2021).

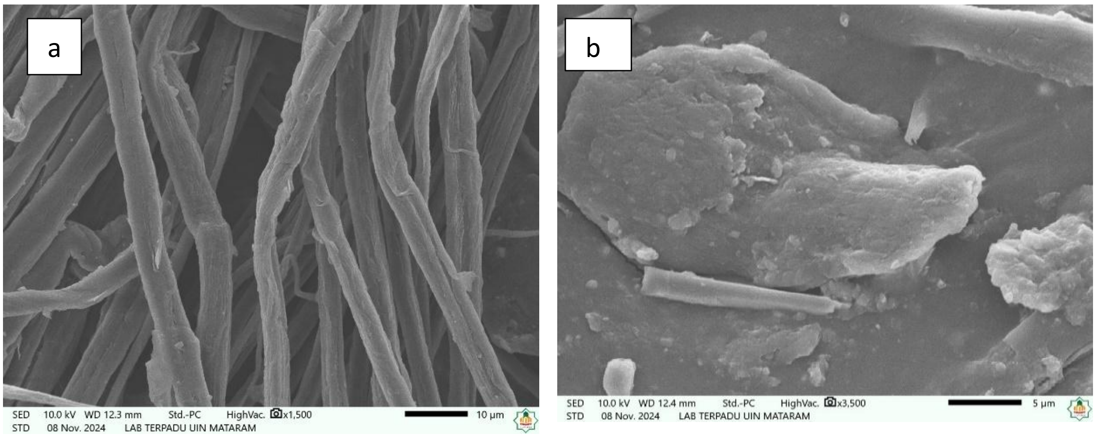

Figure 3. SEM Images of Treated PALF

While the treated PALF, undergoes disintegration, resulting in isolated microfibrils with a much finer structure compared to the long fibers. SEM images of microfibers typically reveal some areas exhibit the accumulation of lignin, pectin, and other coating materials like hemicellulose and wax, forming a thin layer on the rough surface of PALF surface texture, which suggests that the treatment effectively removed much of the impurities and surface coatings. The reduced presence of lignin, waxes, and pectin makes the microfibers more hydrophilic and increases their surface area, promoting better adhesion when integrated into composite matrices. The high surface area is crucial for reinforcing composite materials, as it facilitates stronger bonding with the polymer matrix (Gnanasekaran et al., 2021).

However, even after treatment, some microfibers retain small amounts of residual impurities, which could influence the fiber-matrix interaction. Despite this, the SEM results indicate that these microfibers possess desirable characteristics, such as increased surface area and reduced impurity content, making them suitable for use as reinforcing materials in composites. The presence of rough areas and thin layers of residual coatings in some regions also suggests that further refinement could enhance the overall performance of PALF in composites, particularly by improving its interfacial bonding with other materials(Gholampour & Ozbakkaloglu, 2020).

Tensile Strength Analysis

Tensile strength tests are crucial in assessing the mechanical properties of PALF, as they provide insight into its ability to reinforce composite materials. The tensile strength of PALF is influenced by several factors, including the extraction method, fiber diameter, moisture content, and surface treatment. Natural fibers like PALF exhibit significant variability in their mechanical properties due to these factors, and thus, the tensile strength may differ based on geographic location, processing methods, and environmental conditions (Karolina et al., 2020). In general, PALF has been found to exhibit a relatively high tensile strength compared to other natural fibers like jute and hemp. This study found that untreated PALF exhibited a maximum stress of 4982 MPa, while treated PALF had a maximum stress of 428 MPa. Although the stress decreased, the value is still acceptable for use as a reinforcing material (Rizal & Hamdan, 2021). The treatment process likely caused the observed degradation, leading to a reduction in cellulose crystallinity (Amirulhakim et al., 2021).Surface treatment, such as alkali treatment (e.g., sodium hydroxide), is commonly applied to PALF to enhance its interfacial bonding with polymer matrices in composite materials. Alkali treatment helps remove impurities such as lignin and hemicellulose, improving the fiber's surface roughness and increasing its compatibility with the matrix, thereby improving the tensile strength of PALF-reinforced composites (Yudhanto et al., 2021)(Purkuncoro, 2017).

Table 2. Summary of Tensile Strength Test Data for Pineapple Leaf Fiber Samples

Pineapple Leaf Fiber Samples	Maximum Load (N)	Maximum Stress (MPa)	Maximum Elongation (mm)	Break Point Strain (%GL)
Untreated PALF	4.2612	4982.1	0.7795	3.0689
Treated PALF	14.703	428.29	0.9193	4.0118

Tensile strength tests are crucial in assessing the mechanical properties of PALF, as they provide insight into its ability to reinforce composite materials. The tensile strength of PALF is influenced by several factors, including the extraction method, fiber diameter, moisture content, and surface treatment. Natural fibers like PALF exhibit significant variability in their mechanical properties due to these factors, and thus, the tensile strength may differ based on geographic location, processing methods, and environmental conditions (Karolina et al., 2020). In general, PALF has been found to exhibit a relatively high tensile strength compared to other natural fibers like jute and hemp. This study found that untreated PALF exhibited a maximum stress of 4982 MPa, while treated PALF had a maximum stress of 428 MPa. Although the stress decreased, the value is still acceptable for use as a reinforcing material (Rizal & Hamdan, 2021). The treatment process likely caused the observed degradation, leading to a reduction in cellulose crystallinity (Amirulhakim et al., 2021).Surface treatment, such as alkali treatment (e.g., sodium hydroxide), is commonly applied to PALF to enhance its interfacial bonding with polymer matrices in composite materials. Alkali treatment helps remove impurities such as lignin and hemicellulose, improving the fiber's surface roughness and increasing its compatibility with the matrix, thereby improving the tensile strength of PALF-reinforced composites (Yudhanto et al., 2021)(Purkuncoro, 2017).

CONCLUSION

Based on the results of this research, it can be concluded that alkaline treatment with 5% NaOH and bleaching with NaClO effectively reduce the content of hemicellulose, lignin, pectin, and other impurities while increasing the cellulose content in the fiber. The tensile strength of untreated pineapple leaf fiber (PALF) is higher than that of treated PALF, as the extended drying process in treated fibers led to cellulose degradation. Additionally, the morphology of pineapple leaf fiber subjected to alkali treatment and bleaching revealed a significant reduction in amorphous structures such as hemicellulose, lignin, pectin, and other impurities, while retaining a substantial amount of cellulose content in the fiber.

RECOMMENDATION

Research related to the characterization of pineapple leaf fiber as a composite reinforcing material can include analysis methods using XRD to measure the crystallinity and scale up the material size into nano.

ACKNOWLEDGMENT

We would like to thank the Ministry of Education, Culture, Research and Technology for their support in the form of providing Beginner Lecturer Research grants so that researchers can conduct research and present the results through scientific publications.

REFERENCES

Amirulhakim, H., Juwono, A. L., & Roseno, S. (2021). Isolation and characterization of Cellulose Nanofiber from Subang Pineapple Leaf Fiber waste produced using Ultrafine Grinding method. *IOP Conference Series: Materials Science and Engineering*, *1098*(6), 062067. https://doi.org/10.1088/1757-899x/1098/6/062067

Barhoum, A., Pal, K., Rahier, H., Uludag, H., & Soo, I. (2019). Nanofibers as new-generation materials : From spinning and nano-spinning fabrication techniques to emerging applications. *Applied Materials Today*, *17*, 1–35. https://doi.org/10.1016/j.apmt.2019.06.015

Cherian, B. M., Leão, A. L., De Souza, S. F., Costa, L. M. M., De Olyveira, G. M., Kottaisamy, M., Nagarajan, E. R., & Thomas, S. (2011). Cellulose nanocomposites with nanofibres isolated from pineapple leaf fibers for medical applications. *Carbohydrate Polymers*, *86*(4), 1790–1798. https://doi.org/10.1016/j.carbpol.2011.07.009

Cozier, M. (2014). Biomass recalcitrance. Part I: the chemical compositions and physical structures affecting the enzymatic hydrolysis of lignocellulose. *Biofuels, Bioproducts and Biorefining*, *8*(6), 743. https://doi.org/10.1002/BBB

Duangsuwan, S., Amornsakchai, T., Phinyocheep, P., & Thanawan, S. (2023). Achieving High-Performance Green Composites from Pineapple Leaf Fiber-Poly(butylene succinate) through Both Fiber Alignment and Matrix Orientation across the Thickness. *ACS Omega*, *8*(39), 35693–35705. https://doi.org/10.1021/acsomega.3c02690

Fan, F., Zhu, M., Yang, Y., Fang, K., Cao, X., Deng, Z., Ke, W., Xie, J., Zhang, Z., & Chen, Y. (2022). Degumming and Characterization of Palm Fibers. *Cellulose Chemistry and Technology*, *56*(1–2), 123–130. https://doi.org/10.35812/CelluloseChemTechnol.2022.56.11

Gaba, E. W., Asimeng, B. O., Kaufmann, E. E., Katu, S. K., Foster, E. J., & Tiburu, E. K. (2021). Mechanical and structural characterization of pineapple leaf fiber. *Fibers*, *9*(8), 1–11. https://doi.org/10.3390/fib9080051

Gandara M, Zanini NC, Mulinari DR, Saron C, da R. C. M. (2022). Green composites using recycled plastic bags and pineapple fibers waste. *Journal of Composite Materials*, *11*, 1709–1724.

Gholampour, A., & Ozbakkaloglu, T. (2020). A review of natural fiber composites: properties, modification and processing techniques, characterization, applications. In *Journal of Materials Science* (Vol. 55, Issue 3). Springer US. https://doi.org/10.1007/s10853-019-03990-y

Gnanasekaran, S., Nordin, N. I. A. A., Jamari, S. S., & Shariffuddin, J. H. (2021). Effect of Steam-Alkaline coupled treatment on N36 cultivar pineapple leave fibre for isolation of cellulose. *Materials Today: Proceedings*, *48*(xxxx), 753–760. https://doi.org/10.1016/j.matpr.2021.02.216

Karolina, R., Muharrisa, R., & Handana, M. A. P. (2020). The effect of rice straw fiber addition as sound silencer and its effect to concrete mechanical properties. *IOP Conference Series: Materials Science and Engineering*, *725*(1), 1–7. https://doi.org/10.1088/1757-899X/725/1/012035

Lalhmangaihzuali, P. C., Latha, B. D., More, N., Choppadandi, M., & Kapusetti, G. (2019). Natural fiber reinforced biodegradable staples: Novel approach for efficient wound closure. *Medical Hypotheses*, *126*(March), 60–65. https://doi.org/10.1016/j.mehy.2019.03.021

Purkuncoro, A. E. (2017). *PENGARUH PERLAKUAN ALKALI (NaOH) SERAT IJUK (ARENGA PINATA) TERHADAP KEKUATAN TARIK*.

Rizal, M. Z. M., & Hamdan, A. (2021). Investigation of Single Fibre Tensile Properties of the Pineapple Leaf (PALF). *Journal of Physics: Conference Series*, *2129*(1). https://doi.org/10.1088/1742-6596/2129/1/012078

Septevani, A. A., Burhani, D., & Sudiyarmanto, S. (2018). Pengaruh Proses Pemutihan Multi Tahap Serat Selulosa Dari Limbah Tandan Kosong Kelapa Sawit. *Jurnal Kimia Dan Kemasan*, *40*(2), 71. https://doi.org/10.24817/jkk.v40i2.3508

Sethupathi, Murugan, Khumalo, Mandla, Skosana, Sifiso, Muniyasamy, S. (2023). Recent Developments of Pineapple Leaf Fiber (PALF) Utilization in the Polymer Composites—A Review. *Separations*, *11*.

Soeprijanto, S., Puspita, N. F., Ningrum, E. O., Hamzah, A., Karisma, A. D., Altway, S., & Zuchrillah, D. R. (2021). Produksi Serat Kasar dari Limbah Daun Nanas Melalui Ekstraksi Mekanik di Desa Satak Kabupaten Kediri. *Sewagati*, *5*(3), 307–314. https://doi.org/10.12962/j26139960.v5i3.80

Xiao Hanyue, Mohamed Thariq Hameed Sultan, Muhammad Imran Najeeb, F. S. S. (2024). A short review on the recent progress and properties of pineapple leaf fiber reinforced composite. *E3S Web Conf*.

Yudhanto, F., Wisnujati, A., Yudha, V., Rachmawati, P., & Dantes, K. R. (2021). Effect of Chemical Treatments on Morphological, Physical and Mechanical Properties of Bamboo/ Glass Fibers Hybrid Laminated Composite. *International Journal of Integrated Engineering*, *13*(7), 315–323. https://doi.org/10.30880/ijie.2021.13.07.036