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AN EXPERIMENTAL STUDY OF THE EFFECT OF SAGO PULP MESH SIZE ON THE MECHANICAL PROPERTIES OF COMPOSITES

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ABSTRACT

This study aims to analyze the effect of variations in the mesh size of sago pulp on the mechanical properties of polyester resin-based composites. Sago pulp was used as a reinforcing material with mesh sizes of 20, 30, and 40, and a composition of 40% sago pulp and 60% polyester resin. The method used was a laboratory experiment involving tensile, bending, and impact tests.

Test results show that the 30-mesh size has the highest tensile strength of 2.76 kgf/mm², while the 20-mesh size exhibits the highest bending strength of 2.88 kgf/mm². The 40-mesh size yields the lowest strength values in most tests. These differences are influenced by particle distribution and the quality of the bond between the sago pulp and the resin.

It is concluded that mesh size significantly affects the mechanical properties of the composite, and sago pulp composites have the potential to serve as a more environmentally friendly alternative to wood.

Keywords: sago pulp, composite, mesh size, mechanical properties.

1. INTRODUCTION

1.1 Background

The rapid development of material engineering technology has encouraged continuous innovation in composite materials with superior mechanical properties, lightweight characteristics, and environmentally friendly performance. Composite materials are widely used in various industrial sectors such as automotive, construction, aerospace, marine, and household products because they offer advantages compared to conventional materials such as metals and solid wood. In general, composite materials are formed by combining two or more constituent materials with different physical and chemical properties to produce a new material with improved performance characteristics. The main components of a composite consist of reinforcement material and matrix material, where the reinforcement functions to improve mechanical strength while the matrix acts as a binder and load distributor [5].

Along with increasing environmental awareness and the global demand for sustainable materials, the development of natural fiber-based composites has gained significant attention in recent years. Natural fibers and agricultural waste are considered attractive alternatives to synthetic reinforcement materials because they are renewable, biodegradable, lightweight, inexpensive, and readily available. Compared with synthetic fibers such as glass fiber and carbon fiber, natural fibers also provide lower environmental impacts during production and disposal processes.[12].

Indonesia is known as one of the world’s largest producers of sago. Sago processing industries generate a large quantity of waste material in the form of sago dregs (ampas sagu). During the extraction process of sago starch, only a small percentage of the sago trunk is converted into starch, while the remaining material becomes waste residue. This waste is commonly discarded into rivers or surrounding environments without proper treatment, potentially causing environmental pollution and unpleasant odors. However, sago dregs contain lignocellulosic compounds such as cellulose, hemicellulose, and lignin, which provide potential advantages as reinforcement materials in composite manufacturing [2],[17].

The cellulose content present in sago dregs contributes to the mechanical reinforcement capability of composite materials. Cellulose fibers possess relatively good tensile properties and can improve stiffness and strength when properly bonded with polymer matrices. In addition, the utilization of sago waste as composite reinforcement not only reduces environmental pollution but also increases the economic value of agricultural waste products. The development of composites from sago dregs can therefore contribute to sustainable material engineering while supporting waste management and renewable resource utilization [19].

Among various matrix materials used in composite fabrication, polyester resin is one of the most commonly utilized thermosetting polymers due to its good mechanical properties, low cost, ease of processing, and compatibility with natural reinforcement materials. Polyester resin also exhibits good resistance to chemicals and environmental exposure, making it suitable for structural and semi-structural applications. In composite systems, the interaction between reinforcement particles and the polyester matrix significantly influences the resulting mechanical properties [5].

One of the important factors affecting the performance of particle-reinforced composites is particle size or mesh size. The mesh size determines the distribution of reinforcement particles, surface area interaction, and the quality of bonding between the reinforcement and matrix phases. Smaller particles generally provide larger surface areas, which can improve adhesion between particles and resin. However, excessively fine particles may cause agglomeration and uneven dispersion within the matrix, reducing the effectiveness of stress transfer. Conversely, larger particles may create voids and weak interfacial bonding that can decrease mechanical strength. Therefore, selecting an appropriate mesh size is essential to optimize the mechanical performance of natural fiber composites [3].

Several studies have investigated the use of natural fibers and agricultural waste as reinforcement in polymer composites. Previous research has demonstrated that the mechanical properties of natural fiber composites are highly influenced by reinforcement composition, fiber orientation, particle distribution, moisture content, and fabrication techniques. However, studies specifically examining the influence of sago dregs mesh size on the mechanical behavior of polyester-based composites are still limited. In particular, detailed investigations involving tensile, bending, and impact performance using different mesh variations remain insufficiently explored [13].

Based on these considerations, this study aims to analyze the effect of sago dregs mesh size variation on the mechanical properties of polyester resin-based composites. The research utilizes mesh sizes of 20, 30, and 40 with a composite composition consisting of 40% sago dregs and 60% polyester resin. Experimental testing is conducted through tensile, bending, and impact tests to determine the optimal mesh size that produces the best mechanical performance. The findings of this study are expected to provide scientific contributions regarding the development of environmentally friendly composite materials from agricultural waste and to support the utilization of sago dregs as an alternative material for wood substitution and other engineering applications.

2. RESEARCH METHODS

Research methodology

Research Design

This study employed an experimental research method to investigate the effect of sago dregs mesh size variation on the mechanical properties of polyester-based composites. The experimental method was chosen because it enables direct observation and measurement of the influence of independent variables on the resulting composite performance. The study focused on producing composite specimens using different mesh sizes of sago dregs and evaluating their mechanical properties through laboratory testing.

The study used a quantitative experimental approach in which the independent variable was the mesh size variation of sago dregs, namely mesh 20, mesh 30, and mesh 40, while the dependent variables were the mechanical properties of the composite, including tensile strength, bending strength, and impact resistance.

Time and Place of Research

The preparation of sago dregs and composite specimen fabrication was conducted at the Mechanical Engineering Laboratory of Universitas Abulyatama. Mechanical testing consisting of tensile, bending, and impact tests was carried out at the Material Testing Laboratory of Politeknik Negeri Lhokseumawe. The specimen preparation and testing processes were conducted from December 2025 to January 2026.

Materials and Equipment

The materials used in this research were sago dregs as reinforcement material with mesh size variations of 20, 30, and 40, polyester resin as the matrix material, and peroxide catalyst to accelerate the curing process.

The equipment used during specimen fabrication and testing included a mixer, digital weighing scale, aluminum foil, spoon/spatula, mixing container, ruler, grinding machine, composite mold, steel weight plate, lubricating oil, Universal Testing Machine (UTM), bending testing machine, and Charpy impact testing machine.

Preparation of Sago Dregs

The sago dregs used in this study were obtained from a local sago processing industry. The preparation process involved several stages. First, the sago trunk was cut into smaller sections and processed using a crushing machine while water was added to extract the starch. The remaining residue was collected as sago dregs. The sago dregs were then dried under sunlight to reduce moisture content and facilitate sieving. After drying, the material was sieved using mesh sizes of 20, 30, and 40 to obtain uniform particle sizes for composite fabrication.

Composite Fabrication Process

The composite specimens were fabricated using a hand lay-up method. The composite composition consisted of 40% sago dregs and 60% polyester resin. The fabrication procedure was carried out as follows:

1. Preparing dried sago dregs and all required equipment.
2. Covering the mold surface with aluminum foil and lubricant oil to prevent specimen adhesion.
3. Weighing the sago dregs and polyester resin according to the predetermined composition.
4. Mixing the sago dregs and polyester resin uniformly using a mixer.
5. Allowing the mixture to rest temporarily to remove trapped air bubbles.
6. Adding peroxide catalyst into the mixture according to the required ratio.
7. Pouring the mixture into the mold cavity.

8. Applying pressure using a steel weight plate to obtain a flat composite surface.
9. Allowing the composite to cure at room temperature until fully hardened.
10. Removing the composite board from the mold and preparing it for specimen cutting.

Specimen Preparation

After the composite boards were fully cured, specimens were cut according to testing standards for each mechanical test. Tensile test specimens were prepared according to ASTM D3039 standard. Bending test specimens were prepared according to ASTM C1341-06 standard using rectangular dimensions suitable for three-point bending testing. Impact test specimens were prepared according to ASTM D256-10 standard using the Charpy impact method with V-notch geometry.

Mechanical Testing Procedures

Tensile testing was conducted using a Universal Testing Machine (UTM) to determine tensile strength, elongation, and modulus of elasticity.

Bending tests were carried out using the three-point bending method to determine flexural strength and deformation behavior.

Impact testing was conducted using the Charpy impact method to determine impact resistance and energy absorption capability of the composite material.

Data Analysis

The data obtained from tensile, bending, and impact testing were analyzed quantitatively by comparing the average values of each mechanical property for mesh 20, mesh 30, and mesh 40 composites. The results were presented in tables and graphs to evaluate the effect of mesh size variation on the mechanical performance of sago dregs polyester composites.

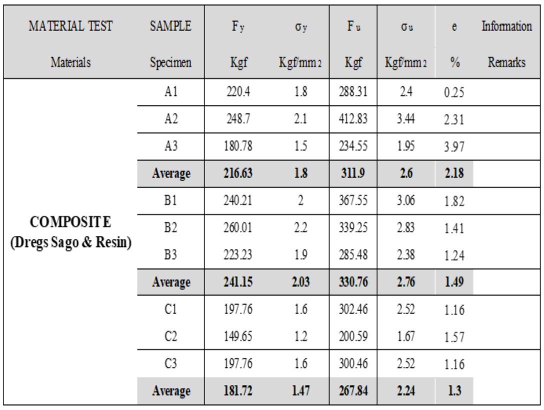
3. RESULTS AND DISCUSSION

3.1 Research Results

Results Testing Pull

Based on the results of tensile testing conducted on January 12, 2026 at the Lhokseumawe State Polytechnic Materials Testing Laboratory at mesh variations of 20, 30, and 40 as shown in the following figure.

Table 1 Data results testing pull



MATERIAL TEST	SAMPLE	F y	σ y	F u	σ u	e	Information
Materials	Specimen	Kgf	Kgf/mm 2	Kgf	Kgf/mm 2	%	Remarks
COMPOSITE (Dregs Sago & Resin)	A1	220.4	1.8	288.31	2.4	0.25	
	A2	248.7	2.1	412.83	3.44	2.31	
	A3	180.78	1.5	234.55	1.95	3.97	
	Average	**216.63**	**1.8**	**311.9**	**2.6**	**2.18**	
	B1	240.21	2	367.55	3.06	1.82	
	B2	260.01	2.2	339.25	2.83	1.41	
	B3	223.23	1.9	285.48	2.38	1.24	
	Average	**241.15**	**2.03**	**330.76**	**2.76**	**1.49**	
	C1	197.76	1.6	302.46	2.52	1.16	
	C2	149.65	1.2	200.59	1.67	1.57	
	C3	197.76	1.6	300.46	2.52	1.16	
	Average	**181.72**	**1.47**	**267.84**	**2.24**	**1.3**	

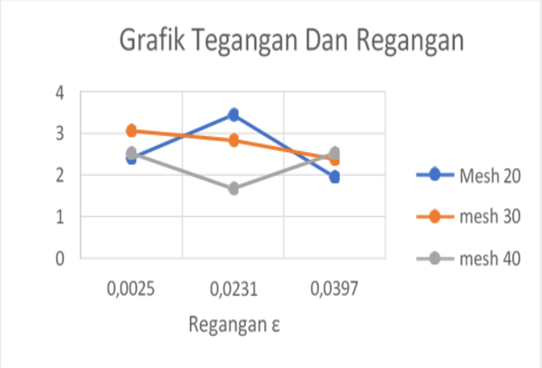
The data in Table 4.1 shows that the average maximum tensile strength value for mesh 20 (σu) is 2.60 kgf/mm² with an average breaking strain of 2.18%. The variation in values between samples is quite large, which indicates the non-uniformity of the distribution of sago pulp fibers and resin matrix bonds. The highest strain occurs in A3. This indicates that the distribution of fibers and matrix-reinforcement bonds is not yet homogeneous, thus affecting the material's ability to withstand tensile loads.

At me sh 30, it has the highest tensile strength compared to other groups. with mark σu average as big as 2.76 kgf/mm² And strain separated 1.49%. This indicates a better fiber-matrix bond and a more homogeneous composite structure, allowing it to withstand greater tensile loads. This means that mesh 30 is mechanically the best, with a combination of high tensile strength and still quite good strain. This condition indicates that the composition or treatment of the specimen with mesh 30 is optimal.

Meanwhile, mesh 40 showed the lowest tensile strength value with an average σu of 2.24 kgf/mm^2 and a breaking strain of 1.30%. This indicates Power support pull Which more low, possibility consequence distribution fiber Which not enough optimal or existence disabled in composite. decreased tensile strength and yield stress compared to the other groups. The relatively small strain indicates the material tends to be more brittle, possibly due to less effective fiber-resin bonding or internal defects.

Analysis Testing Pull

From data Which in can Can in Look connection voltage And strain on the following image



Picture 1. Chart voltage And strain

The stress-strain graph shows that variations in the sago pulp mesh size significantly affect the tensile properties of the composite. At 20 mesh, the maximum tensile stress increases to a maximum value at medium strains, then decreases sharply at higher strains. This behavior indicates that coarser particle sizes are capable of withstanding high tensile loads, but cause stress concentration and failure at the fiber-resin interface at higher deformations.

Composite with mesh 30 show response mechanic Which more stable compared to mesh 20 and mesh 40. The maximum tensile stress tends to decrease slowly with increasing strain, without sharp fluctuations. This indicates that the mesh size of 30 produces a better reinforcement distribution. Which more homogeneous as well as transfer burden Which more effective between dregs sago And matrix resin, so that capable guard stability strength pull during the deformation process.

Meanwhile, the 40 mesh composite exhibited lower tensile stress values and a less consistent pattern. The particle size was too fine. suspected of causing agglomeration and reduced effectiveness mechanical bonding with the resin matrix, thus reducing the material's ability to withstand tensile loads. Based on the graph, mesh 30 can be stated as the most optimal mesh size because it provides the best balance between tensile strength and strain stability.

Table 2. Data results testing bending

MATERIAL TEST	SAMPLE	Cross-section	Distance Support	F_u	σ_u	e	Information
Materials	Specimen	Suction (mm)	Distance (mm)	Kgf	Kgf/mm$_2$	%	Remarks
COMPOSITE (Dregs Sago & Resin)	AI	20 x 6	130	19.47	2.88	0.69	
	A2	20 x 6	130	16.64	2.47	1.11	
	A3	20 x 6	130	22.3	3.3	0.86	
	Average			**19.47**	**2.88**	**0.89**	
	B1	20 x 6	130	16.64	2.31	1.2	
	B2	20 x 6	130	10.98	1.52	1.14	
	B3	20 x 6	130	13.81	1.92	1.11	
	Average			**13.81**	**1.92**	**1.15**	
	C1	20 x 6	130	11.81	1.61	1.11	
	C2	20 x 6	130	11.54	1.81	1.27	
	C2	20 x 6	130	10.78	1.44	0.9	
	Average			**11.38**	**1.62**	**1.09**	

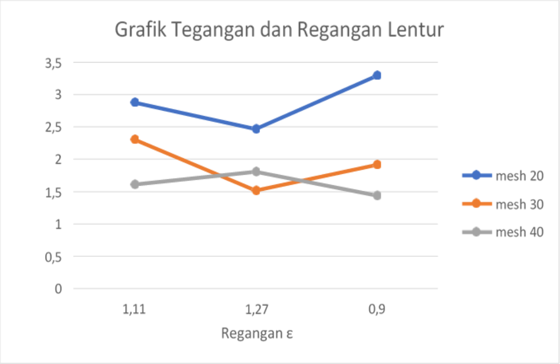
Bending tests are carried out to determine the capabilities of composite materials. dregs sago resin in withhold burden flexible, Which shown through the maximum load value (Fu), maximum bending stress (σu), and bending strain (ε). The test was carried out under the same conditions for all specimens, namely the cross-section 20 × 6 mm And distance support 130 mm, so that difference results which is obtained reflect influence variation size mesh dregs sago And level resin against characteristic mechanic flexible composite. Results bending test shown in Table 4.2, Which show value of Fu, σu, and ε For variation mesh 20, 30, and 40.

On the other hand, at mesh 30 with a coarser mesh size, the bond between phases becomes less optimal so that the material's ability to withstand bending loads decreases.

The highest strain value was obtained at mesh 30, while mesh 20 had the lowest strain value. This indicates that mesh 30 has more ductile properties than mesh 20. The higher strain at mesh 30 can associated with combination size mesh And level resin which allows the material to undergo greater deformation before breaking. While That, mesh 20 with strength flexible Which tall However strain Low values indicate stiffer and more brittle material characteristics. At mesh 40, although the strain value is relatively high, the flexural strength is low, indicating that the material is easily deformed but unable to withstand large loads due to the weak matrix-reinforcement bond.

Analysis Testing Bending

From data bending in can connection between grace And bending strain as in the following figure.



Picture 2. Chart voltage And strain flexible

From the flexural stress-strain graph shows the relationship between flexural strain (ε) and maximum flexural stress (σu) in sago pulp-resin composites with mesh size variations of 20, 30, and 40. This graph is used to describe the mechanical behavior of composite materials when subjected to flexural loading until reaching maximum conditions. Based on the graph, it can be seen that each mesh size variation shows stress-strain characteristics. Which different, Which indicates the existence of influence the size of the reinforcing particles on the flexural properties of the composite.

Composites with a 20-mesh size showed the highest flexural stress, around ±2.5–3.3 Kgf/mm², with low to moderate strain. The finer sago pulp particles increased the contact surface area between the reinforcement and resin matrix, resulting in stronger matrix–reinforcement bonding and a more uniform stress distribution. Consequently, the composite became stiffer and stronger, although it experienced less deformation before failure.

The 30-mesh composite exhibited lower flexural stress, approximately ±1.5–2.3 Kgf/mm². The larger particle size caused less homogeneous reinforcement distribution, leading to stress concentration at certain points. As a result, the material could undergo greater deformation before fracture, making it more ductile than the 20-mesh composite, but with lower flexural strength.

Meanwhile, the 40-mesh composite produced the lowest flexural stress, around ±1.4–1.8 Kgf/mm². The coarser particles weakened the matrix–reinforcement bonding and increased the possibility of void formation and material inhomogeneity. This reduced the composite's ability to withstand bending loads, causing failure at lower flexural stress values.

Overall, the flexural stress–strain results indicate that finer mesh sizes improve the flexural strength of the composite but reduce its strain capability. In contrast, coarser mesh sizes produce more ductile materials with lower flexural strength.

Results Testing Impact

Table 3. Results testing impact

No	Code Specimen	E (Joule)	Price Impact (J/m²)
1	A1	1,486	10391,608
2	A2	1,486	10846,715
3	A3	2,129	15316,546
Average		1,700	12184,956
1	B1	2,544	17189,189
2	B2	2,352	17954,198
3	B3	2,729	19897.81
Average		2,542	18347,066
1	C1	2,763	18543,624
2	C2	2,848	20788,321
3	C3	2,856	18425,806
Average		2,822	19252,584

Impact testing is conducted to determine the composite material's ability to absorb shock energy before failure. Key parameters Which analyzed in testing This is energy absorb impact (E) And impact value (J/m²), which is obtained from the comparison between the energy absorbed by the specimen and the fracture cross-sectional area.

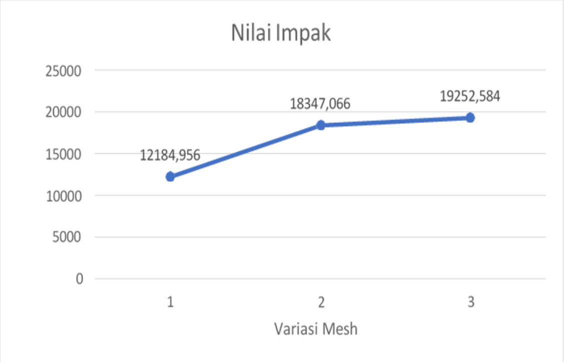
Based on results testing, energy absorb impact show the increase that significant from mesh 20 to mesh 40. Mesh 20 own energy absorb lowest with an average value of 1,700 Joules, while mesh 30 and 40 each showed average values of 2,542 Joules and 2,822 Joules, respectively.

The low absorption energy at mesh 20 indicates that the material is relatively not enough capable withhold burden shock, so that failure happen more fast. On the other hand, the increase in absorbed energy at mesh 30 and 40 indicates that the material has a better ability to absorb energy before fracture occurs. The impact value obtained shows an increasing trend. Which in line with improvement energy absorb. Mesh 20 own average value price impact as big as 12,184,956 J/m², whereas mesh 30 And 40 each showing an average value of 18,347.066 J/m² and 19,252.584 J/m².

The increase in the impact value indicates that the specimens with variations applied to mesh 30 and 40 have better impact toughness compared to mesh 20. A high impact value indicates the material's ability to distribute and absorb shock energy more effectively. effective. Improvement mark price impact from mesh 20 to mesh 40 shows that the mesh size of sago pulp significantly affects the dynamic mechanical properties of the composite. In specimens with a finer mesh size, the reinforcing particles tend to be distributed more evenly within the resin matrix.

Analysis testing Impact

From data Which in Which in can, Can in Look comparison mark impact each mesh as in the following image.



Picture 3.Chart impact value

From the graph above, we can see that this homogeneous distribution allows for better load transfer from the matrix to the reinforcement when the specimen is subjected to shock loading. Furthermore, the finer mesh size increases the surface area. contact between amplifier And matrix, so that the bond interface becomes stronger and more stable. Conversely, in specimens with coarser mesh sizes, the distribution of reinforcement tends to be uneven and causes particle agglomeration. This condition causes stress concentration at certain points, so that cracked more easy formed And develop in a way fast moment impact testing is performed

4. CONCLUSION

4.1 Conclusion

Based on the results of the research and discussion regarding the experimental study of the effect of sago pulp mesh size on the mechanical properties of resin-based composites through tensile, bending, and impact testing, the following conclusions can be drawn:

1. Variations in sago pulp mesh size have a significant effect on the tensile properties of the composite. Mesh 30 produced the highest tensile strength of 2.76 kgf/mm² with an elongation of 1.49%, indicating the most optimal matrix–reinforcement bond.
2. In the bending test, mesh 20 had the highest flexural strength of approximately 2.88 kgf/mm² due to a more homogeneous particle distribution, while mesh 30 exhibited greater toughness with higher flexural elongation.
3. Impact test results indicate that the finer the mesh size, the higher the material's ability to absorb impact energy. Mesh 40 had the highest impact value of 19,252.584 J/m², while Mesh 20 had the lowest at 12,184.956 J/m².
4. Overall, the 30-mesh variant is the most optimal because it provides the best balance between tensile strength, stiffness, and impact toughness compared to the other variants.

4.2 Suggestions

Based on the conclusions obtained, it is recommended that further research be conducted on the effect of variations in resin and sago waste composition, as well as pretreatment of sago waste to improve the interfacial bonding of the composite. In addition, further tests such as microstructure, density, and hardness tests are needed to better understand the material characteristics and evaluate the stability of the composite's mechanical properties over a certain period of use.

BIBLIOGRAPHY

American Society for Testing and Materials. (2006). ASTM C1341-06: Standard test method for flexural properties of continuous fiber-reinforced advanced ceramic composites. ASTM International.

American Society for Testing and Materials. (2010). ASTM D256-10: Standard test methods for determining the Izod pendulum impact resistance of plastics. ASTM International.

American Society for Testing and Materials. (2014). ASTM D3039/D3039M: Standard test method for tensile properties of polymer matrix composite materials. ASTM International.

Bledzki, A. K., & Gassan, J. (1999). Composites reinforced with cellulose based fibres. Progress in Polymer Science, 24(2), 221–274. https://doi.org/10.1016/S0079-6700(98)00018-5

Callister, W. D., & Rethwisch, D. G. (2020). Materials science and engineering: An introduction (10th ed.). Wiley.

Fakri, Z., & Juhan, N. B. B. (2019). Analisis pengujian impak Charpy terhadap sifat mekanik material. Jurnal Teknik Mesin, 6(2), 85–92.

Faruk, O., Bledzki, A. K., Fink, H.-P., & Sain, M. (2012). Biocomposites reinforced with natural fibers: 2000–2010. Progress in Polymer Science, 37(11), 1552–1596. https://doi.org/10.1016/j.progpolymsci.2012.04.003

Gibson, R. F. (2016). Principles of composite material mechanics (4th ed.). CRC Press.

Hull, D., & Clyne, T. W. (2019). An introduction to composite materials (2nd ed.). Cambridge University Press.

Jawaid, M., & Abdul Khalil, H. P. S. (2011). Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review.

Carbohydrate Polymers, 86(1), 1–18.

Kiat, N. (2006). Teknologi pengolahan dan pemanfaatan limbah sagu. Balai Penelitian Tanaman Pangan.

Muslim. (2021). Potensi sagu sebagai sumber bahan baku industri dan pangan nasional. Jurnal Teknologi Pertanian, 14(1), 45–52.

Mwaikambo, L. Y., & Ansell, M. P. (2002). Chemical modification of hemp, sisal, jute, and kapok fibers by alkalization. Journal of Applied Polymer Science, 84(12), 2222–2234.

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

Pratama, A. (2011). Material komposit dan aplikasinya dalam bidang teknik. Andi Offset.

PT Justus Sakti Raya. (2018). Datasheet Yukalac® 157 BQTN-EX Unsaturated Polyester Resin. Jakarta.

Rahman, M. M., Hasan, M., & Huque, M. M. (2013). Physico-mechanical properties of natural fiber reinforced composites. Journal of Reinforced Plastics and Composites, 32(11), 802–813.

Semual Bale, J. (2022). Proses manufaktur material komposit dan aplikasinya. Penerbit Teknik Mesin.

Shalwan, A., & Yousif, B. F. (2013). In state of art: Mechanical and tribological behaviour of polymeric composites based on natural fibres. Materials & Design, 48, 14–24.