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THE EFFECT OF THE NUMBER OF FIBER SHEETS AND NAOH CONCENTRATION ON THE IMPACT STRENGTH OF ALKALI-TREATED ARTHOCARPUS ELASTICUS PEELED FIBER COMPOSITESTITLE

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ABSTRACT
The focus of this study is the effect of NaOH alkali treatment and the number of fiber sheets on the impact strength of Artocarpus elasticus (lantung bark) fiber as a sustainable reinforcing material in natural fiber composites. However, lignin and hemicellulose can prevent the fibers from adhering to the resin. NaOH treatment improves fiber quality by removing these barriers, enhancing their mechanical properties. This study examines how differences in the number of fiber sheets and NaOH concentration affect the impact strength of the composite. The objective of this research is to determine how the number of fiber sheets, NaOH concentration, and combinations of these factors affect the impact strength of Artocarpus elasticus fiber composites subjected to impact testing. The study found that NaOH treatment significantly enhances the impact strength of lantung wood composites, with results continuing to improve. However, for the number of wood fiber sheets, the impact strength was highest after treatment with 4 wood fiber sheets. The optimal combination yielding the highest impact test results was the combination of 9% NaOH alkalization treatment with 4 fiber sheets, resulting in an impact value of 0.08 J/mm².

Keywords : *Artocarpus elasticus, NaOH, Layer, Impact*

1. Introduction

Composites are composed of two or more constituent components that combine to provide greater mechanical qualities than individual parts could on their own. The potential for natural fiber composites to be lighter, more biodegradable, and more environmentally friendly is just one of the many benefits over synthetic fiber composites. Lantung bark, a natural fiber found in Indonesia, is a cost-effective and abundant resource with high cellulose content. Despite its potential as a composite reinforcement material, its utilization is limited to textile crafts and traditional products, and its bark fibers have not been extensively explored

Cellulose, the main component of natural fibers, is required to provide mechanical strength to composites. Lantung wood's high cellulose content enhances its reinforcing properties. However, lignin and hemicellulose concentrations can reduce fiber adhesion to the resin matrix. NaOH alkali treatment can improve fiber quality by removing these obstacles, thereby enhancing the fiber's ability to adhere to the resin matrix.Setiawan et al., (2019) claim that this treatment improves the interfacial relationship by increasing the number of hydroxyl groups on the fiber surface which causes the connection between the fibers to be stronger. According to research by Dantes et al., (2023), alkali treatment of bamboo fibers can improve the impact strength of polyester composites. The treatment lasting two hours had the highest value and decreased at 3 hours, and 4 hours., indicating that alkali is crucial for enhancing the interaction between the polyester matrix and the fiber. However, because of fiber breakdown, impact strength decreases if the treatment is extended

The impact strength of composites is significantly influenced by the fiber volume fraction. Olodu and Ihenyen (2021) found that reinforced polyester composites' impact strength increases with an increase in fiber volume percentage, suggesting that more fibers enhance shock load withstandability. However, the optimal strength is found at a specific fiber volume fraction, and excessive fiber volume can lead to fiber aggregation, highlighting the importance of maximizing fiber volume fraction in composite applications for optimal mechanical properties.

This study explores the potential of lantung wood as a sustainable material in natural composites, focusing on its effectiveness in composites through NaOH treatment and fiber layer variation, highlighting its potential as a competitive reinforcement in the composites industry.The result of this study is to determine the effect of Fiber Sheet Count and NaOH Concentration on the Impact Strength of Alkali-Treated Arthocarpus Elasticus Peel Fiber Composite.

2. Literature Riview

2.1. Previous Research (State of the Art)

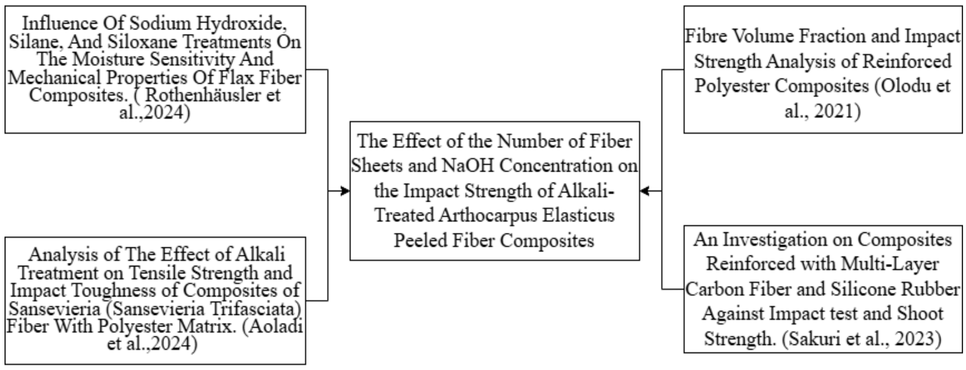

Figure 1 State of the Art

Influence Of Sodium Hydroxide, Silane, And Siloxane Treatments On The Moisture Sensitivity And Mechanical Properties Of Flax Fiber Composites.

The study reveals that sodium hydroxide (NaOH) treatment is more effective than silane and siloxane in enhancing the mechanical properties of hemp fiber composites. NaOH effectively removes impurities on the fiber surface, increasing roughness and strengthening adhesion between the fiber and matrix. This enhances the formation of stronger chemical bonds with the epoxy resin used. Composites with NaOH-treated fibers showed a tensile strength increase of up to 21.9% and modulus increase of up to 13.3% compared to untreated fibers. NaOH also improved the fiber's crystallinity and cellulose content, enhancing the material's modulus and strength (Rothenhäusler et al., 2024)

Analysis of The Effect of Alkali Treatment on Tensile Strength and Impact Toughness of Composites of Sansevieria (Sansevieria Trifasciata) Fiber With Polyester Matrix.

The study reveals that Sansevieria fiber treated with 6% NaOH has the highest tensile strength, with an average value of 52.70 MPa. The lowest tensile strength was found with 0% NaOH treatment. The composite treated with 3% NaOH had the highest impact toughness of tongue-in-law fiber, while the composite treated with 9% NaOH had the lowest average impact toughness (0.017 J/mm^2). Because of the poor link between the matrix and the fiber, the fracture failure manifests as the presence of detached fibers or fiber pull out. The addition of NaOH causes fiber disconnection or breakage, and the number of detached fibers in the composite increases (Aoladi et al., 2019)

Fibre Volume Fraction and Impact Strength Analysis of Reinforced Polyester Composites.

The study reveals that reinforced polyester composites have an effective thickness of 60mm to100mm at fiber framing, with a fiber volume fraction of 0.32 to 0.50. The thickness is influenced by woven roving, providing greater resistance to fracture and impact damage. The impact strength increases with more fibers, indicating increased shock load withstandability. The optimal strength is observed at a certain fiber volume fraction, and a high volume fraction may reduce strength. The study emphasizes the importance of maximizing fiber volume fraction in composite applications for desired mechanical properties (Olodu & Ihenyen, 2021)

An Investigation on Composites Reinforced with Multi-Layer Carbon Fiber and Silicone Rubber Against Impact test and Shoot Strength.

Research indicates that the number of carbon fiber layers in composite materials significantly affects impact resistance. The highest impact strength is observed in specimens with six carbon fiber layers, with a 0.040 Joule/mm^2 impact strength. However, increasing the number of layers to eight and ten results in a decrease in impact strength. This suggests that adding more carbon fiber layers doesn't necessarily increase impact resistance, and increased coatings can decrease the material's ability to absorb impact energy. This highlights the need for a balanced approach in composite design (Sakuri et al., 2023)

2.2. Literature Riview

2.2.1. Composite

Structural materials can be divided into four basic categories: metals, polymers, ceramics, and composites. Composites, which consist of two or more separate materials combined in a structural unit, are typically made from various combinations of the other three materials (Gibson, 2007). Composite materials typically contain two components: fiber and matrix. The fiber can be utilized as a filler, and the matrix can be used to glue the fibers together. A new composite material with distinct mechanical properties and attributes from its component materials will be created by the fiber and matrix mixing. Matrix, a fiber binding substance, and fiber, a filler material, were created on a macroscopic level and physically united. The adjective "composite" denotes a combination or arrangement (Kurniawan et al., 2022)

2.2.2. Lantung Wood Fiber

Artocarpus elasticus is a Moraceace family, also known as lantung plants. Several regional names for the lantung tree may be found in Indonesia, such as Mengko (Aceh), Torop (Medan), Bakil (Malay), Tarok (Minangkabau), Benda/Teureup (Sunda), Terap (Kalimantan), and Taeng (Makassar). The lantung tree belongs to the Moraceace tribe. Moraceace fibers are natural fibers that fall under the category of cellulose fibers. In Indonesia, there are eighteen different kinds of bark that may be utilized to make bark cloth (Hestiawan et al., 2022).

2.2.3. Alkali NaOH

This alkaline treatment process increases fiber strength by reducing components that inhibit the interaction between the fiber and the polymer matrix. The removal of lignin and hemicellulose results in cleaner fibers, rougher surfaces, better adhesion to the matrix, and stronger composites (Tengsuthiwat et al., 2024). The purpose of applying NaOH treatment to fibers is to remove any debris or gum that may have adhered to the fiber's surface, improving the bond between the fiber's surface and the matrix. Not with standing their many benefits, natural fibers also have a number of drawbacks, such as low strength, particularly when it comes to shock loads, poor dependability, an inability to tolerate high temperatures, and a wide range of quality depending on the time of year, age, soil type, and environment. The fibers are treated with alkali (NaOH) to address these deficiencies

2.2.4. Impact Test

The impact test is a method used to evaluate a material's ductility, hardness, and strength. It is commonly used to assess a material's mechanical characteristics. Research shows that steel and aluminum fractures are ductile, but steel has a higher impact price due to its toughness. Variations in the test specimen's size, weight, arm length, and angle are caused by various factors (Sunarno & Zainuddin, 2023). Impact tests, like Charpy and Izod, calculate the energy needed to harm a specimen struck by a pendulum in order to assess a material's resistance to impact and shock loading. Energy is determined from the pendulum's starting and ending heights in both tests, which use specimens with varied shapes but comparable dimensions. These tests reveal information on the impact resistance of materials

3. Research Methods

This research uses experimental methods in the laboratory. Experimental is a study that seeks to find the effect of certain variables on other variables under strictly controlled conditions. This research uses an experimental method to examine how manipulating independent variables affects the impact strength of *Artocarpus elasticus* fiber composites under controlled conditions. The independent variables are the number of fiber layers and the NaOH concentration (3%, 6%, and 9%) used in alkali treatment. Controlled variables such as room temperature, molding pressure, hand lay-up method, test standards, and resin type are kept constant to ensure accurate results. The dependent variable is the impact strength measured through impact testing. By controlling these factors, the study aims to determine the effect of fiber layering and alkali concentration on composite performance with reliable and valid outcomes.

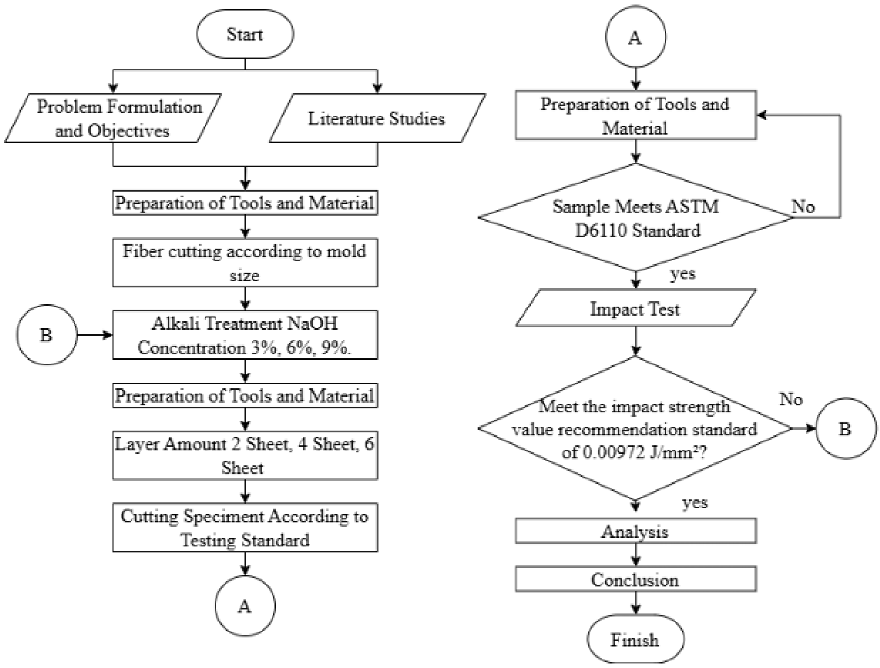

Figure 2. Flow Chart

The explanation of the flow chart of the research entitled “Effect of Fiber Sheet Count and NaOH Concentration on the Impact Strength of Alkali-Treated Artocarpus Elasticus Peel Fiber Composites is detailed as follows:

1) Start: The initial stage is conducted to learn the research process from start to finish.
2) Preparation of Tools and Materials: The stage of preparing research materials and tools.
3) Alkali treatment of lantung wood fiber is the first step, which includes cleaning the fiber surface and calculating the level of alkali treatment based on NaOH concentration.
4) Resin and Hardener Weighing: The process of weighing both to form the right composite.
5) Fabrication of Composite by Hand Lay Up Method: This step is the process of making composites using the vacuum resin infusion method.
6) Specimen Cutting: To prepare the test specimen, the material is split using a band saw machine. Start, It is the initial stage carried out in order to learn the steps of doing the thesis from start to finish. Make sure make it in ASTM D6110 if the result is incorrect for surface and dimension, specimen cutting should be re do
7) Impact Testing: This is a procedure to measure the strength of a material against an impact load.
8) Data Management and Analysis: This stage consists of data processing to determine the values of the tested material properties. Further, analysis is done to come up with conclusions.
9) Conclusions and Suggestions: This is the stage to draw conclusions from the analysis results and make recommendations about the research.

10) Conclusion: Once all the steps are done, the research is closed

In making the conceptual framework of this research using input-output diagrams, where the block diagram is a function and the line diagram is a link.

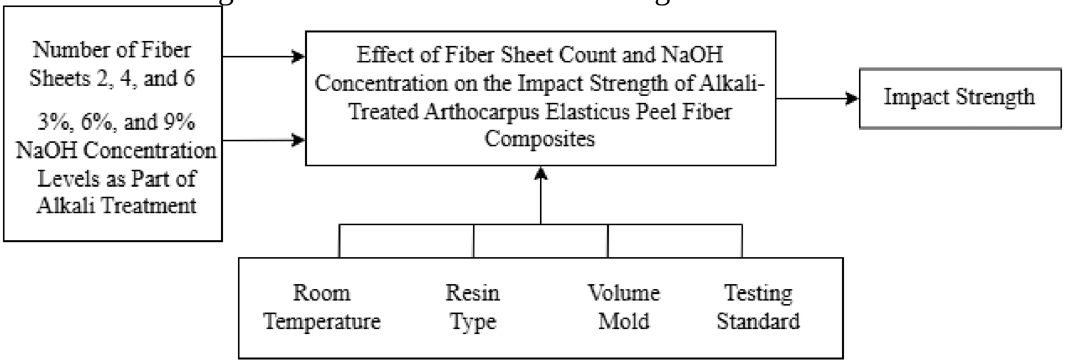

Figure 3. Conceptual Framework

3.1. Manufacture of Composite

1) Preparation of Materials and Tools: Prepare resin, hardener, fiber, NaOH solution (3%, 6%, 9%), and tools such as paper cups, scissors, markers, vacuum, connecting hose, and mold.
2) Fiber Cutting and Cleaning: Cut the fibers to 150x150 mm, then clean them with a brush and water to remove impurities.
3) Alkali Soaking: Soak the fibers in NaOH solution with three different concentrations for 1.5 hours to improve the strength and mechanical properties of the fibers.
4) Fiber Drying: Dry the fibers until they are perfectly dry to ensure they are ready for use.
5) Mold Preparation: Coat the mold with honey wax to make the composite easy to remove after hardening. Install a connecting hose between the mold-resin trap and the mold-resin bin, and add a paper cup in the resin trap for easy cleaning.
6) Resin and Hardener Mixing: Resin and hardener are mixed in a ratio of 2:1 as recommended in the Epoxy Resin and Hardener manual. This ratio can be adjusted according to application needs and working conditions, while following the manufacturer's instructions for optimal results.
7) Hand Lay Up: The process for creating a wood fiber composite starts by layering lantung fibers on a mold coated with wax. Resin and hardener are mixed in a 2:1 ratio and applied evenly over the fibers to ensure complete saturation. The layers are compressed using C-clamps to maintain uniform pressure during curing. Once the resin hardens, the finished composite structure is removed from the mold.
8) Finishing and Drying: Allow the mold to dry for 24 hours (1 day). After that, open the mold using the kapi tool. Remove the sealant tape first before opening the mold to make the process easier.

3.2. Speciment Forming

1) Tool Preparation: Prepare the necessary tools such as a crossbar, marker, milling machine, and band saw machine, and make the specimens with standard ASTM D6110
2) Thickness Scraping: The composite that has been removed from the mold is scraped using a milling machine until it reaches a thickness of 10 mm with a tolerance of ±1 mm. This process is carried out to flatten the composite surface after molding and adjust to the specifications of the test specimen.

3) Specimen Cutting: After scraping, measure the composite according to the size of the impact test specimen. Perform cutting using a band saw machine to obtain a test specimen that matches the predetermined dimensions.

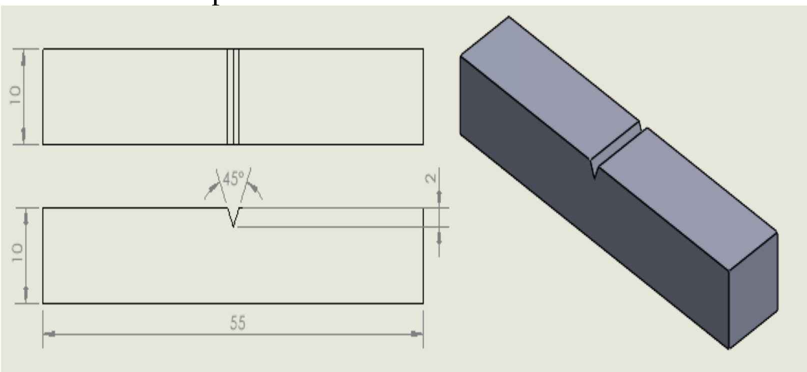

Figure 4. ASTM D6110

3.3. Impact Testing

Impact testing is a method of assessing the strength of materials against sudden stresses or loads, to test mechanical properties and resistance to impact using rapid loading. This test analyzes energy absorption through strain rate, utilizing the kinetic energy of the load. This study utilized the ASTM D6110 standard, with an initial angle of 90° to produce the maximum impact that reveals structural damage to the composite. The final angle was also recorded as a reference for calculating the impact value. The test results are presented in a table including the initial angle, final angle, energy absorbed, and impact value for each specimen. And also use the the formula of fractutre energy to find the impact value

$$E = m.g.\mathrm{R}(\cos\beta - \cos\alpha)$$

Description:
E = Fracture Energy (J)
m = Pandulum Mass (kg)
g = Gravity Acceleration (m/s^2)
R = Pandulum Arm Length (m)
α = Initial Angle (°)
β = Final Angle (°)

$$HI = \frac{E}{A}$$

Description:
HI = Impact Price (J/mm²)
E = Fracture Energy (J)
A = Cross-Sectional Area (mm)

4. Results and Discussions

The data obtained from the impact testing, hereinafter referred to as research data, formed the basis for further analysis in this study. After the testing phase was completed, the raw data were processed through several stages, including classification and interpretation. The processed data were then presented in the form of tables to show numerical values, graphs for visual trends, and a discussion to explain the results and their significance.

Based on the observed results, the impact shown in the table is consistent and can be applied to the overall data obtained throughout the experiment. The trend clearly indicates that both the number of coating layers and the concentration of NaOH solution significantly influence the final contact angle, reflecting surface wettability modifications.Furthermore, Table provides a comprehensive summary of all the measured impact values, consolidating the findings into a single comparative overview for easier analysis and interpretation.

Table 1. Impact Value

No	NaOH	Number of Layers	Impact Value			Total
			1	2	3	
1	3%	2	0,008	0,008	0,008	0,024
2		4	0,02	0,02	0,02	0,06
3		6	0,02	0,03	0,02	0,07
4	6%	2	0,01	0,02	0,02	0,05
5		4	0,06	0,05	0,07	0,18
6		6	0,05	0,05	0,06	0,16
7	9%	2	0,03	0,03	0,03	0,09
8		4	0,08	0,08	0,05	0,21
9		6	0,04	0,05	0,04	0,13
		Total				0,974

These data will be utilized to identify and evaluate the characteristics of the tested material, namely the lantung bark fiber composite.

4.1. Effect of Number of Layer on the Impact Value

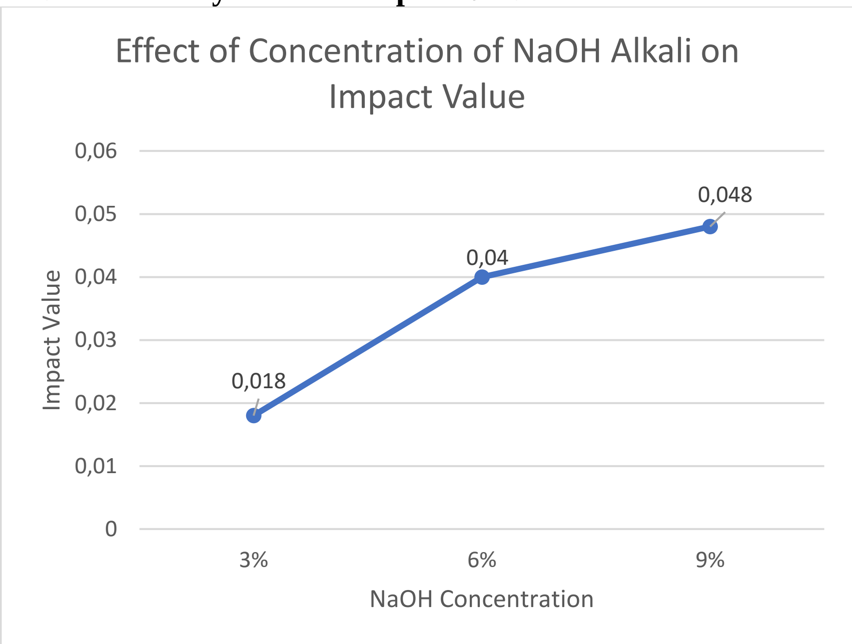

Figure 5. Effect of Number of Layer on the Impact Value

The graph indicates that increasing the number of fiber layers affects the impact value in a non-linear way. The lowest value occurs at 2 layers (0.0182), then rises sharply to the highest at 4 layers (0.05), before decreasing at 6 layers (0.038). This drop is likely due to poor resin penetration, void formation, or internal stresses causing delamination. These findings align with Sakuri et al. (2023), who found that while six layers of carbon fiber improved impact toughness, adding more led to a decline due to brittleness and delamination risk. Therefore, increasing layers does not always improve impact resistance, and using 2 to 6 layers offers an optimal balance of strength and energy absorption.

4.2.Effect of Number Layer on the Impcat Value

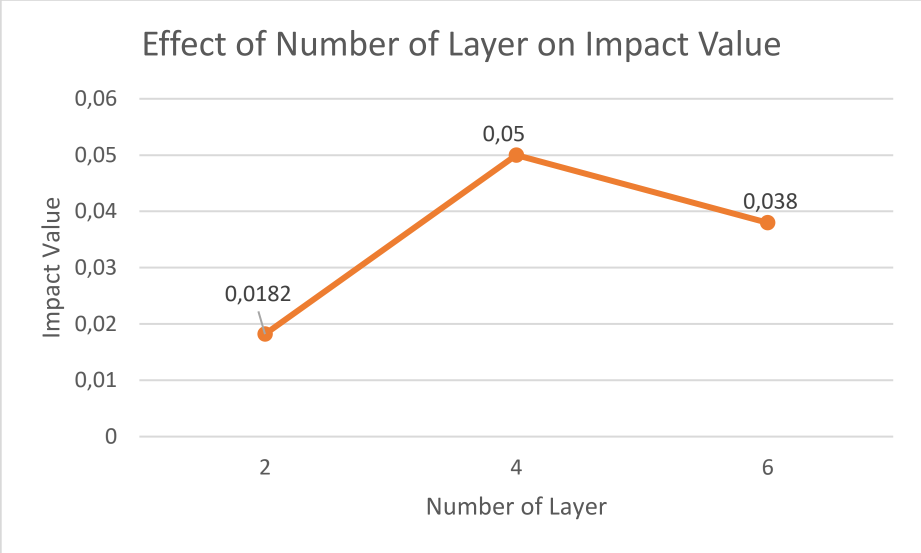

Figure 6. Effect of Number Layer on yhe Impcat Value

The graph illustrates a consistent increase in impact value with rising NaOH concentrations of 3%, 6%, and 9%. The lowest impact value, 0.018, occurs at 3%, indicating insufficient fiber surface modification. At 6%, the impact value climbs to 0.040, and peaks at 0.048 with 9% NaOH. This trend shows that higher NaOH concentration enhances interfacial adhesion by removing surface impurities and increasing fiber roughness, allowing better mechanical interlocking and energy absorption.

These results align with prior studies, such as Rothenhäusler et al. (2024), which demonstrated that NaOH treatment increases fiber crystallinity and bonding with the matrix by removing wax, lignin, and hemicellulose. It leads to better tensile strength and elastic modulus than untreated or silane/siloxane-treated fibers. Thus, this study confirms that NaOH treatment significantly improves mechanical performance due to cleaner, rougher, and more reactive fiber surfaces—supporting its use in optimizing natural fiber-reinforced composites.

4.3 The Effect of Concentration of NaOH and Number Layer on Impact Value

This section presents data processing using two methods for comparison and validation: Minitab 20 software and manual calculation via Microsoft Excel. Minitab 20 offers robust statistical tools commonly used in research, while Excel provides transparent, step-by-step calculations for better understanding of numerical behavior. After initial processing, further analysis is conducted using Design of Experiment (DOE) with a factorial design in Minitab. This method is appropriate due to the presence of two independent variables, each with three levels, allowing analysis of both main and interaction effects. The factorial approach enhances the depth of interpretation, and the statistical results and interaction plots are discussed in the subsequent sections.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	0,010117	0,001265	21,34	0,000
Linear	4	0,008850	0,002212	37,33	0,000
NaOH	2	0,004225	0,002112	35,65	0,000
Number of Layer	2	0,004625	0,002312	39,02	0,000
2-Way Interactions	4	0,001268	0,000317	5,35	0,005
NaOH*Number of Layer	4	0,001268	0,000317	5,35	0,005
Error	18	0,001067	0,000059		
Total	26	0,011184			

Figure 7. Analysis of Variance

the interaction term NaOH with Number of Layers exhibits a P-value of 0.005, which is also lower than the significance level. This suggests that the combined effect of NaOH concentration and the number of layers has a significant interaction effect on the response. In other words, the impact of one factor depends on the level of the other, highlighting the importance of not only studying individual effects but also their interdependence when optimizing material performance.

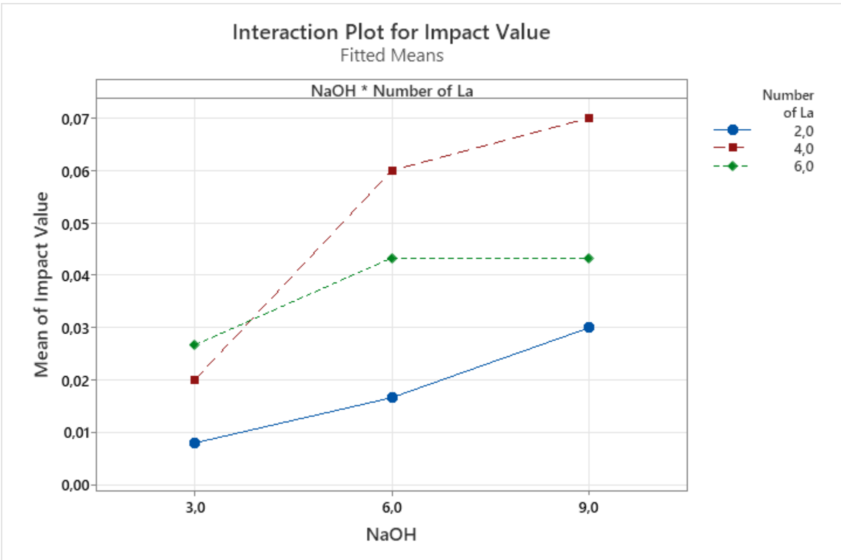

Figure 8. Interaction Plot for Impact Value

The "Impact Value versus NaOH" chart shows how NaOH concentration (3%, 6%, 9%) and fiber layer count (2, 4, 6 layers) affect the composite's mean impact value. In all configurations, the impact value increases from 3% to 6% NaOH, then decreases at 9%, indicating that 6% is the optimal concentration for improving interfacial bonding. Beyond this, excessive treatment may degrade fiber surfaces, weakening the matrix bond.

In the 2-layer setup, the trend is most pronounced: impact value rises from 0.016 at 3% to 0.054 at 6%, then drops to 0.037 at 9%, showing high sensitivity to treatment due to minimal reinforcement. The 4-layer setup also follows this trend but with milder changes (0.019 to 0.050 to 0.043), suggesting added layers help stabilize performance. The 6-layer configuration shows the smoothest curve (0.019 to 0.046 to 0.040), indicating consistent behavior and a balance between strength and stability.

6% NaOH consistently provides the highest impact values, marking it as the most effective treatment. Fewer layers are more reactive to chemical changes, while more layers offer greater mechanical stability.

5. Conclusion

From the study "The Effect of the Number of Fiber Sheets and NaOH Concentration on the Impact Strength of Alkali-Treated Arthocarpus Elasticus Peeled Fiber Composites," it can be concluded that.

1. The number of fiber layers significantly influences the impact strength of *Artocarpus elasticus* bark fiber composites. Among the tested configurations, 4 fiber layers the highest average impact value, suggesting that this configuration provides an optimal balance between reinforcement and matrix bonding. this study confirms that increasing the number of layers does not always enhance impact resistance. Using 2, 4, and 6 layers helps maintain an optimal balance between mechanical strength and energy absorption without introducing structural weaknesses from over-layering.
2. the NaOH concentration is a critical factor affecting impact performance. the effect of alkali treatment is statistically proven to enhance fiber matrix adhesion, especially when the concentration increases from 3% to 6%. However, a decline in impact strength is observed at 9%, likely due to fiber surface degradation caused by excessive chemical treatment. This identifies 6% NaOH as the optimal concentration for improving interfacial bonding without damaging the fibers.
3. The results indicate a significant interaction between NaOH concentration and the number of layers, as shown by the interaction term's P-value of 0.005, which is below the significance threshold. This confirms that there *is* an interaction effect—meaning the influence of one factor depends on the level of the other. Therefore, both individual and combined effects should be considered when optimizing the material's performance.

6. Acknowledgement

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