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# Effect Alkali Immerse Duration and Fiber Weight Fraction of Artocarpus Elasticus Bark Fiber Composites on Impact Strength for Mudguard Material

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***Abstract****. Composite materials are produced by combining two or more different materials, to achieve mechanical properties superior to those of the individual components. One example of a natural fiber-based composite is the composite made from the skin fiber of the lantung wood (Artocarpus elasticus). This study aims to analyze the effect of alkali immerse durations (60 minutes, 90 minutes, and 120 minutes) and fiber weight fractions (5%, 10%, and 15%) on the impact strength of the composite, using lantung wood bark fibers as the control due to their inherent mechanical strength. The experiment was conducted by varying the independent variables, such as alkali immerse duration and fiber weight fraction, and dependent variables including fiber orientation and NaOH concentration (horizontal orientation, 10%). The research method used in this research is design of experimental (DOE) method. Impact testing was performed using a Charpy impact tester, and the resulting data were analyzed quantitatively to evaluate the relationships among the variables. Although the benefits of natural fibers are well-known, there is still a lack of empirical data regarding the effects of alkali immerse duration and fiber weight fraction on the impact strength of the composites. The study purpose is to fill this gap by systematically analyzing the effects of alkali immerse duration and fiber weight fraction on the mechanical performance of lantung wood bark fiber-based composites. The research result show that a 120-minute immerse duration yields an impact value of 0.029 J/mm², while a 10% fiber weight fraction results in an impact value of 0.033 J/mm². The research contributes to the optimization of fabrication parameters, particularly in the automotive sector, such as in the production of lightweight components like rear wheel mudguard for motorcycles.*

**Keywords:** *Composite, Fiber weight fraction, Immerse duration, Impact test, Lantung bark fiber wood.*

## 1. INTRODUCTION

The increasing demand for engineering materials is driven by quick global industrialization, creating a growing challenge: the widening gap between material supply and rising consumption. To overcome this, researchers are focusing on alternative materials that are both abundant and environmentally friendly. Among the promising solutions are natural fiber composites, which are biodegradable, renewable, and competitive with synthetic counterparts (Karunakar et al., 2023). These composites offer a sustainable path forward, replacing non-renewable materials like metals, ceramics, and conventional plastics such as polypropylene (PP). These natural composites offer several advantages, including biodegradability, renewability, corrosion resistance, and effective thermal insulation, while also supporting cleaner production and material innovation (Dantes et al., 2023). In order to

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achieve greater mechanical properties than the individual components, composites are materials made by combining two or more materials with different qualities (Dantes et al., 2023). Biodegradability, corrosion resistance, thermal insulation, and advantageous mechanical qualities make natural fiber-reinforced composites very appealing. The bark of *Artocarpus elasticus*, sometimes referred to as lantung wood, which is widely distributed across Southeast Asia, especially on Sumatra and Kalimantan, is the source of one such understudied fiber. This plant, known locally as Mengko, Torop, Terap, and Taeng, has been utilized traditionally in crafts and textiles but has not been well studied for structural uses (Hestiawan et al., 2022).

Lantung wood is a part of the *Moraceae* family and rich in cellulose, a critical component that contributes to strength, stiffness, and dimensional stability in fiber-reinforced composites. However, the presence of lignin and hemicellulose can block fiber-matrix bonding, reducing overall mechanical performance. To improve compatibility with the polymer matrix, alkali treatment using sodium hydroxide (NaOH) is commonly applied. This process removes non-cellulosic content, increases surface roughness, and enhances adhesion by exposing more hydroxyl groups on the fiber surface (Iqbal & Sugiman, 2024).

Factors like fiber orientation and treatment length also affect the final composite's mechanical performance. Both of these factors have a major impact on the strength and integrity of composites manufactured from lantung bark fibers, according to Syarief and Sumantri (2022). However, uniformity and performance prediction are hampered by variation in fiber qualities, which are brought on by basic differences in chemical composition. Lantung wood bark fiber makes a strong case for advancement as a composite reinforcing material due to its high cellulose content and sustainable origin. Its mechanical performance in these applications has, however, been the subject of few scientific investigations. This work intends to close the research gap regarding to lantung wood fiber and responds to the urgent demand for biodegradable substitutes for synthetic composites. Additionally, it evaluates the impact strength of epoxy composites supplemented with lantung bark fiber, looking at the effects of fiber weight fraction and alkali treatment period. The results may encourage the use of lantung-based composites in real-world applications where flexibility, durability, and impact resistance are crucial, such as motorcycle mudguards (Agung et al., 2020).

This research specifically explores how alkali immersion duration and fiber weight fraction affect the impact strength of *Artocarpus elasticus* bark fiber composites. The experimental setup involves immersing fibers in a 10% NaOH solution for three different durations: 60, 90, and 120 minutes. The fibers are then integrated into an epoxy matrix at weight fractions of 5%, 10%, and 15%. The composites are fabricated using the hand lay-up method, followed by impact testing using a Charpy-type test setup based on a modified ASTM D6110 standard. A 3D-printed mold is used to shape the specimens. Only the immerse duration and fiber weight fraction are considered as variables, while other factors such as resin type, curing agent, and chemical additives are kept default. The objective of this study is to analyze the effects of immersion duration and fiber weight fraction on the impact strength of the composite. Additionally, the study purpose is to determine whether there is a significant interaction between these two parameters that influences the mechanical properties of the material. The results also aim to contribute to the broader field of sustainable materials research by offering new insights into the performance of *lantung* wood bark fibers as reinforcement in natural polymer composites.

## 2. LITERATURE REVIEW

Research on *lantung* wood (*Artocarpus elasticus*) bark fiber composites is relatively limited, though foundational studies have begun to explore its potential. A review of prior investigations shows that alkali treatment duration and fiber weight fraction significantly influence mechanical properties such as tensile strength, impact resistance, and bonding between fiber and matrix. These themes are consistent with findings from studies on other natural fibers like bamboo, jute, and banana. The current study builds upon these foundations by using a modified ASTM D6110 impact testing method to evaluate epoxy-based composites reinforced with alkali-treated *lantung* fiber, particularly for their suitability in automotive components such as motorcycle mudguards.

***Figure 1. Lantung Wood Fiber Bark***

One of the key parameters affecting composite performance is alkali immersion duration. Dantes et al. (2023) investigated the effect of alkali treatment on bamboo fiber-reinforced polyester composites. Their results showed that impact strength improved with NaOH treatment up to two hours, but declined with longer durations. This suggests that overexposure may degrade fiber integrity. Similarly, Gapsari et al. (2024) and Yudiono et al. (2024) highlighted that sodium hydroxide treatment enhances fiber-matrix bonding by removing surface impurities and increasing roughness, which improves interfacial adhesion. These improvements, however, depend on the optimal balance between treatment time and chemical concentration.

Natural fiber composites in general have gained increasing attention due to their reduced environmental impact. The shift toward sustainable materials has prompted substantial research into biodegradable alternatives. Gholampour and Ozbakkaloglu (2019) emphasized that although natural fibers reduce greenhouse gas emissions and carbon footprints, they also introduce drawbacks such as high moisture absorption and poor matrix compatibility. Nonetheless, chemical surface modifications, such as alkali treatment, have shown promise in mitigating these issues.

The choice of matrix material also plays a vital role in composite performance. Epoxy resins are widely used due to their superior mechanical strength and durability compared to other polymers. Jeyapragash et al. (2020) noted that epoxy offers excellent moisture barrier properties and serves effectively as a laminating agent in polymer composites. The addition of a hardener initiates the polymerization process, transforming the liquid resin into a durable solid with enhanced mechanical and chemical resistance.

Sodium hydroxide treatment is one of the most common methods for improving the physicomechanical properties of natural fibers. Chin et al. (2019) demonstrated that bamboo fibers soaked in 10% NaOH for 48 hours exhibited improved tensile strength, increased thermal stability, and a higher crystallinity index. The alkali treatment improved fiber-matrix compatibility by enhancing the fiber surface area and roughness, resulting in stronger composites.

Another crucial factor in composite design is the fiber weight fraction. Sang et al. (2019) reported that increasing fiber content up to a certain point enhances mechanical performance, such as young modulus, but also reduces ductility. Their study on KH550-treated basalt fiber-reinforced PLA composites found optimal mechanical properties at around 20% fiber content, indicating that fiber loading must be carefully optimized for strength without sacrificing flexibility.

Impact strength testing is a key measure of a composite’s toughness and durability. Lucio et al. (2018) found that Charpy impact energy increased with the volume fraction of untreated mallow fibers. Interestingly, they observed that surface treatment in some cases did not yield better performance, suggesting that the effectiveness of treatment methods may vary based on fiber type and matrix compatibility. Their findings reinforce the importance of customizing treatment protocols for each composite system.

Specific to *lantung* bark fiber, Siagian et al. (2024) confirmed its competitive tensile properties relative to well-established natural fibers such as jute and pineapple. Alkali treatment improves surface roughness, aiding mechanical interlocking with the matrix. Chand et al. (2021) further emphasized that *lantung*’s lightweight and eco-friendly characteristics make it suitable for use in automotive and construction composites. However, optimal treatment conditions—such as duration, temperature, and concentration—must be controlled to preserve the fiber’s structural integrity.

*Lantung* wood is characterized by its medium to coarse texture, interlocked grain, and density ranging from 0.55 to 0.75 g/cm³. It exhibits high bending strength, moderate compressive strength, and notable shock resistance, along with good durability against water and insect damage due to natural oils. This makes it particularly attractive for composite applications where resilience and water resistance are critical. The bark fiber, specifically, is smooth, soft, pliable, and washable, with common sheet dimensions of approximately one square meter. Supriyanto et al. (2019) and Senthilraja et al. (2022) documented the fiber’s tensile strength at 257 MPa, break-up strain at 3.54%, and cellulose content at 60.45%, indicating its promising mechanical profile. The crystallinity index of 52.2% and thermal stability up to 228°C further affirm its viability as a reinforcement in lightweight composites.

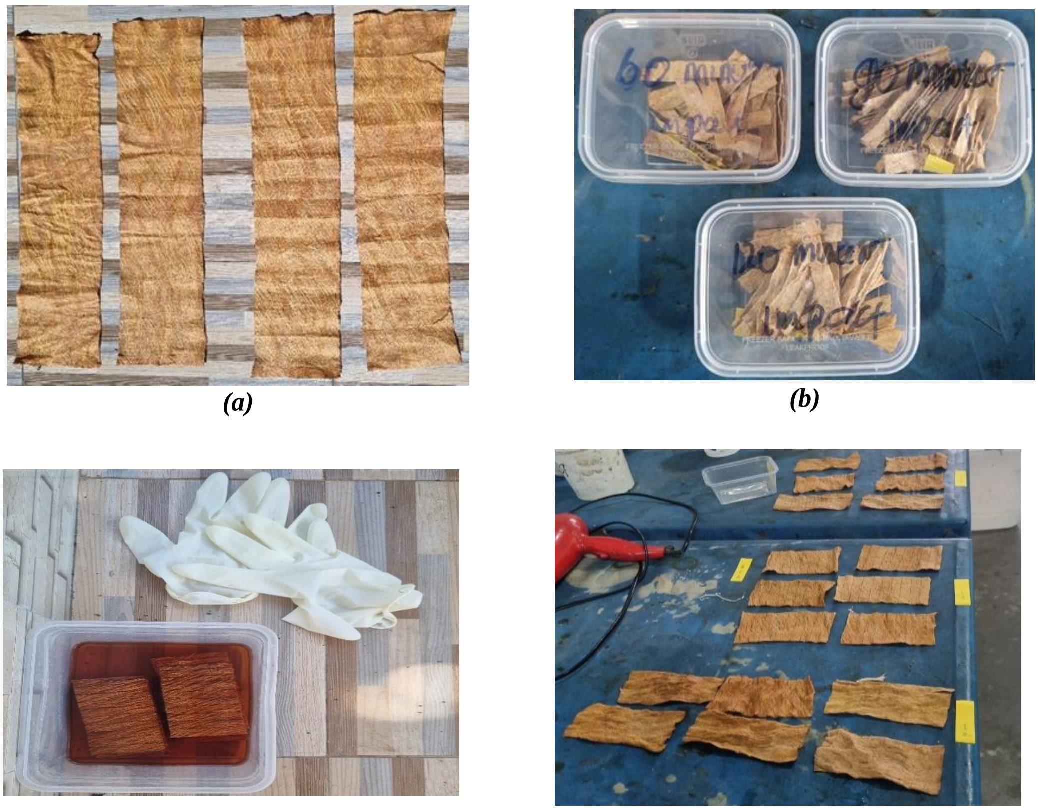
Based on this body of research, the present study hypothesizes that both alkali immersion duration and fiber weight fraction will significantly influence the impact strength of *Artocarpus elasticus* bark fiber composites. The null hypothesis states that neither parameter, nor their interaction, will have a statistically significant effect. The alternative hypothesis asserts that both variables, independently and interactively, affect impact strength. Through experimental testing and data analysis, this study seeks to validate these hypotheses and contribute new insights to the evolving field of natural fiber composites.

## 3. METHODS

This research employed a **Design of Experiments (DOE)** approach to investigate the effects of alkali immersion duration and fiber weight fraction on the impact strength of *Artocarpus elasticus* bark fiber-reinforced composites. The quantitative method allows for statistical analysis of the causal relationship between the independent variables (fiber treatment parameters) and the resulting mechanical properties of the composite.

The experimental workflow included specimen preparation, composite fabrication, mechanical testing, and data analysis, structured to ensure consistency and reproducibility.

The fabrication process began with the collection and preparation of raw materials. *Artocarpus elasticus* bark fibers were cleaned and cut into specified dimensions before being immersed in a 10% NaOH solution for three different durations—60, 90, and 120 minutes—to improve their surface morphology and enhance fiber–matrix adhesion. After treatment, the fibers were washed, dried, and cut further based on calculated fiber weight fractions of 5%, 10%, and 15%. The resin used was a standard epoxy resin with a 2:1 ratio of epoxy to hardener, selected for its superior mechanical and bonding properties.



***(a)*** ***(b)***

***(c)*** ***(d)***

***Figure 2. Lantung Wood Fiber Bark (a) before cutting and (b) after cutting and sorting before immersed in NaOH, (c) Wood bark being immersed in NaOH 10% solution and (d) lantung wood bark fiber drying process***

The hand lay-up method was used for composite fabrication. Wax-coated 3D-printed molds were prepared and filled with the alkali-treated fibers and resin mixture. The composite layers were compressed using C-clamps and allowed to cure at room temperature for 24 to 48 hours. Once cured, the specimens were de-mold and cut to standard dimensions as per the modified ASTM D6110 test requirements.

Impact testing was performed using a Charpy impact test machine. The pendulum hammer was calibrated following ASTM D6110 procedures to ensure accurate and repeatable measurements. Each specimen was notched using a band saw and mounted with the notch facing the impact direction. The pendulum was released from a 90° angle, and the final swing angle was recorded to calculate the absorbed impact energy using gravitational potential energy formulas. The impact strength was determined by dividing the absorbed energy by the cross-sectional area of the specimen.

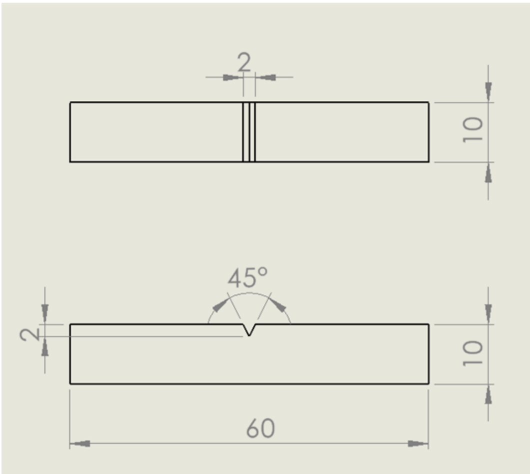



***Figure 3 Modified ASTM D6110 standard (mm)***

Experimental data were collected across 45 test samples, representing all combinations of three immersion durations and three fiber weight fractions, each with five repetitions. The fiber and resin mass for each configuration were calculated based on composite volume and material densities, ensuring precise control over specimen composition.

**Table 1. Fiber Weight Fraction and Resin Mixture Sampling with 5 Times Replication**

| Test | Fiber weight fractions (%) | Immerse time (minute) | Empty media (glass in gr) | Fiber mass (gr) | Resin mass total (gr) | Epoxy (gr) | Hardener (gr) | Replication (x5) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 60 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 2 | 5 | 60 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 3 | 5 | 60 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 4 | 5 | 60 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 5 | 5 | 60 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 6 | 5 | 90 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |

**Table 1. Fiber Weight Fraction and Resin Mixture Sampling with 5 Times Replication**

| Test | Fiber weight fractions (%) | Immerse time (minute) | Empty media (glass in gr) | Fiber mass (gr) | Resin mass total (gr) | Epoxy (gr) | Hardener (gr) | Replication (x5) |
|---|---|---|---|---|---|---|---|---|
| 7 | 5 | 90 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 8 | 5 | 90 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 9 | 5 | 90 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 10 | 5 | 90 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 11 | 5 | 120 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 12 | 5 | 120 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 13 | 5 | 120 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 14 | 5 | 120 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 15 | 5 | 120 | 2.3 | 0.225 | 6.84 | 4.56 | 2.28 | 22.8 + 11.4 |
| 16 | 10 | 60 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 17 | 10 | 60 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 18 | 10 | 60 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 19 | 10 | 60 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 20 | 10 | 60 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 21 | 10 | 90 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 22 | 10 | 90 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 23 | 10 | 90 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 24 | 10 | 90 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 25 | 10 | 90 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 26 | 10 | 120 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 27 | 10 | 120 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 28 | 10 | 120 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 29 | 10 | 120 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 30 | 10 | 120 | 2.3 | 0.45 | 6.48 | 4.32 | 2.16 | 21.6 + 10.8 |
| 31 | 15 | 60 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 32 | 15 | 60 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 33 | 15 | 60 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 34 | 15 | 60 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 35 | 15 | 60 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 36 | 15 | 90 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 37 | 15 | 90 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 38 | 15 | 90 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 39 | 15 | 90 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 40 | 15 | 90 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 41 | 15 | 120 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 42 | 15 | 120 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 43 | 15 | 120 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 44 | 15 | 120 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |
| 45 | 15 | 120 | 2.3 | 0.675 | 6.12 | 4.08 | 2.04 | 20.4 + 10.2 |

The collected data gone through a normality test to ensure it is meet the statistical assumptions. A factorial analysis was then used to evaluate the significance of the main effects and interaction between immersion time and fiber weight on the impact strength. Graphical outputs such as interaction plots, bar graphs, and residual charts were used to visualize the results. To ensure reliability, a standard deviation threshold of ≤5% was applied to the dataset.

The hypothesis guiding this research posits that longer immersion durations and moderate fiber content, particularly in 120 minutes and 10% by weight will yield optimal mechanical performance due to improved fiber–matrix bonding and increased energy absorption.

## 4. RESULTS

This study analyzed the impact strength of *Artocarpus elasticus* bark fiber-reinforced epoxy composites based on two independent variables: alkali immersion duration (60, 90, and 120 minutes) and fiber weight fraction (5%, 10%, and 15%). A total of 45 specimens were tested using the Charpy impact test, with five replications per variable configuration. Impact energy was calculated using pendulum mechanics, and impact strength was derived by dividing energy by the cross-sectional area of the specimen (100 mm²).

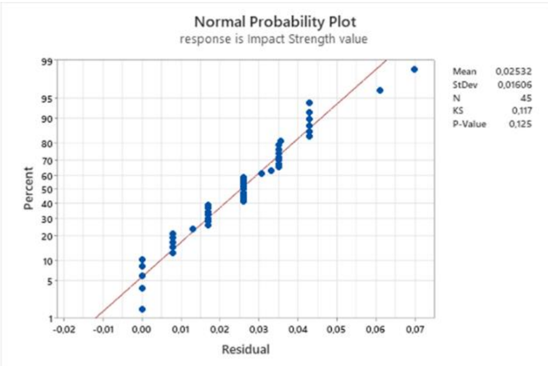
The recorded impact energy ranged from 0.00 to 7.02 J across all samples. The highest single recorded impact strength was 0.070 J/mm², observed in the 120-minute immersion, 10% fiber fraction group. Raw data were processed into mean impact strength values for each test group. Table 2 below presents the average impact strength values across all test conditions.

**Table 2. Average Impact Strength Values (J/mm²)**

| Alkali Immerse Duration | Weight | Impact Strength (J/mm²) | | | | | Average |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 60 minutes | 5% | 0.017 | 0.000 | 0.008 | 0.000 | 0.013 | 0.008 |
| | 10% | 0.025 | 0.026 | 0.030 | 0.033 | 0.036 | 0.030 |
| | 15% | 0.026 | 0.043 | 0.000 | 0.017 | 0.043 | 0.026 |
| 90 minutes | 5% | 0.017 | 0.026 | 0.026 | 0.035 | 0.017 | 0.024 |
| | 10% | 0.043 | 0.026 | 0.043 | 0.026 | 0.033 | 0.034 |
| | 15% | 0.000 | 0.008 | 0.026 | 0.008 | 0.026 | 0.014 |
| 120 minutes | 5% | 0.000 | 0.017 | 0.035 | 0.043 | 0.026 | 0.024 |
| | 10% | 0.061 | 0.061 | 0.035 | 0.008 | 0.008 | 0.035 |
| | 15% | 0.035 | 0.061 | 0.017 | 0.043 | 0.008 | 0.033 |

A visual test was also conducted to assess physical failure characteristics such as matrix cracking, fiber pull-out, and surface quality. Brittle fractures and uneven fiber dispersion were commonly noted in composites with low fiber content or short immersion durations.

The normality of the data was verified using a normal probability plot, indicating that the residuals were normally distributed and suitable for further analysis. The ANOVA results revealed that immersion duration did not have a statistically significant effect on impact strength (P = 0.469), while fiber weight fraction did (P = 0.033). The interaction between the two variables was not statistically significant. The coefficient of determination ($R^2$) for the ANOVA model was 31.34%, suggesting that the combination of immersion time and fiber weight fraction explained a moderate portion of the variation in impact strength.




**Analysis of Variance**

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Duration | 2 | 0,000334 | 0,000167 | 0,77 | 0,469 |
| Weight | 2 | 0,001628 | 0,000814 | 3,76 | 0,033 |
| Duration*Weight | 4 | 0,001592 | 0,000398 | 1,84 | 0,143 |
| Error | 36 | 0,007789 | 0,000216 | | |
| Total | 44 | 0,011345 | | | |

**Model Summary**

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 0,0147094 | 31,34% | 16,08% | 0,00% |

***(a)*** ***(b)***

***Figure 4. (a) Normal Probability Plot and (b) Analysis of Variance Model Summary***

Main effects plots and interaction plots were generated to visualize trends in the data. These plots indicated that both increased fiber content and longer immersion durations generally corresponded to higher impact strength values, although saturation and decline were observed at the highest levels.

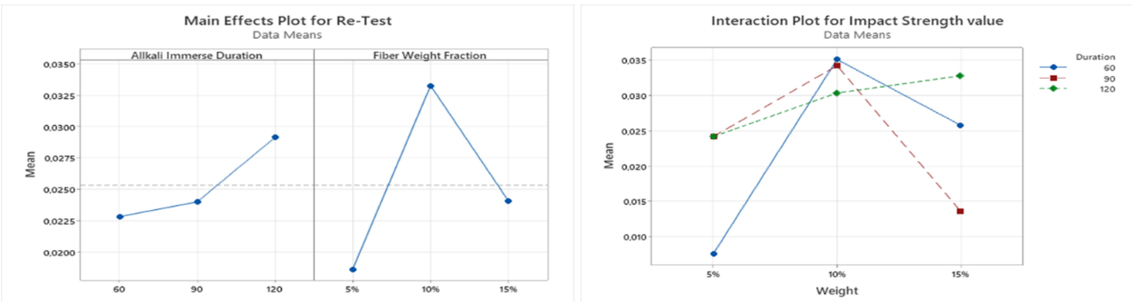



***Figure 5. Main Effects Plot and Interaction Plot of Impact Strength by Alkali Immerse Duration and Fiber Weight***

Finally, a response optimizer function was used to predict the ideal configuration. The model predicted an optimal fiber weight fraction of 10% and an immersion duration of 120 minutes, resulting in a projected impact strength of approximately 0.0346 J/mm² with a desirability index of 0.5672.

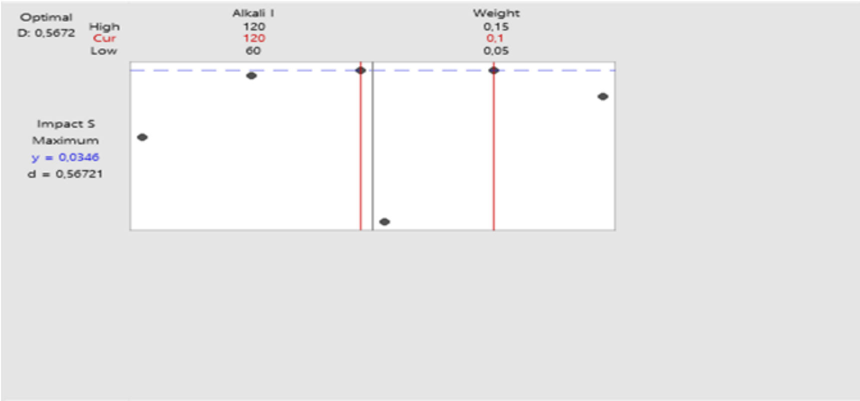



***Figure 6. Response Optimizer Graph for Optimal Result***

## 5. DISCUSSION

This study aimed to investigate the effect of alkali immersion duration and fiber weight fraction on the impact strength of *Artocarpus elasticus* (*lantung*) bark fiber-reinforced epoxy composites. The research was motivated by the need for biodegradable composite materials with improved mechanical performance, and it sought to determine the optimal conditions for fiber treatment and reinforcement that would enhance impact resistance. The main contribution of this study lies in offering insight into the structural behavior of underutilized *lantung* bark fiber in polymer composites, particularly for lightweight applications such as automotive components.

The findings revealed that fiber weight fraction had a statistically significant effect on impact strength, while alkali immersion duration alone did not show significant influence at the 5% significance level. However, practical trends indicated that longer immersion durations generally contributed to improved composite performance, suggesting that chemical treatment does play a supportive role in enhancing fiber–matrix bonding. The highest average impact strength was achieved at 10% fiber content with 120 minutes of immersion, highlighting this configuration as the most consisten.

These results partially confirm the research hypotheses. The hypothesis stating that fiber weight fraction significantly affects impact strength is supported, while the hypothesis regarding the effect of immersion duration is not statistically validated, though observed trends suggest a positive role. The lack of a significant interaction between the two variables suggests that their effects on the composite's mechanical performance operate independently within the tested range.

When compared to previous research, these results align with studies by Gapsari et al. (2024) and Dantes et al. (2023), which showed that moderate alkali treatment improved fiber–matrix adhesion and overall mechanical strength. However, excessive treatment or higher fiber fractions may result in brittleness, fiber agglomeration, or processing defects, which reduce impact performance. Similar findings by Sang (2019) regarding optimal fiber loading confirm that an intermediate reinforcement level (10–15%) often yields the best balance between strength and structural integrity. On the other hand, the statistically insignificant effect of immersion time differs from earlier reports, such as Yudiono et al. (2024), which demonstrated significant improvements in impact resistance with prolonged alkali treatment. This mismatch may be attributed to the specific behavior of *lantung* bark fiber, which could have unique chemical or morphological characteristics that moderate the effects of alkali exposure.

One explanation for the observed inconsistencies in performance, especially at 5% and 15% fiber content, could be related to fiber distribution and resin saturation. At low fiber content, insufficient reinforcement limits the ability to absorb and dissipate impact energy. At higher content, poor dispersion, void formation, and uneven curing may introduce structural weaknesses. Visual inspection confirmed the presence of fiber pull-out, brittle fracture, and matrix cracking, especially in configurations with inadequate bonding or process-induced flaws.

From an applied engineering perspective, the findings suggest that a 10% fiber weight fraction combined with a 120-minute NaOH treatment offers the best potential for practical use in impact-loaded components such as motorcycle mudguards. This configuration offers a balanced combination of strength, resilience, and manufacturability, aligning with goals of sustainability and performance.

Nevertheless, the study is not without limitations. Variability in composite molding due to manual hand lay-up fabrication may have influenced consistency, especially in fiber dispersion and curing uniformity. Mold leakage and manual cutting may also have affected specimen integrity. Additionally, only one alkali concentration (10% NaOH) was used, which may have limited the ability to identify optimal chemical treatment conditions. These factors can influence both the internal validity of the results and their generalizability to other applications or materials.

Future research should explore a broader range of chemical treatment conditions, including varying NaOH concentrations and treatment temperatures. Investigating other mechanical properties such as tensile strength, flexural behavior, and fatigue performance would offer a more comprehensive understanding of the material's capabilities. Moreover, comparative studies with other natural fibers could clarify whether the observed behavior is unique to *lantung* bark or part of a broader trend among tropical hardwood fibers.

In conclusion, this study supports the use of *Artocarpus elasticus* bark fiber as a viable reinforcement for impact-resistant bio-composites. While only fiber weight fraction showed statistical significance, immersion duration contributed meaningfully to performance trends, emphasizing the need for balanced optimization. These findings contribute to the broader field of sustainable materials engineering by introducing a novel, regionally abundant fiber and defining its potential in structural applications.

## 6. CONCLUSION

This study evaluated the effects of alkali immersion duration and fiber weight fraction on the impact strength of *Artocarpus elasticus* bark fiber-reinforced epoxy composites for potential use in motorcycle mudguards.

The results showed that **alkali immersion duration alone had no statistically significant effect** on impact strength, though the 120-minute treatment yielded the highest average performance. In contrast, **fiber weight fraction had a significant influence**, with **10% fiber content producing the best mechanical results**, balancing reinforcement and matrix saturation effectively.

While no significant interaction was found between the two variables, their combination particularly **120 minutes of immersion with 10% fiber content** consistently resulted in the highest impact strength. This highlights the need for careful optimization of both treatment time and fiber content to achieve ideal composite performance.

Limitations include fabrication inconsistencies due to manual lay-up, mold leakage from 3D-printed molds, and a narrow treatment scope (single alkali concentration and ambient curing). These factors may affect the generalizability and reproducibility of the findings. Nonetheless, the study establishes a foundational understanding of *lantung* bark fiber's potential as a sustainable composite reinforcement.

## LIMITATION

While this study provides valuable insight into the mechanical performance of alkali-treated *Artocarpus elasticus* bark fiber composites, several limitations should be acknowledged, as they may affect the validity and generalizability of the findings.

First, the use of a 3D-printed mold introduced issues such as resin leakage and air entrapment, which may have influenced the consistency and surface quality of the composite specimens. These imperfections could have created internal voids or stress concentrators, potentially reducing the measured impact strength values. A more solid mold material, such as acrylic or metal, might have mitigated these issues and improved specimen uniformity.

Second, the fabrication method for manual hand lay-up relied heavily on operator precision. This approach often leads to variations in fiber alignment, resin saturation, and layer consistency, all of which can cause discrepancies in mechanical performance. Automated or controlled molding methods would reduce this variability and enhance reproducibility.

Third, the study employed only a single concentration of NaOH (10%) for alkali treatment. While sufficient to explore general trends, this restricts the ability to fully evaluate the effect of chemical concentration on fiber–matrix bonding. Varying the concentration could reveal optimal treatment parameters and better isolate its influence.

Additionally, the impact testing followed a modified version of ASTM D6110 using a Charpy-type setup. While this method was consistent across tests, the lack of instrumentation for real-time load data limited the analysis to post-impact energy calculations, potentially overlooking detailed fracture behavior or damage evolution.

Finally, external variables such as ambient temperature and humidity during curing were not closely controlled. These environmental factors may have introduced additional variability in matrix hardening and fiber adhesion, subtly affecting test results.

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