



The Effect of Coconut Fiber Soaking in Alkaline Solution on The Tensile Strength of Composites

Danny Arisetya Saputra*, Akhmad Basuki Widodo, Ali Azhar, Intan Baroroh, Tri Agung Kristiyono
Faculty of Engineering and Marine Science. Hang Tuah University, Indonesia

*dannybloom81@gmail.com

Abstract

Over time, the world's composite materials industry is increasingly developing. Generally, fiberglass-reinforced composite materials are developed. However, fiberglass fibers are expensive and not environmentally friendly. The aim of this research was to determine the effect of composites reinforced with coconut fibers soaked in alkali. Specimen making using coconut fiber reinforcement that is pre-soaked using an alkaline chemical compound (Na) with a concentration of 5%. This study carried out tensile testing with variations of coconut fiber and soaked it in alkaline chemical compounds for 1-4 days. The measurement of the tensile strength value in the composite refers to the ASTM D638-02 standard and the tensile strength value will be analyzed using the ANOVA method to determine the significant effect on the soaking treatment of NaOH. The results of the tensile strength test in this study are far from the standard results that have been set by the Indonesian Classification Bureau (BKI) in 2021. So, coconut fiber with alkaline soaking for 1-4 days cannot be used as a substitute for fiberglass as a composite material reinforcement to be applied as the main material of the ship.

Keywords: Coconut fiber, Composite material, Tensile test, Alkaline compounds

1. INTRODUCTION

With time, the development of the composite materials industry worldwide is increasing. Generally, composite reinforcement research uses fiberglass fibers. The disadvantages of fiberglass fibers are that they are expensive, not environmentally friendly, produce CO₂ (Carbon dioxide) gas and dust, which is not good for human health if recycled. As mentioned by Dwijana & Astika (2014), the increasing development of technology allows composites to be designed in such a way as to suit the desired material characteristics so that they can be made stronger, lighter and stiffer [2]. Natural fibers are found in many countries around the world, such as Indonesia, and are also widely used in manufacturing textiles, automotives, and composite materials. Natural fibers also have many advantages, including low density, low price, abundance in many countries, and strength. High specificity, modulus, low emissions, and recyclability.

Composite materials are a group of materials composed of two or more materials combined into one material on a microscopic scale that can form useful products. Another definition of composite materials, as quoted by Groover (1986), states that composite materials are combinations of two or more different materials. This research aims to raise the profile of natural fibers and increase their value to consumers, thereby helping increase their income [3]. Researchers have studied various types of fibers, such as bamboo fibers and glass fibers. One of the natural fibers that has the potential to be further developed as a composite material reinforcement is coconut fiber.

Coconut has many benefits, starting from its fiber, which is used as a material for car seats; the fruit that can be consumed by people; coconut water that helps neutralize toxins in the human body; and the coconut shell, which is used to make briquettes. One coconut can also produce 0.4 kg of coconut fiber containing 30% of fiber. The chemical properties of coconut fiber produce lignin, gas, tar, tannins, potassium, pyroligneous acid, and cellulose [4].

Alkali is abundant in nature and can be naturally produced. The production of alkali metals through electrolysis is performed by decomposing an electrolyte with an electric current flow. During electrolysis, the



copyright is published under [Lisensi Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).

electrical energy is converted into chemical energy. Different reactions occur at the anode (positive electrode) and the cathode (negative electrode). Oxidation occurred at the anode, whereas reduction occurs at the cathode. During electrolysis, electrons flow from the cathode to the anode. The term "alkali compound" refers to the ionic base salts of alkali metals or alkaline earth metals. An alkali can also be defined as a base that dissolves in water. In general, soluble bases have a pH greater than 7.0, indicating that alkalis have a pH above 7. The word "alkali" originates from the Arabic term *al qalīy*, which means "calcined ash" or "heated ash." Alkali is produced by burning the aqueous extract of plant ash called potassium. Potassium mainly consists of potassium carbonate, which has mildly basic properties. When heated with potassium hydroxide, a much stronger base, known as caustic potassium or potassium hydroxide, is produced. Potassium hydroxide is commonly used with animal fats to produce soap, which is an example of a free alkali.

Resin is a material that can be a solid or viscous liquid of plant or synthetic origin. Resins are commonly used for various purposes, such as coatings, adhesives, product raw materials, and others. Resins could change from liquid to solid and homogeneous form, which makes them versatile in various applications. The origin of resins comes from plants, especially trees (conifers), which secrete sap to protect themselves from injury or infection. Synthetic resins are also made from chemicals, mimicking the properties of natural resins. Resins generally have characteristics such as easy to harden, clear, shiny, flammable, and can melt. There are various types of resins including epoxy resin, vinyl ester resin, polyester resin, acrylic resin. In this research, the author uses a type of polyester resin that is strong and durable so it can be used for boat building. Catalysts are also a mixture of resins to become materials or objects. A catalyst is a substance that accelerates the rate of a chemical reaction without reacting or permanently changing the reaction. In everyday language, a catalyst can also be interpreted as something that triggers change or accelerates a process. Catalysts have properties, namely not participating in chemical reactions, accelerating the reaction rate, not changing the position of equilibrium, the amount needed is small, specific, can be poisoned, and has certain stability.

2. METHODS

This research method is conducted using an experimental research approach.

- The first step before starting this research was to conduct a literature review to strengthen the applicable theory.
- The second step in conducting this research was to prepare tools and materials to support the process.
- The third step was the process of creating the laminated composite specimens, which was performed using the alkali soaking method. The coconut fiber composite specimens were first soaked in alkali and then mixed with a polyester resin. There are 12 specimens with variations in the duration of coconut fiber soaking in alkali: 1 day soaking and direct molding, 1 day soaking followed by 1 day of drying and direct molding, 2 days soaking and direct molding, and 2 days soaking followed by 1 day of drying and direct molding, 3 day soaking and direct molding, 3 day soaking followed by 1 day of drying and direct molding, 4 day soaking and direct molding, 4 day soaking followed by 1 day of drying and direct molding.
- The next step was the tensile testing, conducted according to the ASTM D638-02 standard, to determine the tensile strength of each specimen.
- The next step is to analyze the test results using the ANOVA method.
- After analyzing, the next step is to draw conclusions for this research.

3. RESULTS AND DISCUSSION

This research was conducted by experimenting with coconut fibers and alkali compounds. From the tensile test, data were obtained to determine the tensile strength of the coconut fiber composite material, which was soaked in an alkali solution for different durations: one day, two days, three days, and four days, to assess the quality of the composite material specimen. In this test, there were eight variations.

- The first variation is soaking the coconut fiber in an alkali solution for one day and then directly cast or making it into a test specimen.



- The second variation involved soaking the coconut fiber in an alkali solution for 1 day, drying it in a closed room for 1 day, and then casting or making it into a test specimen.
- The third variation is soaking the coconut fiber in an alkali solution for two days and then directly cast or making it into a test specimen.
- The fourth variation involved soaking the coconut fiber in an alkali solution for 2 days, drying it in a closed room for 1 day, and then casting or making it into a test specimen.
- The fifth variation is soaking the coconut fiber in an alkali solution for three days and then directly casting or making it into a test specimen.
- The sixth variation involved soaking the coconut fiber in an alkali solution for 3 days, drying it in a closed room for 1 day, and then casting or making it into a test specimen.
- The seventh variation is soaking the coconut fiber in an alkali solution for four days and then directly cast or making it into a test specimen.
- The eighth variation involved soaking the coconut fiber in an alkali solution for 4 days, drying it in a closed room for 1 day, and then casting or making it into a test specimen.

The method tested in this study involves calculating the tensile strength, strain, and modulus of elasticity. The following are the calculations performed in this study:

Tensile Strength Value:

$$\sigma_{max} = \frac{P_{Max}}{A_0} \quad (1)$$

Table 1. Test results for the first variant

Varian pertama (A)				
No	Code Material	<i>Spesification sample</i>		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	A1	101,3	4,60	45,40
2	A2	101,1	3,90	38,57
3	A3	101,4	4,40	43,39
	Rata – Rata	101,2	4,30	42,45

Table 2. Ttest results for the second variant

Varian Kedua (B)				
No	Code Material	<i>Spesification sample</i>		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	B1	101,6	4,55	44,78
2	B2	101,4	4,40	43,39
3	B3	101,5	4,25	41,87
	Rata – Rata	101,5	4,40	43,34

Table 3. Test results for the third variant

Varian Ketiga (C)				
No	Code Material	<i>Spesification sample</i>		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	C1	101,2	4,50	44,46
2	C2	101,4	3,80	37,47
3	C3	101,3	3,95	38,99
	Rata – Rata	101,3	4,08	40,30

Table 4. Test results for the fourth variant

Varian Keempat (D)				
No	Code Material	<i>Spesification sample</i>		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	D1	101,3	4,30	42,44
2	D2	101,1	4,90	48,46
3	D3	101,1	3,55	35,11
	Rata – Rata	101,1	4,25	42,00



copyright is published under [Lisensi Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).

Table 5. Test results for the fifth variant

Varian Ketiga (E)				
No	Code Material	Spesification sample		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	E1	101,1	4,55	45,00
2	E2	101,3	4.80	37,38
3	E3	101,4	3.90	38,46
	Rata – Rata	101,2	4,41	40,28

Table 6. Test results for the sixth variant

Varian Ketiga (F)				
No	Code Material	Spesification sample		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	F1	101,2	4,30	42,49
2	F2	101,1	3.50	34,61
3	F3	101,4	3.75	36,98
	Rata – Rata	101,2	3,85	38,02

Table 7. Test Results for the Seventh Variant

Varian Ketiga (G)				
No	Code Material	Spesification sample		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	G1	101,4	5,50	54,24
2	G2	101,2	3.57	35,27
3	G3	101,3	3.45	34,05
	Rata – Rata	101,3	4,17	41,18

Table 8. Test Results for the Eighth Variant

Varian Ketiga (H)				
No	Code Material	Spesification sample		
		Ao (mm ²)	F. Ultimate (KN)	Ultimate stregh (N/mm ²)
1	H1	101,3	4,55	44,91
2	H2	101,1	4.45	44,01
3	H3	101,1	4.00	39,56
	Rata – Rata	101,2	4,33	42,82

From the table above, the average ultimate strength is used to create a graph to determine the best tensile strength value.

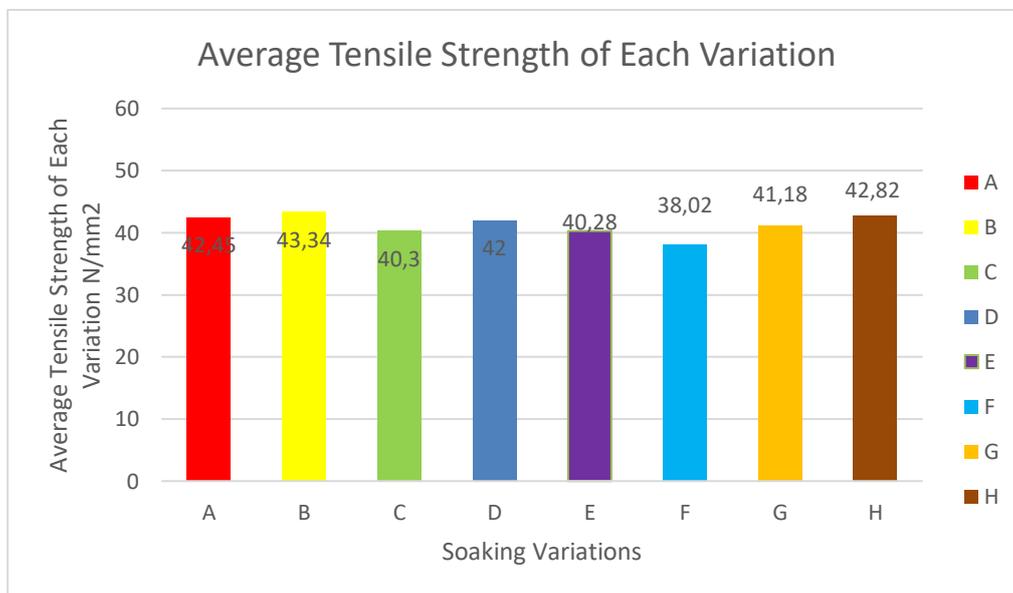


Figure 1. Diagram of average tensile strength for each variation.



copyright is published under [Lisensi Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).

From the graph above, it can be interpreted that the effect of alkali soaking for 1 day followed by drying for 1 day (B) results in a higher tensile strength compared to other variations, namely variations A, C, D, E, F, G, and H. Tensile test specimens with eight variations were evenly distributed during the composite manufacturing process, allowing the bonding between the coconut fiber and the matrix to form optimally. This directly enhances the tensile strength of the coconut fiber-reinforced composite soaked in an alkali solution.

Strain Value (Elongation):

$$\varepsilon = \frac{L_1 - L_0}{L_0} \times 100\%$$

(2)

Table 10. Elongation calculations

No.	Varian	Spesimen	L0(mm)	L1(mm)	ε (%)
1	1 Day Alkali Soaking, Direct Casting (A)	A1	150	151,4	0,93
		A2	150	151,2	0,80
		A3	150	151,7	1,13
		Rata-rata	150	151,4	0,95
2	1 Day Alkali Soaking, 1 Day Drying, Direct Casting (B))	B1	150	151,9	1,26
		B2	150	151,6	1,06
		B3	150	151,2	0,8
		Rata-rata	150	151,5	1,04
3	2 Day Alkali Soaking, Direct Casting (C)	C1	150	151,1	0,73
		C2	150	151,5	1,00
		C3	150	151,3	0,86
		Rata-rata	150	151,3	0,86
4	2 Day Alkali Soaking, 1 Day Drying, Direct Casting (D)	D1	150	151,3	0,86
		D2	150	151,5	1,00
		D3	150	151,3	0,86
		Rata-rata	150	151,3	0,90
5	3 Day Alkali Soaking, Direct Casting (E)	E1	150	151,1	0,73
		E2	150	151,8	1,2
		E3	150	151,5	1,00
		Rata-rata	150	151,4	0,97
6	3 Day Alkali Soaking, 1 Day Drying, Direct Casting (F)	F1	150	151,4	0,93
		F2	150	151,3	0,90
		F3	150	151,8	1,2
		Rata-rata	150	151,5	1,01
7	4 Day Alkali Soaking, Direct Casting (G)	G1	150	151,2	0,8
		G2	150	151,7	1,13
		G3	150	151,5	1,00
		Rata-rata	150	151,4	0,97
8	4 Day Alkali Soaking, 1 Day Drying, Direct Casting (H)	H1	150	151,4	0,93
		H2	150	151,2	0,8
		H3	150	151,7	1,13
		Rata-rata	150	151,4	0,95

From the table above, the average ultimate strength is used to create a graph to determine the best strain value.

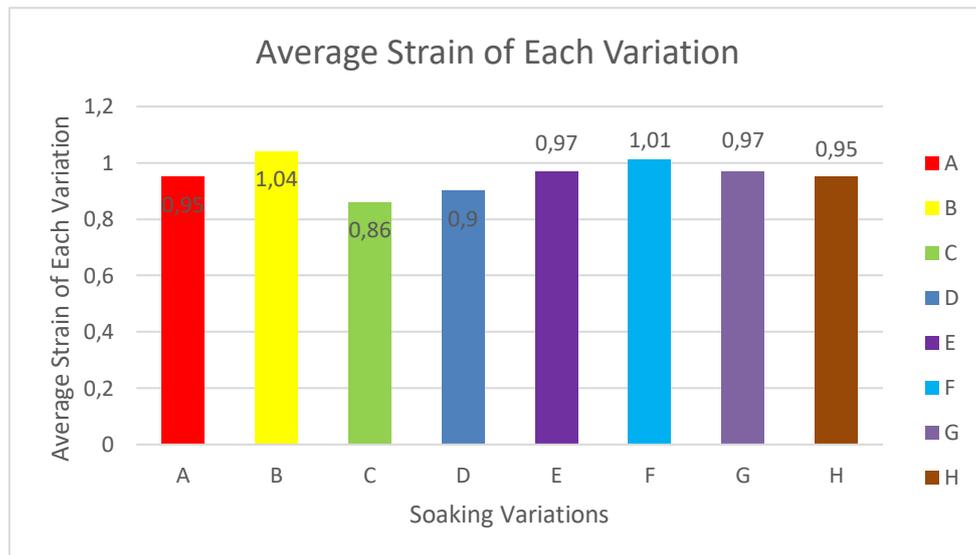


Figure 2. Diagram of average strain for each variation.

From the graph above, it is known that the highest average tensile strain is found in the composite specimen after 1 day of alkali soaking, followed by 1 day of drying before casting, which is 1.04%, while the lowest strain is found in the 2-day alkali soaking with direct casting specimen, which is 0.86%. Based on these data, it is evident that 1 day alkali soaking and 1 day drying before casting lead to an increase in the tensile strain. This high strain value indicates that in the 1-day alkali soaking and 1 day drying composite, a strong fiber-matrix interfacial bond is formed. Consequently, when subjected to loading, the material did not immediately break.

Modulus of Elasticity Value

$$E = \frac{\sigma_{Max}}{s} \quad (3)$$

Table 12. Modulus of elasticity calculations

No	Varian	Spesimen	UTS (N/mm ²)	ϵ (%)	E (N/mm ²)
1	1 Day Alkali Soaking, Direct Casting (A)	A1	45,40	0,93	48,81
		A2	38,57	0,80	48,21
		A3	43,39	1,13	38,39
		Rata-rata	42,45	0,95	45,13
2	1 Day Alkali Soaking, 1 Day Drying, Direct Casting (B)	B1	44,78	1,26	35,53
		B2	43,39	1,06	40,93
		B3	41,87	0,8	52,33
		Rata-rata	43,34	1,04	42,93
3	2 Day Alkali Soaking, Direct Casting (C)	C1	44,46	0,73	60,90
		C2	37,47	1,00	37,47
		C3	38,99	0,86	45,33
		Rata-rata	40,30	0,86	47,90
4	2 Day Alkali Soaking, 1 Day Drying, Direct Casting (D)	D1	42,44	0,86	49,34
		D2	48,46	1,00	48,46
		D3	35,11	0,86	40,82
		Rata-rata	42,00	0,90	46,20
5	3 Day Alkali Soaking, Direct Casting (E)	E1	45,00	0,73	51,70
		E2	37,38	1,2	50,20
		E3	38,46	1,00	50,11
		Rata-rata	40,28	0,97	50,67
6	3 Day Alkali Soaking, 1 Day Drying, Direct Casting (F)	F1	42,49	0,93	48,70
		F2	34,61	0,90	50,20
		F3	36,98	1,2	49,51



		Rata-rata	38,02	1,01	49,47
7	4 Day Alkali Soaking, Direct Casting (G)	G1	54,24	0,8	67,8
		G2	35,27	1,13	31,12
		G3	34,05	1,00	34,05
		Rata-rata	41,18	0,97	53,44
8	4 Day Alkali Soaking, 1 Day Drying, Direct Casting (H)	H1	44,91	0,93	48,29
		H2	44,01	0,8	55,01
		H3	39,56	1,13	35,00
		Rata-rata	42,82	0,95	52,74

From the above table, the average ultimate strength was obtained to create a graph to determine the best strain value.

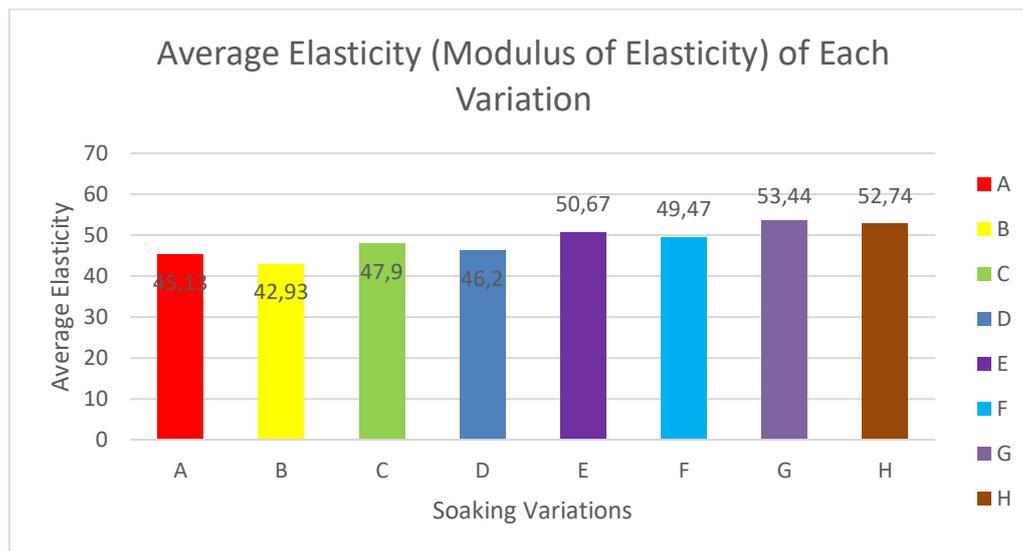


Figure 3. Diagram of average elasticity for each variation.

From the graph, it is known that the highest average modulus of elasticity is found in the coconut fiber specimen with variation G, which is 53.44 N/mm², while the lowest is in the specimen with variation B, which is 42.93 N/mm². Based on these data, the 4-day alkali soaking with direct casting (G) produces a better coconut fiber composite material than the other variations (A, B, C, D, E, F, and H). After calculating the tensile strength, strain (elongation), and modulus of elasticity values, a statistical test was conducted using the Statistica Product and Service Solution (SPSS) software. This analysis aimed to determine the differences in the average values of the tensile test results, specifically the ultimate tensile strength.

Table 13 Test of Normality

Kode Material	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Ultimate Stress A	0.272	3	.	0.947	3	0.555
Ultimate Stress B	0.179	3	.	0.999	3	0.951
Ultimate Stress C	0.307	3	.	0.904	3	0.398
Ultimate Stress D	0.193	3	.	0.997	3	0.892

The following values were obtained based on the normality test results, as indicated by the significance (sig) values, the following values. Variation A (1-day alkali soaking, direct casting) = 0.555, Variation B (1-day alkali soaking, 1-day drying, direct casting) = 0.951, Variation C (2-day alkali soaking, direct casting) = 0.398, Variation D (2-day alkali soaking, 1-day drying, direct casting) = 0.892. It can be concluded that because the significance values were greater than 0.05, the data followed a normal distribution. Therefore, the tensile strength values for each variation exhibited a normal data distribution pattern, fulfilling the fundamental assumptions required for parametric statistical analysis. A normality test was conducted to ensure that the

collected data fell within a reasonable range (approximately the average value), making it valid for further statistical analysis.

Table 14. Test of homogeneity of variances

Kode	Levene Statistic	df1	df2	Sig.
Ultimate Stress (Based on Mean)	1.458	3	8	0.297
Based on Median	0.834	3	8	0.512
Based on Median and with adjusted df	0.834	3	5.360	0.527
Based on trimmed mean	1.416	3	8	0.308

From the homogeneity test results conducted using the Levene Test, the overall significance value was 0.297, which is greater than 0.05, the probability threshold, which indicates that the data variance across the different variations is homogeneous, meaning that the three groups in this study can be considered statistically similar. Additional hypothesis testing using the One-Way ANOVA method is necessary to analyze any significant differences between the groups more comprehensively.

Table 15. Test of descriptives

Kode	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean (Lower Bound)	95% Confidence Interval for Mean (Upper Bound)	Minimum	Maximum
A	3	42.4533	3.51002	2.02651	33.7340	51.1727	38.57	45.40
B	3	43.3467	1.45548	0.84032	39.7310	46.9623	41.87	44.78
C	3	40.3067	3.67631	2.12252	31.1742	49.4391	37.47	44.46
D	3	42.0033	6.68570	3.85999	25.3951	58.6115	35.11	48.46
Total	12	42.0275	3.81332	1.10081	39.6046	44.4504	35.11	48.46

Based on the SPSS descriptive output data, the differences in the average tensile strength values of the bagasse fiber composite material were as follows:

1. Variation 1 (A) – Average tensile strength: 42.45
2. Variation 2 (B) – Average tensile strength: 43.34
3. Variation 3 (C) – Average tensile strength: 40.30
4. Variation 4 (D) – Average tensile strength: 42.00

Descriptively, it can be concluded that the highest average tensile strength is found in Variation 2 (B) with a value of 43.34.

Table 16 Test of anova

Sumber Variasi	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.650	3	4.883	0.269	0.846
Within Groups	145.305	8	18.163	–	–
Total	159.955	11	–	–	–

Based on the One-Way ANOVA test results shown in the table above, the following conclusions can be drawn:

1. Total variance between groups = 14.650
2. Total variance within groups = 145.305
3. Average variance between groups for each variation = 4.883
4. Average variance within groups for all variations = 18.163

From these values, it can be observed that the total variance within groups is greater than the total variance between groups. Based on the One-Way ANOVA test results, the significance value obtained was 0.846, which was greater than 0.05. This indicates that there was no significant difference in the tensile strength of the specimens. This finding contrasts with that of a previous study by Marbangun (2022), where the One-Way ANOVA test resulted in a significant value of $0.00 < 0.05$, indicating a significant difference among the specimens in that study.

4. CONCLUSION

Based on the test results and subsequent analysis of the coconut fiber composite material after alkali soaking, the following conclusions can be drawn the tensile strength of the coconut fiber composite varies



copyright is published under [Lisensi Creative Commons Atribusi 4.0 Internasional](https://creativecommons.org/licenses/by/4.0/).

across different soaking durations, leading to different tensile strength values. The highest tensile strength was found in variation G1, with a value of 54.24 N/mm², and an elasticity modulus of 67.8 N/mm². The highest strain (elongation) was observed in variation B1, with a value of 1.26%. These results indicate that the alkali soaking duration significantly influences the mechanical properties of the coconut fiber composites.

The tensile strength test results for all soaking variations are significantly lower than those of the BKI standard. To achieve a tensile strength that meets the BKI standard (98 N/mm²), a linear regression method was applied. The research found that 18 days of coconut fiber soaking in alkali, followed by 1 day of drying before casting, would be required to match the tensile strength specified in the BKI standard. Therefore, coconut fiber composites treated with alkali soaking are not suitable for use in hull section, as they do not meet the BKI tensile strength requirement of 98 N/mm².

References

- [1] Bale, J. S., Pell, J. M. & Woru, P., The Effect of Alkali Treatment on the Tensile Strength of Polyester Composites Reinforced with Woven Banana Stem Fibers, National Seminar on Technological Innovation – UN PGRI Kediri, 2018
- [2] Dwijana, I. Gusti, K. & Astika, I. Made., Tensile properties and fracture mode of polyester composites reinforced with woven coconut fiber, Journal of Mechanical Engineering Dynamics, 2014
- [3] Groover, Mikell P *Industrial Robotics: Tecnology, Programming, and Applications*, New York: McGraw-Hill Co, 1986
- [4] Kembuan, H., Lay, A., Mahmud, Z., Novarianto, H. & Rindengan, B. Characterization of Hybrid Coconut Flesh for Food Industry Raw Materials Research Report, Collaborative Project for National Agricultural Research Institutional Development, 1995.
- [5] Sonief, A. A., Maryanti, B., Slamet, W., The Effect of alkali treatment on the tensile strength of coconut fiber-polyester composites, Journal of Mechanical Engineering Design, 2011
- [6] Gu H., Tensile Behaviours of the Coir Fibre and Related Composites after NaOH treatment, Materials and Design, 2009
- [7] Rout J, Misra M., Tripathy S.S, Nayak S.K., Mohanty A.K. The Influence of Coir-Polyester Composites, Composite Science and Technology, 2001
- [8] Kuncoro Diharjo, The Effect of Alkali Treatment on the Tensile Properties of Ramie Fiber-Polyester Composites, Journal of Mechanical Engineering, 2006
- [9] Ella, S., Karmin., Fenoria, P., Arif, B., Analysis of the Effect of Alkali Treatment on the Mechanical Properties of Oil Palm Fruit Fiber-Reinforced Composites, Journal of Applied Technology, 2023
- [10] Bakri, Micromechanics of Natural Cellulose Fibres Using Raman Spectroscopy, Thesis of master of Phislosophy, Manchester University UK, 2009

