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Mechanical Performance and Structural Suitability of Natural Fiber Composites: A Comparative Study with E-Glass and S-Glass Composites

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Abstract: The present study aims to mechanically characterize four natural fiber composites coir, banana, pandanus kaida, and coconut leaflet rachis against synthetic E-glass and S-glass composites. Tests including Brinell hardness, impact energy absorption, abrasion wear, and tensile strength were conducted to assess mechanical properties. Banana fiber composites exhibited the highest BHN (Brinell Hardness Number) of 25.53, while S-glass polyester had the lowest at 12. Pandanus kaida fiber composites showed the highest impact energy among natural fibers at 1.8 J, though S-glass polyester had the highest at 4 J. Coir fiber composites had a relatively high wear rate of 0.22%, while E-glass and S-glass composites had lower wear rates of 0.1% and 0.08%. Coir also displayed the highest tensile strength among natural fibers at 6.00 MPa, outperforming some synthetic composites. Natural fiber composites demonstrated competitive mechanical behaviour and certain fibers exhibited enhanced hardness and wear resistance, suitable for durable structural applications. Microscopic evaluation revealed wear mechanisms and fiber-matrix adhesion. Though synthetic fibers excelled in tensile strength and impact resistance, natural fibers offer low weight, cost-effectiveness, and sustainability. Future research should explore hybridization and surface modifications to enhance performance and promote broader industrial use of natural fiber composites.

Keywords: Banana fiber, Coir fiber, Coconut leaflet rachis fiber, Composite materials, Mechanical properties, Natural fiber, Pandanus kaida fiber.

1. Introduction

Natural fiber-reinforced composites have grown fast into prominence owing to their benefits towards the environment together with their cost-effectiveness and satisfactory mechanical properties. They are composites containing coir, banana, pandanus kaida, and coconut leaflet rachis fibers embedded in polymer matrices such as polyester resin, rendering them sustainable and functional [1]. The keen interest in a material of this kind stems from the desire for replacements for synthetic fiber composites. E- or S-glass reinforced materials, despite having superior mechanical properties, continue to face media criticism for their non-degradability and for consuming excessive energy during their production [2]. Coir fiber, extracted from coconut husks, is popularly regarded for its toughness, high lignin content, and good resistance to microbial degradation. There are reports that coir fiber composites possess good tensile strength and impact resistance, thus suitable for application when moderate mechanical performance is required [3]. Banana fibers derived from the pseudostems of banana plants can be used to produce composites with favourable tensile and flexural properties. These mechanical characteristics may be further improved through appropriate chemical treatments and by optimizing the fiber loadings. Pandanus kaida fiber, though much less thoroughly studied, has demonstrated potential considering its good mechanical properties and its local availability in certain areas [4]. Coconut leaflet rachis fiber is yet another source of reinforcement available since it can be collected from coconut trees in the midribs of coconut leaves.

The mechanical behaviour in natural fiber composites is influenced by many factors, adhesion between matrix and fiber, fiber orientation, and fiber volume fraction. Proper surface treatment of the fiber improves interfacial bonding with the matrix, leading to improved load transfer and overall composite strength. Besides, incorporating natural fibers into polymer matrices makes lower-density

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composites than glass-fibers by resulting in lower weighted structural applications. Despite this, natural fiber composites usually possess lower mechanical properties than synthetic fiber composites. These fibers have become attractive alternatives for many applications due to their higher specific properties, biodegradability, and lower environmental impact.

In this study, samples of composites reinforced with 100% coir, 100% banana fiber, 100% pandanus kaida fiber, and 100% coconut leaflet rachis fiber, with polyester resin as the matrix, were developed. The mechanical properties of these composites were determined by Brinell hardness tests, impact energy tests, percentage of abrasion wear resistance, and tensile strength tests, all performed per American Society for Testing and Materials (ASTM) specifications [5]. Microscopic examination focused on analysing the fiber-matrix interface and the effects of abrasive wear on the composites. The results were compared with those of E-glass and S-glass fiber-reinforced composites to assess the viability of natural fibers as alternative reinforcement materials. This comparison enhances the understanding of the mechanical behaviour of natural fiber composites and supports the development of optimized designs to meet performance requirements, while promoting the use of sustainable materials in engineering and manufacturing [6]. Natural fibers' favourable attributes are eco-friendliness, cost-effectiveness and moderate mechanical properties which prepare them for a promising future in various applications. Research and development that will further improve natural fiber composites are, thus, taking priority in whatever phase of business sectors.

E-glass fibers and S-glass fibers, which are frequently used in composite materials, offer high strength, stiffness, and durability. In contrast, these materials have disadvantages that include high energy consumption in their manufacture. They cannot decay in nature, and their disposal would raise environmental concerns. Also, these synthetic fibers have a brittle nature, with tendency for micro-cracking and cause health problems because of dust inhalation during processing. These synthetic fibers have high density, increasing weight onto the structure of composites and limiting the application in lightweight usage [2]. To address these limitations of synthetic fibers, natural fiber composites should serve as sustainable alternatives [7]. As examples of naturally sourced fibrous materials include coir fiber, banana fiber, pandanus kaida fiber, and coconut leaflet rachis fiber which are eco-friendly, biodegradable, and lightweight, while still maintaining acceptable mechanical performance. The mechanical properties of fibers, including tensile strength, impact strength, and wear resistance which make them suitable for many engineering applications. Their low energy demands in production and processing further reduce their environmental footprint. A considerable research gap exists in the area that has been widely researched for E-glass and S-glass composites but relatively less for native fiber composites [8]. Mechanical performance data on synthetic fiber composites is abundant; however, additional research into natural fiber composite systems under different loading conditions and the influence of various environmental parameters is needed. This study aims to bridge that gap through tensile tests, along with Brinell hardness, wear, and impact tests, in assessing the feasibility of natural fibers in composite applications rather than synthetic fibers [9].

Thus, this research aims to advance the investigation of natural fiber composites and their potential to replace synthetic fiber composites in specific applications. It recognises the need for tailor-made composite designs to meet required mechanical properties [10]. In doing so, it supports the promotion of sustainable materials in engineering and manufacturing.

2. Materials and Method

2.1 Raw Materials

Natural fiber extraction strongly relates to its mechanical properties, subsequently determining its composite applications. Coir fibers originate from the coconut's husk by separating the husk, then following a series of processes, including retting, extraction if not sucked, washing, drying, and eventually grading. Retting, which ultimately breaks down the lignin and pectin by soaking the husks in water, is the major process under which long, durable fibers are obtained. After retting, the fibers can be separated by beating, followed by thorough washing and sun-drying. The high lignin content of coir fibers gives them the qualities of being stiff and tough while also resisting moisture and decay. In banana fiber extraction, the outer layers of the sheath are peeled away, and the fibrous inner layers are processed using traditional manual scraping methods [11]. The extracted fibers are then washed to remove non-cellulosic materials and sun-dried under controlled conditions using shrivelling techniques. Mechanical combing is subsequently performed to enhance fiber flexibility and improve adhesion within the composites [12].

To extract Pandanus kaida fibers, a complex series of processes such as harvesting, retting, and mechanical processing was performed. The first batch involved collecting dry, long leaves of Pandanus kaida, which were then subjected to several operations to remove thorns and sharp edges, followed by retting to break down non-fibrous materials. Water retting involves submerging the leaves for several days to weeks, allowing the natural action of microbes to loosen the fibers. Chemical retting hastens it with mild alkali solutions. Once retting was complete, the softened leaves were scraped with knives and beaten with wooden tools, so that the inclusion of fibers from the leaf pulp was accomplished properly. With hard leaves, mechanical decorticators were at times used to make the extraction process easier. After the extraction, the fibers were washed thoroughly to remove residual impurities and sun-dried. The dried fibers were further combed, and hand separated to improve quality and ensure uniformity in length. The finished product was then bundled and stored in dry conditions to prevent mould and decay.

Same as above, the extraction of coconut leaflet rachis fibers commences with implementing a systematic method that includes collecting mature coconut leaves and separating the leaflets from the central rachis (midrib). The rachis was sunbaked using air drying for several days to allow the moisture to reduce and facilitate the loosening of fibers, which renders fiber extraction easier. Under some conditions, retting involves soaking in fresh water for several weeks to degrade non-fibrous materials and make out the fibers [13]. After it has softened, the manual extraction involves beating with wooden mallets to separate the fibers.

These fibers were then combed and scraped to remove the pith and other non-fibrous matter. This goes on to great lengths of cleaning to remove any unexpected impurities to achieve the best cleaning. After this, the cleaned fibers were sun-dried again to remove moisture, bundled, and stored away to prevent the fungus and decay through drying. The method of extraction along with any treatment performed on this class of fiber will directly impact its final properties such as tensile strength, surface roughness, and moisture-resistant properties [14]. Proper retting and separating techniques can maximize fiber-matrix bond strength, thereby enhancing the overall performance of fiber-reinforced composites. By using better methods of extraction, these natural fibers can represent good alternative resources to synthetic fibers, E-glass, and S-glass for engineering applications [15].

Table 1 - Sample composition and density

Sample no.	Composition	Density (kg/m^3)
C1	Coir fiber 100%	1374
C2	Banana fiber 100%	1140
C3	Pandanus kaida fiber 100%	1306
C4	Coconut leaflet rachis fiber 100%	2150

According to Table 1, the outcome of density measurements for these natural composite fibers exhibited immense variation in fiber types and their composition. Density levels ranged from the highest among the coconut leaflet rachis fiber composite, 2150 kg/m^3, to a lesser extent of lower density,1374 kg/m^3, for coir fiber composite. The banana fiber composite again showed the least density of 1140 kg/m^3, which seems to relate to the fact that banana fibers are themselves lightweight. The fiber of the pandanus kaida composites had a moderate density of 1306 kg/m^3 and was in a position of virtue in any structural loading system. As inferred from the density variation, the type of fiber influences the compactness, mechanical performance, and potential applications of the composite.

2.2 Composite Preparation

The following composites were prepared using various natural fibers: coir (100%), banana fiber (100%), pandanus kaida fiber (100%), and coconut leaflet rachis fiber (100%). These fibers were selected for their high availability, low cost, and protection of the environment in contrast to synthetic fibers [16]. The polyester resin used in the present investigation, was a commercially available ready-to-use liquid with a density of 1.35 g/cm^3 at room temperature [17]. The resin was mixed with 1.5% by weight of hardener to facilitate crosslinking and curing of the composites. Preparation of the composite samples involved cleaning and drying the natural fibers, cutting them to the required length, and mixing them with the polyester resin [18]. The blended fibers were manually layered alternately with the resin to achieve a uniform and homogeneous thickness in the final composite. The fiber volume fraction was kept constant at 40%, and the resin layers varied so that curing was uniform, and the fiber distribution throughout the matrix was effectively homogeneous. After lay-up, the composite materials were cured at a uniform load of 50 N, thus allowing the resin to be set properly as per the curing procedure [19].

Figure 1 – Natural fiber composite test samples

Figure 1 shows test samples of natural fiber composites. Mechanical tests were performed on the composites to test their quality and compare them with E-glass and S-glass composites. The procedures observed all standard ASTM methods to make sure that results would be reliable and reproducible. The Brinell hardness test was performed according to ASTM E10 in a sample size of 15 mm × 15 mm × 15 mm for resistance to indentation against a defined load. In this process, a steel ball of 10 mm diameter was pressed with a 62.5N force against the surface of the composite sample. The diameter of the indentation was measured to obtain the hardness number [19].

The Izod impact test was performed on the composites to determine their impact resistance, such as those mentioned in ASTM D256. This method uses a pendulum-type impact tester that strikes the specimen, and the energy absorbance during the fracture was measured to assess the impact resistance of the composite material. Abrasion resistance of the composites was tested as part of a wear test according to ASTM G99, whereby each sample measuring 10 mm × 10 mm × 50 mm has undergone controlled abrasive conditions under a load of 9.81 N with a speed of 60 rpm at 400 cycles. SAE 30 lubricant was employed as the wear test fluid, symbolizing a realistic situation, and weight loss was one of the metrics that was quantified as a percentage of the initial mass of the samples [20].

The tensile strength of the composites was determined according to ASTM D638 with specimens 165 mm × 19 mm by 5 mm in thickness. Uniaxial tensile loading was carried out until failure, in which case the recorded highest load aided in the computation of the tensile strength of the composites [21]. The fiber-matrix interface and morphology of the composites, before and after wear tests, were assessed using the optical microscope. This observation revealed how wear affected the microstructure and fiber-matrix adhesion in the case of the involved materials. The density of the composites was calculated after careful determination of the samples' compositions. The volume fraction of each fiber was calculated based on the weight fraction and density of the fibers, while overall composite density was derived from a weighted average of the fiber and resin densities [22]. Coupled with the microscopic analysis, these tests expounded comprehensively the mechanical performance and wear characteristics of the natural fiber composites and benchmarked with E-glass and S-glass fiber composites based on the results obtained from the tests. This puts the viability of using these natural fibers as alternative replacement materials to synthetic fiber-reinforced composites in engineering undertakings [23].

3. Results and Discussion

The results obtained from tests of natural fiber composites conducted specifically for the determination of Brinell hardness, impact energy, wear and tear by abrasion, and tensile strength provide preliminary details of structural stability, durability, and potential performance of these composites in contrast with traditional synthetic materials. The results showed a significant variation in mechanical properties among the tested samples, proving that type and composition of fibers affected the performance. The hardness test showed that the coconut leaflet rachis fiber sample had the highest Brinell Hardness Number (BHN) of 28.64, which indicates significant resistance to deformation.

The coir fiber sample showed the least BHN of 18.82, thus symbolizing relatively lower rigidity. Impact test results showed that pandanus kaida fiber has the highest energy absorption at 1.80 J, which may be attributed to the flexibility of the fibers and the ability to effectively dissipate impact forces. Abrasion resistance has shown a wide variety of results among the samples, while coir fiber displayed the lower abrasion wear of 0.22 with a lesser tendency of surface degradation than pandanus kaida fiber, which recorded slightly higher wear of 0.31, a sign of moderate resistance against wear. Tensile strength test results have revealed that the coir fiber composite had the highest tensile strength of 6.00 MPa. So, it will contribute to a great ability to take load under high-stress applications. Mechanical properties of the tested sample results are summarized in Table 2 below.

Table 2 - Mechanical properties of samples

Sample no.	Brinell Hardness Number	Impact Energy (J)	Abrasion Wear Percentage (%)	Tensile Strength (MPa)
C1	18.82 (±0.67)	1.47 (±0.07)	0.22 (±0.12)	6.00(±0.04)
C2	25.52 (±0.09)	1.40 (±0.00)	0.29 (±0.09)	4.41(±0.63)
C3	21.92 (±0.03)	1.80 (±0.00)	0.31 (±0.08)	4.19(±0.87)
C4	28.64(±0.04)	1.40 (±0.00)	0.25 (±0.07)	4.84(±0.84)

So, those results indicate that the mechanical performance of natural fiber composites can be tailored for application contexts based on hardness, abrasion resistance, energy absorption, and tensile strength.

3.1 Brinell Hardness Number

Natural fiber composites were investigated, using the Brinell hardness, tests to examine their prospective viability as sustainable substitutes for synthetic composites, namely E-glass and S-glass. As shown in Figure 2, the analysis of the Brinell hardness test showed a pronounced fluctuation of hardness among the fiber types. The coconut leaflet rachis fiber composite had the highest hardness reading, 28.64 BHN, implying a rigid structure and a very strong stiffening role within the matrix. This was significantly better than synthetic composites, as E-glass had a BHN of 16 while S-glass had the lowest with a value of 12 BHN. The banana fiber composite was observed with 25.52 BHN indicating a high mechanical integrity.

The composite of the pandanus kaida fibers was recorded at 21.92 BHN, indicating the consistent structural performance of the composite. Coir-based composites had an average of 18.82 BHN, the minimum observed because they probably were the least porous and flexible. However, the natural fiber composites claimed to offer a certain level of hardness are nonetheless promising because they occupy a wider span beyond the hardiness of their synthetic counterparts. Hence, they are viable construction materials for moderate to high mechanical strengths.

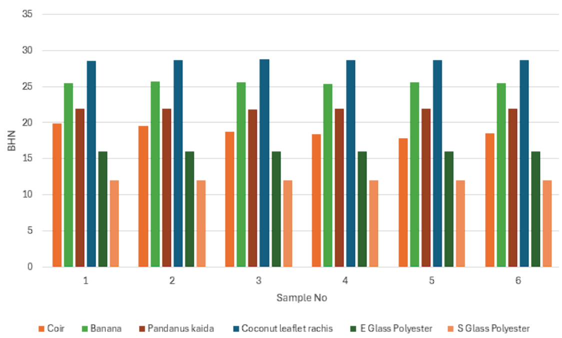


Figure 2 - Brinell Hardness number of samples

The BHN of natural fiber composites was gathered and analyzed and presented in Figure 3. The averages of six samples were plotted with standard deviations for each sample type. The results indicate that coconut leaflet rachis fiber composites exhibited the highest hardness value of 28.64, followed by banana fiber composites at 25.52, Pandanus kaida fiber composites at 21.92, and coir fiber composites at 18.82. Standard deviations were considerably low for all samples. In particular, coir fiber showed the least hardness value. In contrast, the standard deviations for banana and coconut leaflet rachis fiber composites displayed relatively low variations as well. The low value of standard deviation indicates uniformity among the samples, suggesting uniform and reproducible hardness characteristics. This demonstrates the structural reliability of these natural fiber composites and makes them promising materials for applications requiring high hardness and mechanical stability.

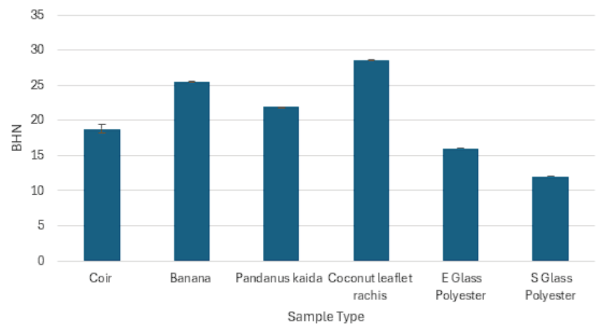


Figure 3 - Average value of Brinell Hardness number

3.2 Impact Energy

In Figure 4, the results of the impact energy tests suggest that the composites have different impact energy absorption capacities. The impact energy absorbed by the pandanus kaida fiber composite was the highest, absorbing 1.80 J among natural fiber composites, thereby making it a suitable candidate for applications requiring greater impact resistance.

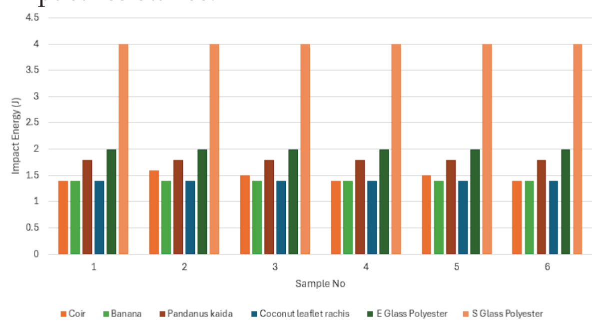


Figure 4 - Impact energy of samples

This exceptional ability to absorb energy can be attributed to the bending flexibility and elongation potential of the fiber, which allows it to effectively disperse impact force and avoid sudden failure. Coir fiber showed impact energy of 1.47 J, while banana and coconut leaflet rachis composites showed the same impact energy values of 1.40 J. All contestants are moderately impact-resistant in comparison to one another.

On the other hand, these natural fiber composites are observed to have low impact energy values when compared to synthetic fiber composites that exhibited E-glass at 2.00 J and S-glass at 4.00 J, respectively, giving an insight into the stronger and tougher composition of synthetic fiber composites than natural fiber composites. The impact energy values for the natural fiber composites were analysed and are presented in Figure 5, which indicates the average impact energy together with error bars showing standard deviation.

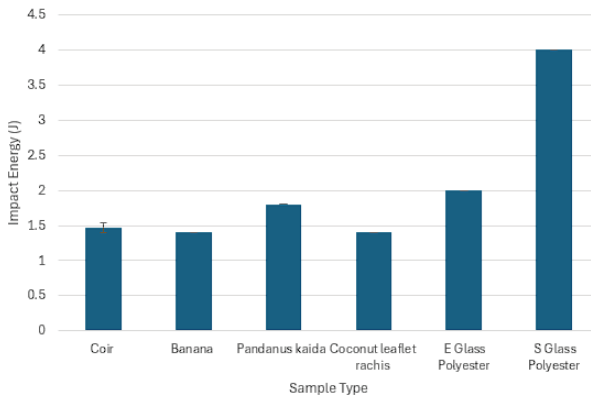


Figure 5 -Average value of impact energy

Among the tested composites, the pandanus kaida fiber composite shows maximum impact energy at a value of 1.8 J, indicating the maximum efficiency with which it can absorb and dissipate sudden loads. The coir fiber composite showed slightly less impact energy with 1.47 J, while banana and coconut leaflet rachis fiber composites both showed an impact energy of 1.4 J among the composites. The standard deviation values were minimal with pandanus kaida, banana, and coconut leaflet rachis fibers showing no variation. Therefore, it is very consistent for energy-absorbing characteristics.

3.3 Wear Percentage

The different composites exhibited varied wear resistances. A coconut leaflet rachis fiber composite exhibited the lowest constant wear percentages, at 0.25. This performance, as shown in Figure 6, resembled that of synthetic composites of E-glasses and S-glasses and could reach values of 0.10 and 0.08, respectively, as minimum recorded wear percentages. The coconut leaflet rachis composite was reported to be highly wear-resistant, owing to its compact and dense structure. Thus, it provides good fiber-matrix adhesion and reduces shedding or loss of material under severe conditions.

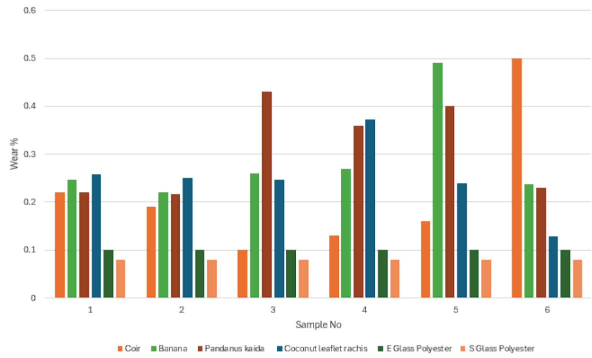


Figure 6 - Abrasion wear percentage of samples

In terms of wear, the kaida pandanus fiber composite had a reasonable wear resistance (0.31% wear) and was able to better resist surface degradation when compared to coir and banana fiber composites. The banana fiber composite showed a wear percentage of 0.29. In contrast, coir fared slightly lower at a wear percentage of 0.22, thus indicating that it was more sensitive to wear than other composites. The weak to moderate bonding between the fiber and matrix correlates with increased wear with coir and banana fiber composites, which may have ultimately resulted in material loss.

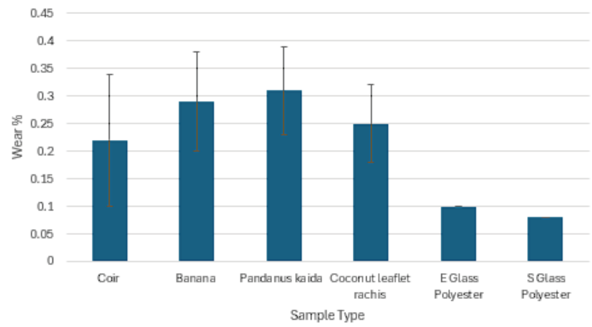


Figure 7 - Average value of abrasion wear percentage

An evaluation of the resistance of the natural fiber composite samples developed in this research should have been completed with the results presented in Figure 7, where the average percentage of wear and error bars portraying standard deviation are shown. Out of all tested composites, the pandanus kaida fiber composite had the highest wear percentage of 0.31, indicating very low resistance to the abrasive conditions they must endure preventing surface degradation. The next highest wear percentage was banana with 0.29, followed by coconut leaflet rachis fiber composite with better resistance to wear and a comparably lower value of 0.25. The coir fiber composite sustained the least wear of 0.22 since it resisted material loss best during the wear test. The highest values of 0.12 for coir fibers were observed. These results suggest that natural fiber composites give rise to a little more wear than their synthetic counterparts but still provide reasonable resistance to wear within the limits for applications where moderate durability is acceptable.

3.4 Tensile Strength

The study also compared the tensile strength of some fibers. The tensile strength of composite materials widely ranges according to fibers. The value of tensile strength of coir fibers varies between 5.92 MPa and 6.04 MPa. It has the highest tensile strength among the 6 samples. Whereas for Pandanus kaida, it widens more than that to about 2.79 MPa. It has a wide range of 3.19-5.98 MPa, placing it in the group of intermediate tensile strength values. The tensile strength of coconut leaflet rachis fibers varies from 3.16 MPa to 5.81 MPa. Though it is weaker than coir composites, it is still viewed as a potential material for certain applications. According to Figure 8, the reinforced E glass polyester showed the weakest tensile strength with 2MPa on all samples, while S glass polyester had a tensile strength of 4MPa. Natural fibers such as coir and banana fibers do provide good opportunities in the making of composite materials with satisfactory mechanical properties and sustainability. The tensile strength of coir fiber exceeded S Glass Polyester in what is thus looked upon as an eco-friendly alternative for structural applications. However, variability in tensile strength indicates the need to optimize fiber-processing and treatment methods for improved performance and consistency of natural-fiber composites.

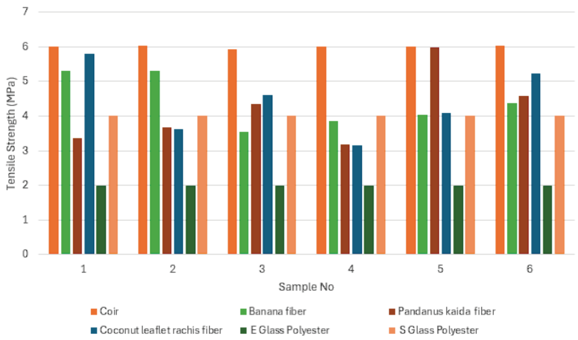


Figure 8 - Tensile strength of the samples

As the results are shown in Figure 9, the average tensile strength of the natural fiber composites was analysed. Among the tested samples, the coir fiber composite displays the highest tensile strength of 6 MPa. It indicates superior mechanical performance compared to other natural fiber composites. Respectively, the banana fiber and coconut leaflet rachis fiber composites demonstrated relatively comparable tensile strengths of 4.41 MPa and 4.42 MPa. The comparison shows that both fibers are equally capable of carrying loads. The tensile strength of the pandanus kaida fiber composite was slightly lower than that of others, measuring 4.19 MPa, but that mostly happens due to the structure of the fiber, the bonding effectiveness, and the fiber-matrix interaction.

The standard deviation shows some degree of variability in the tensile strength of the samples. In contrast, the coconut leaflet rachis fiber, banana fiber, and pandanus kaida fiber composites exhibited higher values of standard deviation. It indicates that it has a greater effect on processing conditions, fiber orientation, and matrix distribution on their tensile properties. These findings indicate the immense potential of natural fiber composites in structural applications and point to further improvement to be carried out in the processing and fabrication of fibers. So that mechanical uniformity and overall performance would be enhanced.

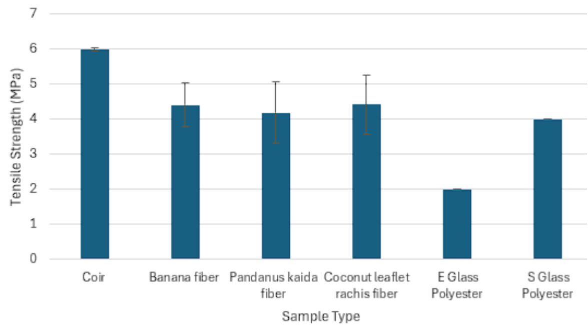


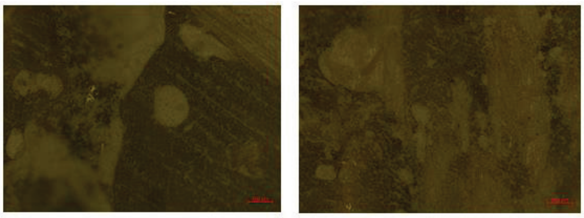
Figure 9 - Average value of tensile strength

3.5 Microscopic Image

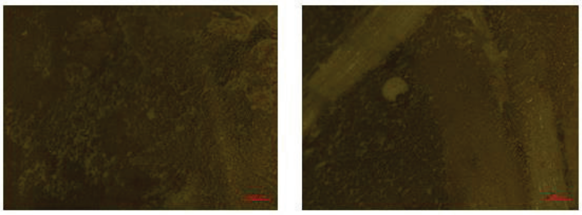
Microscopic inspection of the fiber composites was carried out both before and after conducting the wear test, which greatly contributed to the study of surface morphology and material degradation mechanisms. Images presented in Figure 10 illustrate the predominant structural differences developed in the coir, banana, pandanus kaida, and coconut leaflet rachis fiber composites because of abrasive forces on their surfaces. All the samples before the wear test presented relatively smooth surfaces, with well-integrated fibers within the matrix. This suggests that, in most cases, considerable interfacial bonding was achieved. The post-wear analysis showed conspicuous changes in surface textures exhibiting fiber exposure, matrix removal, and micro-crack formation to varying degrees. The roughness of coir-based composites (Figure 10 (a)) together with fiber pull-out was greatly evident after the wear test, which indicates weaker fiber-matrix adhesion and greater material losses. The banana fiber composite (Figure 10 (b)) displayed moderate wear damage, exposing fiber and featuring a more uniform wear pattern. This shows relatively better load distribution. In contrast, the pandanus kaida composite exhibited slightly smoother worn surfaces and less fiber detachment (Figure 10 (c)), which correlates with its higher capacity to absorb impact energy. The coconut leaflet rachis composite (Figure 10 (d)) presents the least surface degradation, with merely minor abrasions, lending additional support to its superior hardness and wear resistance.Figure 10 (e) indicates the coir sample's microscopic analysis which had the maximum wear resistance among other samples. Low number of voids directly affect to have a high wear resistance.

These microscopic analyses are fully consistent with quantitative wear percentage results, proving that both fiber type and matrix interaction contribute to a significant degree of variation in the wear resistance of natural fiber composites. These results indicated that composites with stronger fiber-matrix bonding and with higher hardness generally demonstrate better wear resistance characteristics, thus representing more appropriate materials for usage where durability and extended mechanical performances are required.

Before After



(a)



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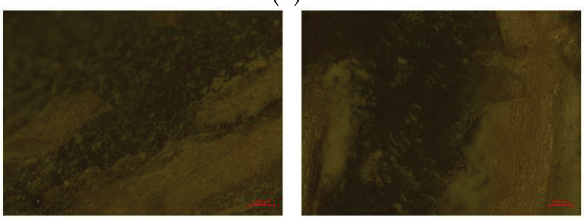

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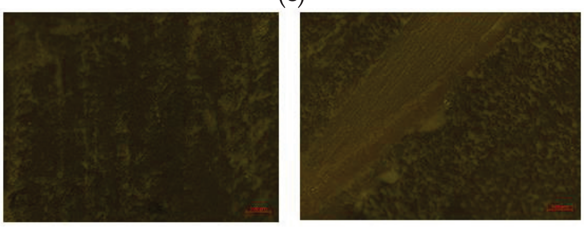

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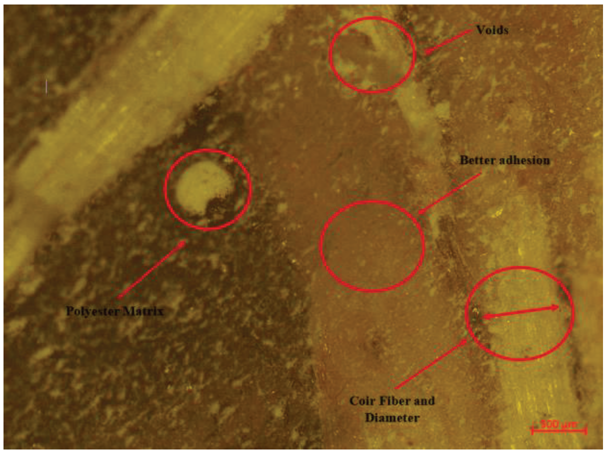

(e)

Figure 10 - Microscopic images of (a) Coir (b) Banana (c) Pandanus Kaida and (d) Coconut leaflet rachis samples before and after wear test and (e) Maximum wear resistance sample's internal structure.

4. Conclusions

This research outlines the mechanical analysis of natural fiber-reinforced composites made from coir, banana fiber, Pandanus kaida, and coconut leaflet rachis fibers. Results indicate that these materials are very beneficial for future endeavours towards developing sustainable alternatives to synthetic composites such as E-glass and S-glass.

Among the investigated composites, coconut leaflet rachis fiber offered the most elevated value of Brinell hardness (28.64 ± 0.04) and high resistance to wear (0.25 ± 0.07). Its showing suitability in applications that require durability and surface integrity. The hardness of banana fiber was quite good (25.53 ± 0.09) while that of pandanus kaida exceeded impact energy (1.80 ± 0.00 J). Its demonstrating ability to mitigate the shock and absorb the forces generated effectively. While coir composites may have been less mechanically advantageous in comparison with the other natural fiber composites. They nevertheless surpassed synthetic opposites on several parameters, hardness being one of them. The E-glass and S-glass composites comparison has proved that while synthetic composites have higher impact energy, natural fiber composites also could perform competitively concerning hardness and wear resistance. Combined with their environmental benefits, low weight, and cost competitiveness, this gives natural fiber composites great promise in a host of engineering applications. In summary, this research provides valuable information on the mechanical properties of natural fiber composites, which should aid the introduction of biomaterials into design processes for sustainability.

This study evaluated types of natural fibers as well as a comparison of their mechanical properties to synthetic fiber composites. Future work will study the mechanical behaviour of composites by investigating the fiber orientation and arrangement in the matrix. This will reveal the correlation between long term performance evaluation and effectiveness in terms of flexibility across different industrial scenarios.

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