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EVALUATION OF ABACA FIBER AS A SUSTAINABLE ALTERNATIVE TO SYNTHETIC FIBERS IN WET LAY-UP PROCESS

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ABSTRACT

Synthetic fibers have been widely used in the fabrication of aircraft composite parts because of their excellent mechanical and physical properties. However, there are growing concerns about non-biodegradability and high energy consumption during production has opened opportunities for exploring the use of more sustainable alternatives. In composite structure fabrication, the wet lay-up process is one of the simplest methods utilized in industrial applications, small-scale applications, and education settings in aviation. This process is performed by manual layering of fibers with a liquid type of resin, making it suitable for experimental studies.

This study was conducted to evaluate the use of abaca fiber as a sustainable alternative to synthetic fibers in the wet lay-up process in aviation education settings and aircraft applications. This study employs an experimental-comparative research design using the wet lay-up process to fabricate monolithic structures from abaca and synthetic fibers.

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Composite specimens are produced using abaca and synthetic fibers as reinforcement materials, combined with a resin matrix, and molded in a flat mold. A total of 58 specimens were prepared for the tests conducted in this study. All specimens are fabricated with uniform thickness to ensure a fair comparison. The number of layers for both materials is also adjusted based on the thickness of each fiber type.

The properties evaluated in this study include tensile strength, flexural strength, water absorption test, and density/specific gravity test. The quantity of specimens produced for both abaca fiber reinforced composites and synthetic fiber reinforced composites is as follows: seven specimens for the tensile strength test, seven specimens for flexural strength, five specimens for the water absorption test, and ten specimens for the density/specific gravity test. Laboratory testing procedures from DOST-STD are used to obtain the necessary data. The collected data are analyzed using mean and independent samples t-test to identify whether significant differences exist between the mechanical and physical performance of abaca fiber and synthetic fiber composites.

Findings revealed that synthetic fiber reinforced composites demonstrated significantly higher mechanical properties than abaca fiber reinforced composites. In terms of physical properties, abaca fiber composites showed higher water absorption and lower density, while synthetic fiber composites demonstrated lower water absorption but higher density. The results showed that synthetic fiber composites provide better overall mechanical performance and water or moisture resistance, while abaca fiber composites offer lightweight characteristics and potential as a sustainable alternative material to synthetic fibers for non-

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critical applications in aircraft and as a substitute material for aviation education and specific aircraft structural applications.

Keywords: *abaca fiber, synthetic fiber, composite materials, wet lay-up process, sustainability, tensile strength, flexural strength, water absorption, density*

INTRODUCTION

In modern aircraft engineering and manufacturing, the demand for cost-efficient, lightweight, and environmentally sustainable materials has substantially increased. Other industries such as aerospace, automotive, and marine engineering have also continued to seek materials that can provide high strength-to-weight ratios while minimizing the impact on our environment. Normally, synthetic fibers like fiberglass, carbon fiber, and aramid fiber have been widely used in the fabrication of aircraft composite parts because of their excellent mechanical and physical properties. However, there are growing concerns about non-biodegradability and high energy consumption during production has opened opportunities for exploring the use of more sustainable alternatives.

In the field of aviation education, there is a growing interest in integrating sustainability concepts into laboratory activities. Aviation Institutions are increasingly encouraged to conduct studies or research on using eco-friendly materials and processes that not only demonstrate the fundamental concepts but also promote awareness of sustainable development in the field of aviation. As a result, the utilization of sustainable alternative materials in laboratory experiments and projects has become an important area of study.

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Composite Materials are commonly introduced early in aviation education due to their importance in different aircraft engineering applications and the numerous advantages that it gives to the aircraft's structure, such as having a high strength-to-weight ratio, being non-corrosive, durable, and more. In the fundamentals of composite training, synthetic fibers like fiberglass are commonly used as reinforcement materials in composite fabrication, especially in wet lay-up processes due to their availability and mechanical and physical properties. However, these materials are not environmentally friendly or sustainable and may pose risks to the health and safety of the students and instructors when handled in laboratory environments.

Due to the said concerns, natural fibers have emerged as potential alternative materials that are more suitable for educational use. One promising material is the Abaca Fiber, a natural fiber that is very abundant in the Philippines. This natural fiber is widely known for its high strength and biodegradability. It also gives an opportunity for students to promote the use of sustainable materials while doing hands-on laboratory activities like composite fabrication. The use in aviation educational settings may engage the students to be environmentally responsible in engineering practices.

The wet lay-up process is commonly used in fundamentals of composites training to introduce the students to the basics of composite fabrication. Integrating abaca fiber into this process will show the evaluation of its practicality, ease of use, and performance. However, there is limited information on it regarding its effectiveness compared to synthetic fibers when applied specifically in the wet lay-up process.

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Composite Materials are widely used today and have become an essential part of modern engineering due to their superior characteristics like durability, resistance to corrosion, and, most of all, having a high strength-to-weight ratio. Among these, Fiber Reinforced Plastics (FRP) are utilized in industries such as aerospace, marine, automotive, and construction. Synthetic Fibers like fiberglass and carbon fiber remain dominant because of their consistency in performance and availability.

Despite the advantages of synthetic fibers, the increasing concern for the sustainability of the environment has led researchers across the globe to explore eco-friendly alternatives. The manufacturing process and disposal of synthetic materials greatly contribute to environmental pollution, and they are not biodegradable. In the case of composite materials, natural fibers may be used as alternatives to synthetic fibers. One of the most promising alternative materials is the abaca fiber, also known as Manila, which is the strongest natural fiber in the world. It has made an impact in recent years due to its potential in composites. It is known for its high tensile strength, stiffness, biodegradability, resistance to corrosion and saltwater, and low impact on the environment.

In composite structure fabrication, the wet lay-up process is one of the simplest methods utilized in industrial applications, small-scale applications, and education settings in aviation. This process is performed by manual layering of fibers with a liquid type of resin, making it suitable for experimental studies. It is cost-effective and easy to perform but may introduce variability in fiber distribution and resin content, which might affect the final output of a composite structure.

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Although there are several studies on the use of natural fibers in composites, there is still a gap in comprehensive evaluations comparing natural fibers with synthetic fibers in terms of mechanical and physical properties. Most of the existing studies focus only on one or two parameters like tensile strength and water absorption, without providing a holistic comparison between the two materials.

The use of abaca fiber as an alternative to synthetic fibers in aviation-related composites remains limited due to insufficient data on its performance compared to traditional synthetic fibers like fiberglass. This study aims to address the said gap by evaluating abaca fiber as a sustainable alternative to synthetic fibers using the wet lay-up process. This study will show the comparison between abaca fiber composites and synthetic fiber composites based on tensile strength, flexural strength, impact resistance, water absorption, and density. The results of this study may greatly contribute to the growing body of knowledge on sustainable materials that support the development of eco-friendly composite applications.

This study aims to evaluate the potential use of abaca fiber as a sustainable alternative to synthetic fibers for the wet lay-up process in the aviation education context. It also seeks to assess its suitability in terms of handling, fabrication, and mechanical performance, while also determining its value as a sustainable alternative material in aircraft education and technology-related programs.

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Related Literature and Studies

According to Shakir and Singh (2023), abaca fiber has gained attention in modern engineering because it is lightweight, environmentally friendly, biodegradable, and possesses favorable mechanical properties suitable for composite applications. Abaca fibers possess high tensile strength compared to other natural fibers, which makes them suitable for composite applications. The growing environmental concerns about the use of synthetic fibers encouraged industries and even institutions to use sustainable alternative materials like abaca fibers. Based on the literature of the authors, the increasing demand for sustainable materials has encouraged the use of natural fibers like abaca as alternatives to synthetic fibers in composite fabrication.

Radoor et al. (2020) explained that natural fibers such as abaca, sisal, and pineapple fibers are increasingly being used in polymer composites because of their biodegradable nature. Natural fibers can be beneficial for use because they reduce the environmental burden caused by synthetic materials like fiberglass, carbon fiber, and aramid fiber. Abaca fibers offer good mechanical properties such as tensile strength and flexibility, which makes them effective materials for reinforcement in composite structures.

According to Liu and Ma (2023), the chemical treatment of sodium hydroxide (NaOH) and silane coupling agents can significantly enhance the surface characteristics of abaca fiber used in composites. The researchers also emphasized that untreated abaca fibers are naturally hydrophilic, which can lead to poor bonding and moisture absorption. The findings showed

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that chemical agents can modify the surface properties of abaca fibers, resulting in better composite performance.

Wet lay-up processing remains one of the most economical fabrication techniques because it only requires minimal equipment and can be performed in an educational laboratory setting. Fiber-reinforced composites fabricated through wet lay-up processing methods can improve structural performance according to Xu et al. (2021). Based on their literature, proper resin application and fiber distribution are vital in achieving high-quality composite materials.

Natural fibers are increasingly being used in educational and research settings because of their sustainability and affordability. According to Asyraf et al. (2022), natural fiber composites are widely investigated by researchers and academic institutions due to their sustainability, biodegradability, and renewable characteristics align with modern engineering education.

According to the literature of Khan et al. (2018), the mechanical and physical properties of natural fiber composites vary depending on the fiber type, fiber orientation, fiber loading, and fabrication method. Reported values of fiber-reinforced composites' tensile strength, flexural strength, water absorption, and density cover a broad range due to material composition and manufacturing conditions. The researchers classified tensile strengths of 30 to 70 MPa as low, 71 to 110 MPa as moderate, and 111 to 150 MPa as high. Flexural strengths of 50 to 83 MPa were classified as low, 84 to 117 MPa as moderate, and 118 to 150 MPa as high. In terms of the physical properties, the researchers classified water absorption percentage values of less than 2% as low, 2.1% to 5% as moderate, and greater than 5% as

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high. Likewise, density values of 1.10 to 1.23 g/cm³ as low, 1.24 to 1.37 g/cm³ as moderate, and 1.38 to 1.50 g/cm³ as high.

Abaca fibers showed favorable mechanical properties, including tensile strength and flexural performance, in the study conducted by Alshgari et al. (2022). Based on their research, abaca fiber composites can be a promising reinforcement material because of their lightweight and sustainable composite applications.

According to Kumar and Raj (2021), uniform resin application and proper fiber arrangement are essential in achieving consistent mechanical performance of the composite material. They studied the wet lay-up method of fabrication using natural fibers and observed that proper alignment of the fibers can significantly affect the strength and quality of the composite material.

Natural fiber-based composites have attracted interest from researchers and industrial practitioners because they are biodegradable, lightweight, renewable, and economical alternatives to synthetic fibers, as discussed by Akter et al. (2022). Based on their research, they explained that these materials have a broad range of potential applications and sustainability benefits.

Natural fiber reinforced composites have gained attention because they offer several advantages like low density, biodegradability, renewability, and cost-effectiveness, according to the study conducted by Hasan et al. (2020). Natural fibers are capable of replacing synthetic fibers in selected engineering applications while maintaining acceptable mechanical

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performance. Their study also highlighted that natural fiber composites greatly contribute to sustainable development by promoting eco-friendly manufacturing practices.

According to the study conducted by Hedge et al. (2021), natural fiber-reinforced composites have emerged as sustainable alternatives to synthetic fiber composites due to their biodegradability and low environmental impact. Natural Fibers possess acceptable strength-to-weight ratios and offer environmental benefits due to their biodegradable nature. The study also emphasized that natural fibers can help reduce dependence on synthetic fibers like fiberglass and carbon fiber while promoting eco-friendly practices.

Natural fiber composites greatly contribute to environmental conservation by reducing non-biodegradable waste while maintaining acceptable mechanical properties, as discussed by Hirondo et al. (2020). Abaca fiber combined with plastic materials can also be utilized as sustainable construction materials. Their literature also stated that abaca fibers are abundant in the Philippines, which makes them practical and economical for local engineering applications.

Abaca fibers possess high tensile strength, making them suitable reinforcement materials for composite fabrication according to Paglicawan et al. (2021). Natural fibers are becoming popular alternative materials replacing synthetic fibers in composite fabrication because of their sustainability and biodegradability. In their literature, they also emphasized the importance of using locally available materials in engineering projects.

Abaca fiber-reinforced composites have received increased attention because of their sustainability, environmental friendliness, and favorable mechanical properties, based on the

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literature of Barba et al. (2020). They also highlighted that fiber-reinforced composites can provide significant property enhancement while promoting the use of renewable materials.

Abaca fibers are increasingly used as reinforcement material in the development of composites because they are biodegradable, lightweight, and derived from renewable resources, based on the literature of Lapuz et al. (2022, 2023). These properties make abaca fibers suitable for educational applications and laboratory-scale experimentation where safe handling and material accessibility are important considerations.

According to Siy et al. (2020), the hydrophilic nature of untreated abaca fibers can result in poor adhesion of fiber and matrix in composites. The researchers improved the hydrophilic properties of abaca fibers through saline treatment, which enhanced their compatibility with resin matrices.

Lalusin and Antaran (2022) conducted a study on abaca fibers and discovered that it exhibited high tensile strength, confirming its potential as reinforcement material in the fabrication of composites. They have also concluded that the fiber structure of abaca significantly influenced its tensile performance. Their research supports the use of abaca fiber in engineering composite applications where high strength and lightweight applications are desirable.

Abaca Fibers showed high tensile strength, confirming their suitability as reinforcement for composite fabrication, according to Señeris et al. (2024). They also observed significant tensile strength characteristics among locally grown abaca varieties and emphasized that its

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light weight characteristics and durability make them desirable materials for composite engineering applications.

According to Alcivar-Bastidas et al. (2023), abaca fiber reinforced composites show improved mechanical behaviour when properly treated, particularly fiber-matrix bonding and flexural strength. The study emphasized that natural fibers like abaca fiber are low-cost, lightweight, and can be environmentally sustainable alternatives to synthetic fiber reinforcements. However, synthetic fiber composites still show higher mechanical strength, while abaca fiber composites provide an advantage in sustainable applications and are safer in fabrication applications.

According to Emolaga et al. (2022), the incorporation of abaca fibers into synthetic fiber reinforced composites produced lightweight hybrid laminates with acceptable mechanical properties. The study showed that abaca fibers can partially replace synthetic fibers while reducing material cost and contributing to sustainability.

Based on the study conducted by Custodio et al. (2020), chemical treatments applied to abaca fibers significantly modify their internal structure by removing non-cellulosic components. The said treatments enhance the fiber's interfacial interaction with composite matrices and generally improve surface roughness.

The reviewed foreign and local literature and studies revealed that abaca fiber is a promising reinforcement material for composite fabrication due to its lightweight characteristic, sustainability, biodegradability, and favorable mechanical properties. Authors including Shakir and Singh (2023), Radoor et al. (2020), and Asyraf et al. (2022) emphasized

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the growing use of natural fibers as environmentally friendly alternatives to synthetic fibers in composite engineering applications.

The studies also showed that abaca fiber possesses acceptable tensile strength and flexural properties, which makes it suitable as a composite reinforcement material. Research conducted by Alshgari et al. (2022), Lalusin and Antaran (2022), and Señeris et al. (2024) confirmed the potential of abaca fiber in producing durable and lightweight composite materials. Authors including Liu and Ma (2023), Siy et al. (2020), and Custodio et al. (2020) emphasized that chemical treatments can improve fiber-matrix bonding and improve the overall performance of abaca fiber composites.

Furthermore, Xu et al. (2021) and Kumar and Raj (2021) identified the wet lay-up process as a practical and economical fabrication method capable of producing quality composite materials when proper fiber distribution and resin applications are observed. Based on the literature of Khan et al. (2018), the researchers classified measured mechanical and physical properties into low, moderate, and high categories to facilitate interpretation of the experimental results.

Overall, the reviewed literature and studies support the use of abaca fiber as a sustainable alternative to synthetic fibers. However, there remains a need to compare the mechanical and physical properties of abaca fiber composites and synthetic fiber composites fabricated using the same process. Thus, this study aims to evaluate and compare the performance of abaca fiber and synthetic fiber composites fabricated through the wet lay-up process.

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MATERIALS AND METHODS

This study used an experimental-comparative research design to evaluate and compare the mechanical and physical properties of abaca fiber composites and synthetic fiber composites. The experimental approach of this study allows for controlled fabrication and testing of materials to determine the differences between the two materials in terms of their performance.

This study involved the preparation of composite specimens for two different reinforcement materials, which are abaca fiber and synthetic fiber, while maintaining the same consistent method of fabrication, including the tools, equipment, and standard procedures. The fabricated specimens were subjected to standardized testing procedures to measure tensile strength, flexural strength, water absorption, and density.

The fabrication of the specimens subjected to testing followed a standardized wet lay-up procedure to ensure consistency. Both abaca and synthetic fiber samples were produced as monolithic structures, and the thickness of each specimen was controlled and set at 3mm to maintain uniformity between the two materials. Due to the differences in fiber characteristics, the number of layers for both materials was adjusted to achieve the same thickness.

After fabrication, the specimens were subjected to laboratory testing at DOST-STD using standard procedures. The results obtained from the tests were analyzed and compared to determine whether abaca fiber can be a viable sustainable alternative to synthetic fibers.

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A total of fifty-eight (58) specimens were prepared and tested in this study. Each material consisted of five (5) to ten (10) specimens for each test conducted to ensure reliability and consistency of results. The specimens were grouped according to the type of tests performed, which are the tensile strength test, flexural strength test, water absorption test, and density/specific gravity test.

The use of multiple specimens for both materials per test allowed for the computation of average values and minimized the effect of experimental errors. All specimens were prepared to ensure that the differences in the results were due to material properties rather than variations in fabrication.

Data Gathering Procedures

The composite panels and specimens were fabricated and prepared in the composite laboratory of PATTS College of Aeronautics. Mechanical and physical testing was conducted at the Department of Science and Technology–Standards and Testing Division (DOST-STD).

Composite Panels. Four composite panels were fabricated for the study:

- Two panels were reinforced with abaca fiber, measuring 7 in × 11 in and 15 in × 6 in.
- Two panels were reinforced with synthetic fiber, measuring 7 in × 11 in and 15 in × 6 in.

All four panels were fabricated by the wet lay-up process under similar environmental and processing conditions. Depending on the test, five to ten specimens of each material were prepared, following the quantities specified by DOST-STD.

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Table 1

Quantity of Specimens Required per Test by DOST-STD

Test Type	Abaca	Synthetic Fiber	Total
Tensile	7	7	14
Flexural	7	7	14
Water Absorption	5	5	10
Density	10	10	20
Total	29	29	58

Table 1 presents the number of specimens required for each test by DOST-STD. To enable a fair comparison, both abaca-fiber and synthetic-fiber composite specimens were prepared to a target thickness of 3 mm, as required by the testing facility. The number of fiber layers was adjusted according to each material's characteristics to achieve the same overall thickness.

Material Preparation

All required fibers, resin, hardener, tools, and equipment were prepared before fabrication. The abaca and synthetic fiber fabrics were cut to the required panel dimensions. The number of layers was planned according to the target specimen thickness. The pre-cut fiber layers were then arranged in the planned stacking sequence. Before lay-up, the fibers were checked to ensure that they were dry and free from visible contamination. The number of layers needed to achieve the target thickness was checked before resin application. The resin and hardener were measured according to the manufacturer's specified mixing ratio.

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The resin and hardener were mixed for approximately 2–3 minutes, until the mixture appeared uniform. Care was taken to minimize the introduction of air bubbles during mixing.

The first fabric layer was placed on the flat working surface over one half of the bagging film. Resin was applied to the first fiber layer. The bagging film was folded over the layer, and a squeegee was used to spread the resin until the fiber was fully wetted. The resin application and layering steps were repeated until the planned layers had been assembled to the required thickness. A flat plate was used as the base for vacuum bagging. Sealant tape was applied along the sides of the plate. A non-perforated release film was secured over the plate with tape. The resin-wetted fiber lay-up, forming the monolithic structure, was placed on the non-perforated release film. A perforated release film was placed over the composite lay-up to allow excess resin to pass through. Bleeder/breather cloth was placed over the perforated release film to absorb excess resin. A second non-perforated release film was placed over the bleeder/breather cloth. Another layer of bleeder/breather cloth was placed above the release film. The two sniffer assemblies for the vacuum line and gauge were positioned at the sides of the plate. The bagging film was placed over the assembly and sealed to the sealant tape. The vacuum hose and gauge were connected to the sniffer assemblies.

The vacuum system was then switched on. The bagging film and seals were checked for air leaks. A negative pressure of −30 inHg was maintained during curing, as specified in the study procedure. The vacuum was maintained during curing, which was carried out for approximately 24 hours at room temperature. The setup was left undisturbed during the curing period. After curing was complete, the vacuum gauge was removed. The vacuum-

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bagging materials were removed. Each composite panel was carefully separated from the flat-surface mold. The panels were cut into specimens using a band saw. The specimen edges were trimmed to the required dimensions using cutting tools. The edges were smoothed with sandpaper when necessary. Each specimen was inspected for visible defects, including voids, dry spots, and uneven thickness. The specimens were conditioned at room temperature for 24 hours before testing. The panels were cut to the dimensions specified by DOST-STD for the tensile, flexural, water absorption, and density tests.

Testing Procedures

For the tensile test, DOST-STD specified specimen dimensions of 6.5 in × ¾ in. The panels were cut to size with a band saw, and an angle grinder fitted with a sanding disc was used to smooth the edges and achieve the required dimensions. Specimens of both abaca-fiber and synthetic-fiber composites were mounted in a Universal Testing Machine (UTM) and pulled until failure to determine the maximum tensile stress the material could withstand. Tensile strength was calculated from the maximum load and the specimen cross-sectional area.

For the flexural test, the required specimen dimensions were 100 mm × 10 mm. The panels were cut to size with a band saw, and an angle grinder fitted with a sanding disc was used to smooth the edges. Each specimen was positioned on supports in a three-point bending setup, and a load was applied at the center until failure to evaluate resistance to bending. Flexural strength was determined from the maximum load recorded during testing.

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For the water absorption test, the required specimen dimensions were 3 in × 1 in. The panels were cut to size with a band saw, and the edges were smoothed using an angle grinder fitted with a sanding disc. Each specimen was weighed before immersion, submerged in water for 24 hours, then removed, dried, and weighed again. The percentage of water absorption was calculated from the increase in specimen mass after immersion.

For the density test, the required specimen dimensions were 1 in × 1 in. The panels were cut to size with a band saw, and the edges were smoothed using an angle grinder fitted with a sanding disc. The mass of each specimen was measured with a digital weighing scale, and its volume was calculated from the measured dimensions. Density was determined as mass per unit volume.

For tensile and flexural testing, a Universal Testing Machine (UTM) applied controlled loads to the specimens and recorded the corresponding measurements of load and displacement used to determine material strength.

Water absorption was evaluated using a digital weighing scale to measure specimen mass before and after the 24-hour water immersion period. The change in mass was used to calculate the percentage of water absorbed.

Density/specific gravity measurements were based on the mass and volume of each specimen. Mass was measured with a digital weighing scale, and specimen dimensions were measured with a digital caliper to calculate volume.

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All measurements were recorded on data sheets for organized analysis. Because the study did not involve human participants, its principal ethical considerations concerned laboratory safety, accurate recording, transparent reporting, and responsible handling and disposal of materials.

Laboratory safety procedures were followed during composite fabrication. Goggles, gloves, masks, and a laboratory gown were used when handling fibers, resin, and other materials. Cutting tools and other equipment were handled cautiously to reduce the risk of injury.

Data were recorded and reported with attention to accuracy and transparency, and limitations encountered during the research were acknowledged. Materials were handled responsibly, and resin and hardener waste was disposed of according to recommended safety guidelines.

The study observed respect for intellectual property by properly citing all the sources of information used in the research. With this, the ideas and findings of other researchers were properly acknowledged. The study was conducted strictly for aviation educational purposes only, and the results are not intended for direct application in critical and structural components of an aircraft. The findings are presented solely to contribute to the growing knowledge on aircraft composites and to support further research in sustainable alternative materials.

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Statistical Treatment of Data

The data collected from all the experimental tests were analyzed using appropriate statistical methods to ensure accurate interpretation and comparison between abaca fiber and synthetic fiber composites. The statistical methods used in this study include descriptive statistics, standard deviation, and independent-samples t-tests. The researcher utilized appropriate statistical tools to analyze, interpret, and present the data gathered from the mechanical and physical testing of abaca fiber composites and synthetic fiber composites fabricated through the wet lay-up process. All data were encoded, tabulated, and analyzed using the Statistical Package for the Social Sciences (SPSS).

Descriptive statistics were used to analyze the data collected in this study to evaluate abaca fiber and synthetic fiber composites performed through the wet lay-up process. These statistical tools enabled the researcher to present the data in an organized manner to facilitate a better understanding of the performance of each material.

Mean was the statistical tool used to describe the mechanical and physical properties of the abaca fiber composites and synthetic fiber composites in terms of tensile strength, flexural strength, density, and water absorption. The mean was used to determine the average value of the test results. The mean was used to determine the central value of the results obtained from the five (5) to ten (10) specimens for each test. This provides a representative value for each material in terms of tensile strength, flexural strength, water absorption, and density.

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Inferential statistics will be used to determine whether there are significant differences in the performance of the abaca and synthetic fiber composites based on the gathered test results. Independent Samples t-test was used to determine whether a significant difference existed between the mechanical and physical properties of abaca fiber composites and synthetic fiber composites in terms of tensile strength, flexural strength, density, and water absorption. The test was deemed appropriate because the study involved the comparison of two independent groups using numerical data obtained from experimental testing. The level of significance for this study was set at 0.05.

The data collected from the tests conducted were analyzed to compare both the mechanical and physical properties of abaca fiber and synthetic fiber composites. The analysis emphasized on interpreting the results of tensile strength, flexural strength, water absorption, and density in order to evaluate the performance of each material.

The computed mean values for all the tests were used as a primary basis for comparison between the performances of the two materials. These values depict the average performance of the specimens and provide an indication of which material performs better in each category. The standard deviation was also used to assess the reliability of the results obtained from the specimens.

A comparative analysis was performed by examining the differences in the mean values between abaca fiber and synthetic fiber composites. Higher values in terms of the material's tensile and flexural strength indicate better mechanical performance, while lower

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values in the water absorption test show higher moisture resistance. For density, lower values indicate lighter material, which may be beneficial depending on the application.

To further validate the comparison between the two materials, an independent samples t-test was performed to determine whether the observed differences between the two materials were statistically significant. The decision whether to accept or reject the null hypothesis was based on the p-value at a 0.05 level of significance.

RESULTS AND DISCUSSION

The following items are the tabulated data from the tests conducted by the DOST-STD for abaca fiber composites.

Table 2

Tabulated Data of the Tensile Strength Test of Abaca Fiber Composite

Specimen	Tensile Strength (MPa)	Tensile Modulus (MPa)	Stress at Tensile Strength (%)	Stress at Break (MPa)	Stress at Break (%)
1	42.10	5130	1.1336	42.10	1.1336
2	43.04	4820	1.2538	43.04	1.2538
3	48.38	5660	1.0913	47.75	1.0913
4	39.01	5480	1.0569	39.01	1.0569
5	48.60	5630	1.1526	47.38	1.1526

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Table 2 shows the DOST-STD-performed tensile strength test on five specimens only. Table 2 presents the tensile strength results of the abaca fiber composite specimens. The tensile strength values gathered ranged from 39.01 MPa to 48.60 MPa. Among the five specimens tested, Specimen 5 has the highest tensile strength at 48.60 MPa, while Specimen 4 has the lowest tensile strength at 39.01 MPa. The results indicate that the tensile strength values of all the specimens were relatively close to one another, which shows a consistent tensile performance of the abaca fiber composite. The variation in tensile strength among the specimens may be attributed to differences in fiber distribution and fiber-matrix adhesion.

Overall, the findings indicate that the abaca fiber composite possesses the ability to withstand tensile loading, with tensile strength values consistently exceeding 39 MPa. Based on the mechanical property values in the study of Khan et al. (2018), this suggests that abaca fiber reinforcement may be suitable for applications requiring low tensile strength.

Table 3

Tabulated Data of the Flexural Strength Test of Abaca Fiber Composite

Specimen	Flexural Modulus (MPa)	Flexural Strength (MPa)	Flexural Strain at Break (%)	Flexural Stress at Break (MPa)	Maximum Flexural Strain (%)
1	4510	76.3	2.7	76.3	2.7
2	3890	76.5	3.3	73.3	3.3

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3	4930	73.5	2.6	14.6	2.6
4	4340	67.7	2.7	13.5	2.7
5	4260	75.1	2.6	71.4	2.6

Table 3 shows the DOST-STD only performed flexural strength test on 5 specimens only. Table 3 presents the flexural test results of the abaca fiber composite specimens. The recorded flexural strength values from the test ranged from 67.7 MPa to 76.5 MPa. Among the five specimens tested, Specimen 2 has the highest flexural strength at 76.5 MPa, while Specimen 4 has the lowest flexural strength at 67.7 MPa. The results show that the flexural strength values of the specimens were comparable, demonstrating the ability of the abaca fiber composites to withstand bending loads. The small variation in flexural strength among the specimens suggests a consistent flexural performance of the composite material. Differences in the recorded values may be attributed to variations in fiber distribution, alignment, and bonding between the abaca fibers and the matrix during fabrication.

Overall, the findings show that the abaca fiber composites show satisfactory flexural strength, with most specimens exhibiting values above 73 MPa. Based on the mechanical property values in the study of Khan et al. (2018), this indicates that the material has good resistance to bending stresses and can carry moderate loads when subjected to flexural forces.

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Table 4

Tabulated Data of the Water Absorption Test of Abaca Fiber Composite

Specimen	Weight Before (g)	Weight Before (g)	Absorption (%)
1	10.7675	11.2830	4.7876
2	10.9346	11.4881	5.0619
3	11.0182	11.5703	5.0108

Table 4 shows the DOST-STD only performed water absorption test performed on three specimens. Table 4 presents the water absorption test results of the abaca fiber composite specimens. The percentage of water absorption ranged from 4.79% to 5.06% after immersion. Among the specimens tested, Specimen 2 has the highest water absorption value at 5.06%, while Specimen 1 has the lowest water absorption value at 4.79%. The results show that all specimens absorbed a relatively similar amount of water, which indicates consistent moisture absorption behavior among the abaca fiber composite specimens. The slight differences in absorption percentages may be attributed to variations in fiber distribution and porosity within the composite structure.

Based on the physical property values in the study of Khan et al. (2018), the findings reveal that abaca fiber composites have a moderate capacity to absorb water with absorption

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values close to 5%. This behavior is expected since abaca fibers are natural fibers that contain cellulose that has an affinity for moisture.

Table 5

Tabulated Data of the Density Test of Abaca Fiber Composite

Specimen	Weight of Specimen in Air (g)	Weight of Specimen in Liquid (g)	Volume of Sample (L)	Density at 23°C (g/cm³)	Specific Gravity of Sample in Water at 23°C
1	3.7687	0.4081	3.3693	1.1186	1.1214
2	4.0736	0.4399	3.6432	1.1183	1.1211
3	3.7347	0.3949	3.3483	1.1154	1.1182

Table 5 shows the DOST-STD only performed Density Test on three specimens only. Table 5 presents the density test results of the abaca fiber composite specimens. The recorded density values ranged from 1.1154 g/cm³ to 1.1186 g/cm³. Among the specimens tested, Specimen 1 has the highest density at 1.1186 g/cm³, while Specimen 3 has the lowest density at 1.1154 g/cm³. The results show that the density values of the specimens were very close to one another, showing very minimal variation among the specimens. This suggests that the composite fabrication process produced a uniform material with an even distribution of abaca fibers and matrix throughout the specimens.

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Overall, the findings demonstrate that the abaca fiber composite possesses a consistent density of approximately 1.12 g/cm³. Based on the mechanical property values in the study of Khan et al. (2018), the density value is low. The relatively low density of the composite suggests its potential suitability for applications where lightweight materials are desirable.

The following table presents the descriptive statistics of the mechanical and physical properties of abaca fiber composites in terms of tensile strength, flexural strength, density, and water absorption.

Table 6

Mean Values of Mechanical and Physical Properties of Abaca Fiber Composite

Property	Mean
Tensile Strength (MPa)	44.226
Flexural Strength (MPa)	73.820
Density (g/cm³)	1.117
Water Absorption (%)	4.953

Table 6 presents the mechanical and physical properties of abaca fiber composites in terms of tensile strength, flexural strength, density, and water absorption. The results showed that the abaca fiber composites obtained a tensile strength with a mean of 44.226 MPa and a flexural strength with a mean of 73.820 MPa. Moreover, the composites recorded a density

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with a mean of 1.117 g/cm³ and a water absorption percentage with a mean of 4.953%. These findings describe the measured mechanical and physical properties of the abaca fiber composites evaluated in the study. The results exhibited that the abaca fiber reinforced composites showed measurable and acceptable mechanical and physical properties that indicate their potential as composite reinforcement materials.

Table 7

Tabulated Data of the Tensile Strength Test of Synthetic Fiber Composite

Specimen	Tensile Strength (MPa)	Maximum Load (N)	Stress at Tensile Strength (%)
1	183.72000	17989.067	3.95454
2	207.78828	16920.270	164.41527
3	199.29663	15833.013	166.88628
4	207.48859	16677.389	184.77481
5	192.72527	17474.007	152.16469

Table 7 shows the DOST-STD only performed tensile strength test on five specimens. Table 7 presents the tensile strength test results of the synthetic fiber composite specimens. The recorded tensile strength values ranged from 183.72 MPa to 207.79 MPa. Among the five specimens tested, Specimen 2 has the highest tensile strength at 207.79 MPa, while Specimen

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1 has the lowest tensile strength at 183.72 MPa. The results indicate that the synthetic fiber composite demonstrated high tensile strength on all specimens. Although there are slight variations, the tensile strength values remained within a relatively narrow range, which suggests uniformity in the fabrication process and effective bonding between the synthetic fiber reinforcement and the matrix material. The variation in tensile strength may be attributed to factors such as fiber distribution and minor manufacturing inconsistencies. Nevertheless, the results show that the synthetic fiber composite shows excellent resistance to tensile loading, which enables it to withstand significant applied forces before failure.

Based on the mechanical property values in the study of Khan et al. (2018), the findings demonstrate that synthetic fiber reinforcement provides high tensile strength performance, with all specimens exhibiting values above 180 MPa. Compared to natural fiber composites, synthetic fiber composites generally offer superior tensile properties due to the inherent strength and durability of glass fibers, making them suitable for structural and engineering applications that require high load-bearing capacity.

Table 8

Tabulated Data of the Flexural Strength Test of Synthetic Fiber Composite

Specimen	Flexural Modulus (MPa)	Flexural Strength (MPa)	Flexural Strain at Break (%)	Flexural Stress at 5% Deformation (MPa)	Maximum Flexural Strain (%)
1	17500	164	5.1	146	5.1
2	18500	183	5.1	154	5.1

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3	18000	173	5.1	113	5.1
4	17900	171	5.1	146	5.1
5	16700	169	5.1	153	5.1

Table 8 shows that DOST-STD only performed a flexural strength test on five specimens. Table 8 presents the flexural strength test results of the synthetic fiber composite specimens. The recorded flexural strength values ranged from 164 MPa to 183 MPa. Among the five specimens tested, Specimen 2 has the highest flexural strength at 183 MPa, while Specimen 1 has the lowest flexural strength at 164 MPa. Based on the mechanical property values in the study of Khan et al. (2018), the results show that the synthetic fiber composite demonstrated high resistance to bending loads, as shown by the consistently high flexural strength values obtained from all specimens. The small variations among the results suggest good uniformity in the fabrication process and effective reinforcement provided by the synthetic fiber reinforced composite.

Differences in flexural strength values may be attributed to minor variations in fiber alignment and resin distribution. However, the overall consistency of the results indicates that the composite material maintained reliable flexural performance under loading conditions.

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Table 9

Tabulated Data of the Water Absorption Test of Synthetic Fiber Composite

Specimen	Weight Before (g)	Weight Before (g)	Absorption (%)
1	15.1907	15.2462	0.3654
2	15.5397	15.6041	0.4144
3	15.2073	15.2773	0.4306

Table 9 shows the DOST-STD-performed water absorption test on three specimens only. Table 9 presents the water absorption test results of the synthetic fiber composite specimens. The recorded water absorption values ranged from 0.3654% to 0.4306%. Among the specimens tested, Specimen 3 has the highest water absorption at 0.4306%, while Specimen 1 has the lowest absorption value at 0.3654%. The results show that the synthetic fiber composite absorbed only a minimal amount of water after immersion. The absorption values were relatively close to one another, which demonstrates consistent moisture resistance on all tested specimens. The slight differences between the specimens may be attributed to resin distribution and the possible presence of microscopic voids within the synthetic fiber reinforced composites.

Based on the mechanical property values in the study of Khan et al. (2018), the findings indicate that the synthetic fiber reinforced composites possess excellent resistance to water absorption, with all specimens recording absorption values below 0.5%. This low level of water absorption can be attributed to the non-hygroscopic nature of synthetic fibers. The

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results also suggest that synthetic fiber reinforced composites are suited for applications exposed to wet or humid environments, where moisture or water resistance is an important requirement.

Table 10

Tabulated Data of the Density Test of Synthetic Fiber Composite

Specimen	Weight of Specimen in Air (g)	Weight of Specimen in Liquid (g)	Volume of Sample (L)	Density at 23°C (g/cm³)	Specific Gravity of Sample in Water at 23°C
1	5.1858	2.0245	3.1696	1.6363	1.6404
2	4.7242	1.9953	2.7362	1.7268	1.7312
3	4.9698	1.9966	2.9815	1.6674	1.6715

Table 10 shows the DOST-STD performed density test on three specimens only. Table 10 presents the density test results of the synthetic fiber composite specimens. The recorded density values ranged from 1.6363 g/cm³ to 1.7268 g/cm³. Among the specimens tested, Specimen 2 has the highest density at 1.7268 g/cm³, while Specimen 1 has the lowest density at 1.6363 g/cm³. The results show that the density values of the synthetic fiber reinforced composite specimens were relatively close to one another, which suggests a uniform fabrication process and consistent material composition. The slight variation in density may

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be attributed to differences in fiber distribution, resin content, and the possibility of the presence of small voids within the composite structure.

Based on the mechanical property values in the study of Khan et al. (2018), the results demonstrate that the synthetic fiber reinforced composites have an average density of approximately 1.68 g/cm³, which is high. The results also suggest that the synthetic fiber reinforced composites offer a combination of material uniformity and structural strength, which makes it suitable for applications where improved mechanical performance is necessary.

The following table illustrates the mechanical and physical properties of synthetic fiber composites in terms of tensile strength, flexural strength, density, and water absorption.

Table 11

Summary Mean Values of Mechanical and Physical Properties of Synthetic Fiber Composites

Property	Mean
Tensile Strength (MPa)	198.206
Flexural Strength (MPa)	172.000
Density (g/cm³)	1.677
Water Absorption (%)	0.413

Table 11 shows the descriptive statistics of the mechanical and physical properties of synthetic Fiber composites in terms of tensile strength, flexural strength, density, and water

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absorption. The synthetic fiber composites obtained a tensile strength with a mean of 198.206 MPa and a flexural strength with a mean of 172 MPa. In addition, the composites recorded a density with a mean of 1.677 g/cm³ and a water absorption percentage with a mean of 0.413%. The findings exhibited that synthetic fiber reinforced composites showed better mechanical and physical properties compared to abaca fiber reinforced composites.

Table 12

Test of Significant Difference between the Mechanical and Physical Properties of Abaca Fiber Composites and Synthetic Fiber Composites

Property	t-value	Df	p-value	Decision	Interpretation
Tensile Strength (MPa)	-31.153	8	0.000	Reject	Significant
Flexural Strength (MPa)	-27.852	8	0.000	Reject	Significant
Density (g/cm³)	-21.056	4	0.000	Reject	Significant
Water Absorption (%)	51.245	4	0.000	Reject	Significant

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The following table presents the results of the Independent Samples t-test conducted to determine the significant difference between the mechanical and physical properties of abaca fiber composites and synthetic fiber composites in terms of tensile strength, flexural strength, density, and water absorption. Table 12 presents the results of the independent samples t-test conducted to determine the significant difference between the mechanical and physical properties of abaca fiber composites and synthetic fiber composites.

The results showed significant differences in tensile strength with a t-value of -31.153, p value of 0.000 and degrees of freedom value of 8; flexural strength with a t-value of -27.852, p value of 0.000 and degrees of freedom value of 8; density with a t-value of -21.056, p value of 0.000 and degrees of freedom value of 4; and water absorption with a t-value of 51.245, p value of 0.000 and degrees of freedom value of 4.

Since all computed p-values were lower than the 0.05 level of significance, the null hypothesis was rejected. A comparison of the mean values showed that abaca fiber composites obtained lower tensile strength, flexural strength, and density than synthetic fiber composites. However, abaca fiber composites exhibited higher water absorption than synthetic fiber composites. These findings indicate that the mechanical and physical properties of the two composite materials differ significantly.

The following table presents the comparison between abaca fiber composites and synthetic fiber composites based on the results of the mechanical and physical tests conducted in terms of tensile strength, flexural strength, density, and water absorption.

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Table 13

Comparison Between Abaca Fiber Composites AND Synthetic Fiber Composites Based on the Results of the Mechanical AND Physical Tests

Property	Abaca Fiber Composite	Synthetic Fiber Composite	Comparative Description
Tensile Strength (MPa)	44.226	198.206	Abaca fiber composite obtained a lower value
Flexural Strength (MPa)	73.820	172.000	Abaca fiber composite obtained a lower value
Density (g/cm³)	1.117	1.677	Abaca fiber composite obtained a lower value
Water Absorption (%)	4.953	0.413	Abaca fiber composite obtained a higher value

Table 13 presents the comparison between abaca fiber composites and synthetic fiber composites based on the results of the mechanical and physical tests. The results showed that synthetic fiber composites obtained higher mean values in tensile strength, flexural strength, and density than abaca fiber composites. In contrast, abaca fiber composites recorded a higher mean value in water absorption. These results show variations in the measured

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properties of the two composite materials. Based on the test results, synthetic fiber composites exhibited higher tensile strength, flexural strength, and density, whereas abaca fiber composites exhibited higher water absorption.

The results imply that synthetic fiber composites are more suitable for aircraft applications that require higher mechanical strength, stiffness, and resistance to moisture absorption. Their higher tensile and flexural strengths indicate a greater ability to withstand tensile and bending loads, while their lower water absorption suggests better dimensional stability and durability in humid or wet environments. On the other hand, the lower density value of abaca fiber composites indicates a lighter material, which may be advantageous in aircraft applications where weight reduction is important. However, the higher water absorption percentage and lower mechanical strength of abaca fiber composites suggest that additional treatments may be necessary to improve their performance for structural applications.

Despite these limitations, abaca fiber composites remain a sustainable alternative in low load applications aircrafts and non-structural aircraft applications, including cabin interior panels, partitions, and decorative components. They also have an advantage in terms of sustainability due to their renewable nature and biodegradability.

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Conclusion

Based on the findings of the study, the following conclusions were drawn. Abaca fiber composites possess low mechanical and accepted physical properties for lightweight composite applications. The material demonstrated the ability to withstand low to moderate tensile and flexural loads while maintaining a relatively low density. However, the higher water absorption values show that water or moisture susceptibility remains one of its limitations. Despite this, abaca fiber composites show potential for non-structural applications where low to moderate strength and lightweight characteristics are needed.

Synthetic fiber reinforced composites revealed excellent mechanical and physical properties. The material showed significantly higher tensile and flexural strength values, which indicate better structural performance. Its low water absorption and consistent density suggest excellent durability and resistance to environmental factors. These characteristics make synthetic fiber composites highly suitable for aviation education applications and aircraft structural applications that demand strength, reliability, and moisture resistance.

There are significant differences between the mechanical and physical properties of abaca fiber reinforced composites and synthetic fiber reinforced composites. The statistical analysis confirmed that the two materials differ substantially in tensile strength, flexural strength, density, and water absorption. Therefore, the performance of synthetic fiber composites cannot be considered equivalent to that of abaca fiber composites. The rejection of the null hypothesis supports the conclusion that material type significantly influences composite performance. However, due to the results of the tests, abaca fiber composites can

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still be used in an aviation education setting and applications in aircraft where low to moderate mechanical strength is needed.

Based on the comparative analysis, synthetic fiber composites demonstrated better overall performance in terms of mechanical strength and water resistance. However, abaca fiber composites showed lower density, which makes them lighter and potentially more sustainable. While synthetic fiber composites remain the preferred choice for structural and high-performance applications, abaca fiber composites show potential as an eco-friendly alternative for educational settings, laboratory instructional materials, and other non-critical applications in aircraft where extreme mechanical strength is not required.

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