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SYNTHESIS AND CHARACTERIZATION OF MECHANICAL AND PHYSICAL PROPERTIES OF FALSE BANANA (ʾƏNÄSÄTƏ) FIBER REINFORCED COMPOSITE MATERIAL

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Abstract

The use of environmentally friendly materials has recently been promoted due to increased awareness of environmental issues. To offer a better world for future generations, we must decide what we will utilize and serve today. When resources and products reach the end of their useful lives, resource preservation and degradation become issues. Biodegradable products manufactured from renewable resources address these issues. This research aims to develop a biodegradable resource of false banana (ʾənäsätə) fiber as reinforcement with polyester resin composite material manufactured by hand lay-up method at room temperature. The mechanical and physical properties of the produced sample were investigated. include tensile, flexural, impact strength, and water absorption. The fiber surface was treated with NaOH alkaline in distilled water solution. In composites, the fiber orientations were 0^o, 90^o, $45^o/-45^o$, $0^o/90^{o,}$ and chopped, at 40% fiber volume fraction. The sample's production process was performed successfully. A chopped sample is an easier manufacturing process relative to the other. As the result, 0^o fiber direction scored the highest tensile strength, which is 181.41MPa. In the flexural and impact strength test, a 90^o oriented fiber was observed with the highest value, which is 81.43 MPa and 9.75 joules, respectively. The samples were immersed in distilled water until saturated. The highest percentage of water absorption was $45^o/-45^o$ oriented fiber. Many researchers have recently shown interest in natural fiber composites material for aerospace and automotive applications, such as aircraft radomes and interior cabin components, as well as remarks on natural fiber composites' future trends and problems. This article provides readers with a positive perspective and piques industry players' interest in the potential of using natural fiber composites in aerospace applications to improve current aerospace material performance, particularly in terms of lightweight and environmental sustainability.

Keywords: ***Composite, Fiber, Manufacturing, Matrix, Reinforcement, Sustainability***

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I. Introduction

A composite material is made up of at least two materials that work together to provide properties that are better than the sum of their parts. Composite materials are used for parts mostly because of their weight savings and relative stiffness and strength. New products, processes, and applications are constantly being developed in the composites industry, such as the use of hybrid virgin and recycled fibers, as well as faster and more automated manufacturing. Like all engineering materials, composites have specific strengths and limitations that should be considered during the specification process. However, the ability to adjust the combination of reinforcement and matrix to satisfy the necessary final properties of a component has been the major driving force behind the production of composites. Fiber extraction has been done from ʾənäsätə (False banana), sisal, jute, and banana for making new environmentally friendly and biodegradable composite materials (these composites are called 'Green Composites' for some reason) [1]. Recent research in natural fiber composites has resulted in a major change in renewable-source fabrics and increased support for global sustainability. These natural fiber composites possess moderate strength and thermal stability when they are recyclable, but they need specific application deals with particular places.

The need for renewable fiber reinforcement composites was increased in the last decade. The literature contains several studies on the manufacture of composite boards using particles or fibers from a different source and synthetics binder for bonding the fibers. Composite materials focused their attention on a lightweight natural fiber composite to create economical and lightweight engineering applications. Natural fibers were found in large amounts in nature, and their biodegradability features, their contribution to global environmental sustainability, the fact that they are economical, and have a good balance between mechanical properties and lightweight makes them preferable [2]. The treatment of composite materials is aimed at improving the mechanical properties of alkali-treated fabric composites compared to untreated fabric composites [3] [4]. The effect of fiber concentration and fiber size was conducted on mechanical properties. According to the result, small-size rice husk fibers have maximum tensile strength, and large-size rice husk fibers have a minimum tensile strength. The composites were prepared by the hand layup method [5]. The Fourier transform infrared spectroscopy spectra analyzed the corresponding peak

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of cellulose fiber and Urea Formaldehyde resin composite for a mechanical property of compressive strength and water absorption test, and it was found that fiber loading increased the mechanical strength of composites up to 30% of fiber loading. Additionally, the cellulose fiber loading is increased while the water absorption of the composite increases. Because of this, the composites were more biodegradable and eco-friendlier [6]. The effect of alkaline treatment of soaking time on the natural fiber surface and the mechanical property of tensile strength was presented [7]. Fiber dispersion was identified as a major factor influencing the characteristics of short fiber composites and a particular challenge for Natural Fiber Composites (NFCs), which commonly have hydrophilic fiber and hydrophobic matrices. The use of longer fibers can increase their tendency to agglomerate. Good fiber dispersion promotes good interfacial bonding by reducing voids by ensuring that fibers were completely surrounded by the matrix [8].

This paper explored the technical properties of a new product produced from ʾənäsätə fiber. The product was tested to determine its usefulness as new composite material and analyze its mechanical characteristics (such as tensile strength, impact strength, and flexural strength) to the convenient production of eco-design methodology based on the inherent product of ʾənäsätə fiber, which is extremely abundant in South Nations Nationalities and Peoples Regional State, Ethiopia.

II. Research Methodology

The hand lay-up technique is the easiest way to process composites. This approach has a low infrastructure requirement as well. By using this technique, samples were manufactured and their mechanical and physical properties were analyzed. ʾənäsätə fiber as reinforcement and unsaturated polyester resin as a matrix were utilized as a composite material.

A. False Banana (ʾənäsätə) Fiber and Preparation

ʾənäsätə plant is used to produce foods like *'qoč'o'* and *'bula'*, especially in the southern region of Ethiopia. ʾənäsätə fiber is extracted in the process of preparing food as shown in Fig. 1. The false banana plant does not require very large rainfall and grows in tropical countries at an elevation of 1000m-1600m. It requires a warm climate. The lengths of the strands vary substantially depending on the fiber's particular source and treatment during fiber extraction. Fiber strands from the middle sheaths can be as long as 15 ft or more if stripped from the whole length of the sheaths, as in hand or machine stripping; normal length ranges from 3 to 15 ft [9]. Polyester resin is used as a matrix.

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This resin is used as a critical matrix material for a wide variety of applications [10]. Alkaline treatment is one of the most used treatments of natural fibers when used as reinforcement in thermoplastics and thermosets. In this study, sodium hydroxide (NaOH) was chosen because of its low cost and effectiveness [11],[12]. ʾənäsätə fiber is used in Ethiopian house construction for an interior part by mixing with gypsum. Therefore, based on its properties, it is chosen for the production of composite material because it has high mechanical strength and availability. The physical properties of the fiber are as follows: - a diameter is 0.2-0.26mm, Density is 1.38g/cm^3, and specific gravity is 0.9.

A B c

Fig. 1. Fiber production, A) Plantation, B) Fiber production, and c) Dried fiber

Sample Preparation Method

The preparation of this composite material utilized false banana (ʾənäsätə) fiber and polyester resin. The size of the molding profile was 350mm in width, 400mm in length, and 4mm in thickness prepared by cast iron. NaOH solution was used for fiber surface treatment. After immersing the fiber for 24 hours, it was dried by sunlight, and the fiber orientation was prepared as shown in Fig. 2. Then, the release agent (wax) was coated on the mold surface to prevent the polymer stitched on the surface. Fibers were cut and positioned as per the size of the mold in the form of a chopped strands, 0^0, 90^0, 45^0, and $0^0/90^0$ as shown in Fig. 3. The liquid polyester resin was then carefully combined with a hardener in a 10:1 ratio based on a manual prescription of hardener and poured onto the reinforcement board. The resin was uniformly spread by using a roller brush; it is used to remove air and excess matrix. The thickness of the composite panel was 4±0.15.

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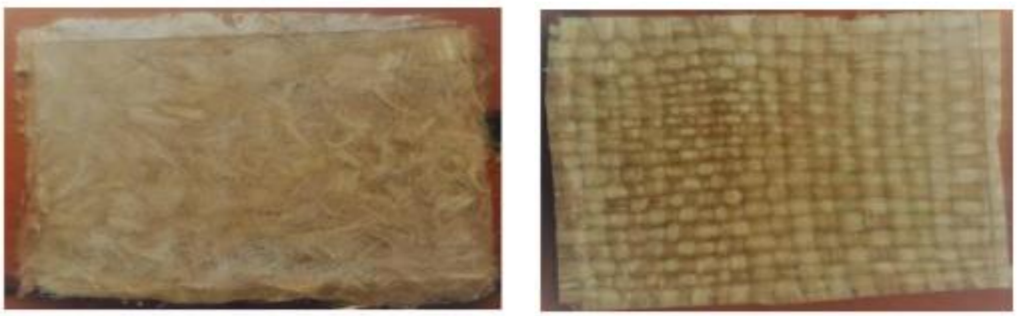
a b

Fig. 2. Preparation of fiber orientation, a) Unilateral and b) Bilateral



A **B**

C **D**

Fig. 3. Composite Products, a) Chopped type, b) Bilateral (0°/90°), c) Bilateral (45°/45°), and d) Unilateral (0° or 90°)

C. Mechanical Properties

The mechanical and physical properties of the built composites of the natural fiber-reinforced composite material were investigated. These are tensile strength, flexural strength, impact strength, and water absorption. The investigated product of composites was cut as per ASTM standards

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dimension that is D638 for a tensile test, D790 for a flexural test, D256 for an impact test, and D5229M-12 for a water absorption test.

III. Results and Discussion

Manufactured composites of the ʾənäsätə fiber are the reinforcement and the polyester resin forms the matrix, which cross-links the reinforcing fiber and gives its shape with special oriented reinforcement. In addition to this work, the influence of the reinforcing fiber orientation was studied. As shown in experiments, changes in the fiber orientation angle can decrease the strength of the material in specific test directions that significantly improved the mechanical properties of oriented reinforcement composite materials [13].

A. Tensile Strength Analysis

The ultimate tensile strength test analysis is dependent on the fiber orientation as shown in Fig. 4 set up of the Universal Material Testing Machine. The 0°-oriented sample is the highest ultimate tensile strength. It scored 181.41MPa because fibers are oriented parallel to the direction of applied force as shown in Fig. 6b. Concerning fiber orientations, tensile strength will be greatest in the loading direction [14],[15]. Not all specimens broke in the middle section as shown in the failure mode of the specimen. Because the experiments were performed, a significant difference was shown between specimens with the same build parameters. However, in the same building parameter of the specimen, no significant difference was performed [16].

A B C

Fig. 4. Tensile test, A) specimen, B) Universal Material Testing Machine (Bairoe, Model No. HUT-2000) (Federal Technical and Vocational Education Training Institute lab, Addis Ababa, Ethiopia), and C) The failure mode of the tensile-tested specimen (ware 1, 90 deg.; 2, 0/90 deg.; 3, 45 deg.; 4, Copped fiber)

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B. Flexural Strength Analysis

A flexural strength property test was carried out in terms of the force-deflection relationship using the standard method of testing ASTM D790 [17]. Universal Testing Machine (hydraulic universal Amsler testing machine) as shown in Fig. 5 performed the test. The results have recorded the force and deflection in the table with a constant speed of 0.6 mm/min at room temperature by applying a maximum load cell of 25kN. Flexural strength was increased due to the perpendicularity of the fibers loading with a force direction increase as shown in Fig. 6a; the 90^o specimen of loading fiber composite was observed with the highest value of 81.43 MPa. The perpendicular direction of loading with the fiber orientation was the higher flexural strength compared to the other [18]. Therefore, when the angle of the fiber loading direction was decreased, the flexural strength also decreased. Chopped fiber is made of a maximum 50mm length randomly and yet evenly distributed strand. It is an easier manufacturing process relative to the other. In addition, good strength was observed. Especially, it is very important for preventing surface cracking because it is a control of three-dimensional force [19]. The failure mode of flexural-tested specimens was observed almost at the center, but some samples were not like that because the thickness and fiber distribution was not exactly the same overall surface. The thickness of the entire area varies by ±0.25mm.

a **b** **c**

Fig. 5. Flexural test, a) Specimen, b) Universal testing machines (hydraulic universal Amsler testing machine) Ethiopian environment and forest research institute lab, Addis Ababa, Ethiopia, and c) The failure mode of flexural-tested specimen

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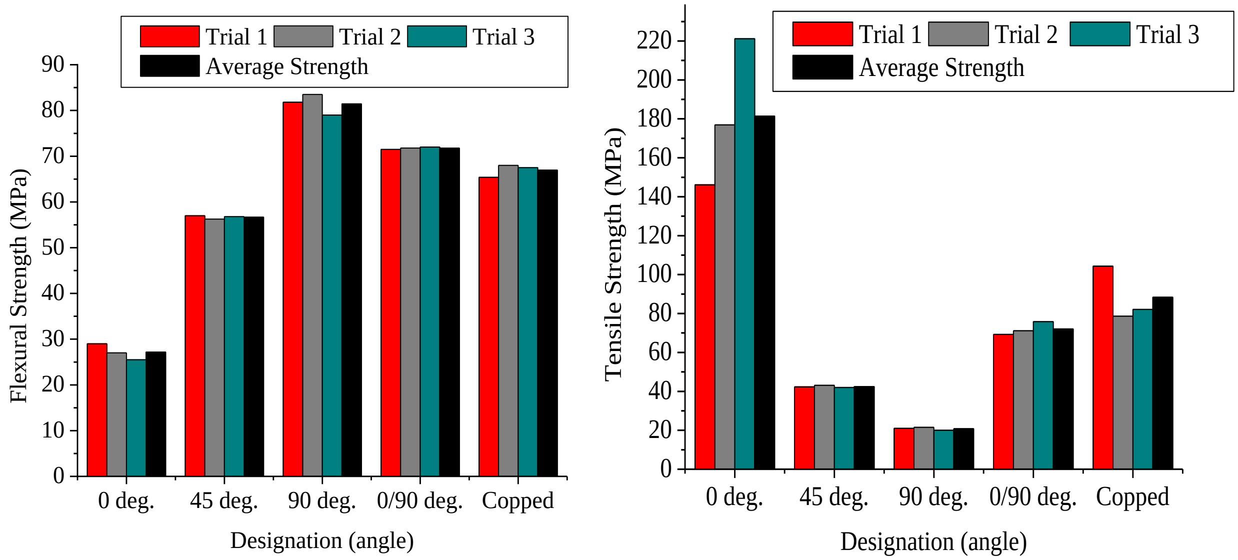

a b

Fig. 6. Strength analyses a) Flexural, b) Tensile strength

C. Impact Strength Analysis

The Izod impact test is used to determine and compare a material of hardness or toughness. V-notches are used on Izod specimens (Fig. 7) to prevent deformation due to energy. In this work, the capacity of a machine is performed at 30J (model; EKE MAT 20) impact on the specimen. The orientation of fibers is the perpendicular direction from a direction of impact force on the specimen having the highest value [20]. Therefore, the sample 90^{o} oriented fiber scored the highest value which is 9.75 joules. The 45^{o}/45^{o} and chopped fiber orientation conducted a high energy absorption capacity than the 0^{o}/90^{o} orientation as shown in Fig. 8.

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a **b** **c** **d** **E**

Fig. 1. Impact testing specimen, a) 90^0 with force direction, b) 0^0 with force direction, c) $0^o/9^o$ fiber orientation, d) $45^o/45^o$ fiber orientation, and e) chopped fiber

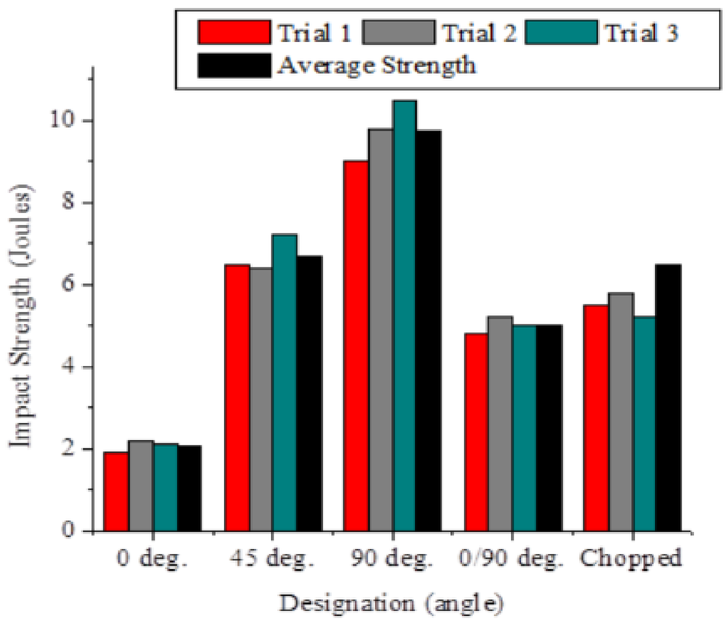

Fig. 8. Impact strength tested analysis

D. Water Absorption Analysis

The samples were soaked in purified water for 120 hours to study water absorption behavior. The water absorption test is used to measure material quality and strength [21]. The 45^o oriented fiber's mechanical strength is found to be lower. As shown in Fig. 8, the highest percentage of water absorption was by the 45^o oriented overlapped fiber portion, which is 15.67% within formed porous portion in the middle part of overlapping fiber and rest portion fiber is not getting wet easily [22]. Water absorption for ʾənäsätə fiber with unsaturation polyester resin composite was

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constant after 72 hours. Wood plastic composites absorb more water as a result of hydrophilic content factors [23].

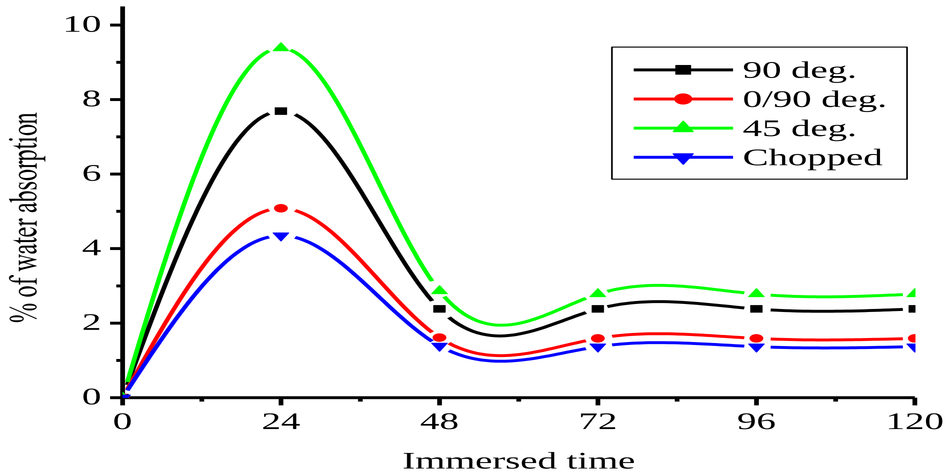

Fig. 9. Rate of water absorption

IV. Conclusion

Samples have been successfully produced by the Hand Lay-up method. The study showed that although the amount of fiber in the composite is the same, they have different mechanical properties due to different fiber orientations. The studied mechanical properties are tensile strength, flexural strength, impact strength, and water absorption rate. Therefore, as the degree of fiber orientation increased from the direction of applied force, the mechanical properties of a composite decreased. The highest value of tensile strength was 0^{o} oriented fiber which scored 181.41MPa because of fibers oriented parallel to the direction of applied force. The highest value of the flexural strength specimen of 90^{o} oriented fiber loading composite was observed at 81.43 MPa. The chopped fiber was an easier manufacturing process relative to the other. In addition, good strength was observed. Especially, it is very important for preventing surface cracking because it is a control of three-dimensional force. The impact strength value of the V-notch set-up in a perpendicular direction is higher than that in the longitudinal direction of the fiber. The sample of the 90^{0}-oriented fiber performed at the highest value of 9.75 joules. The 45^{0}/45^{0} and chopped fiber orientations conducted a high energy absorption capacity than the 0^{0}/90^{0} orientations. The water absorption analysis was performed in distilled water until the saturation phase for 120 hours. The highest percentage of water was absorbed in the sample of 45^{0}/45^{0} oriented fiber.

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