ISSN (E): 2959-3921 Ethiopian International Journal of Engineering and Technology (EIJET)
(P): 2959-393X (Provisional) Volume 1, Issue 1, 2023
DOI: https://doi.org/10.59122/134CFC10

Synthesis and Characterization of Mechanical and Physical Properties of False Banana (ʾənäsätə) Fiber Reinforced Composite Material

Belay Taye Wondmagegnehu[1*], Zewdie Alemayehu[2]
[1,2] School of Mechanical and Automotive Engineering, Dilla University, Ethiopia
*Corresponding Author's Email: belaytaye1@gmail.com

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. As resources and products reach the final stage of their usability, the preservation of remaining materials and reduction of degradation emerge as challenges that must be addressed. Biodegradable materials produced from recyclable resources deal with these issues. This study intends to make a recyclable resource of false banana (ʾənəsätə) fiber as reinforcement with polyester resin composite material produced 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 manufacturing process was accomplished fruitfully. A chopped sample is a simpler production process compared 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

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 1, Issue 1, 2023

I. Introduction

According to [1] composite material is basically a combination of at least two different materials, engineered to create superior properties—the whole being much better than the individual pieces. These materials are primarily chosen for manufacturing parts because they offer outstanding weight savings combined with impressive stiffness and strength [1]. The composites industry is constantly pushing limits by developing new products and processes, such as combining brand-new fibers with recycled ones and moving toward faster, more automated production [1]. However, like any engineered material, composites come with unique advantages and disadvantages that must be carefully weighed during the design and selection process [1]. Fiber extraction has been done from ʾənəsätə (False banana), sisal, jute, and banana for producing new ecofriendly and recyclable composite materials referred to as 'Green Composites' [2]. 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 [3]. The treatment of composite materials is aimed at improving the mechanical properties of alkali-treated fabric composites compared to untreated fabric composites [4] [5]. 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 [6]. The Fourier transform infrared spectroscopy spectra analyzed the corresponding peak 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 [7]. The effect of alkaline treatment of soaking time on the natural fiber surface and the mechanical property of tensile strength was presented [8]. Fiber dispersion was identified as a major factor influencing the characteristics of short fiber composites and a particular challenge for Natural Fiber

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

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 [9].

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

ʾƏnəsätə plant is used to produce foods like *'qoč'o'* and *'bula',* mainly in the southern Ethiopia. ʾənəsätə fiber is removed from the pseudo stem of the plant in the procedure of extracting edible food from it [1] as indicated in Fig. 1. The false banana plant is drought resistant and grows in tropical countries between elevations of 1000m-1600m [1]. It needs a warm climatic condition. The lengths of the strands differ considerably based on the fiber's specific source and handling during fiber removal [1]. 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 [10]. Polyester resin is used as a matrix. This resin is used as a critical matrix material for a wide variety of applications [11]. Alkaline treatment is among the dominantly used treatments of natural fibers when employed as reinforcement in thermoplastics and thermosets [1]. In this study, sodium hydroxide (NaOH) was chosen because of its low cost and effectiveness [12],[13]. 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.

Received: *23 February 2022;* **Revised:** *25 March 2023;* **Accepted:** *27 March 2023;* **Published:** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

A B c

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

B. Sample Preparation Method

The manufacturing of this composite material used false banana (ʾənəsätə) fiber and polyester resin as ingredients [1]. The size of the molding profile was 350mm in width, 400mm in length, and 4mm in thickness produced by cast iron [1]. NaOH solution was employed for fiber surface treatment [1]. After immersing the fiber for 24 hours, it was sun dried, and the fiber orientation was prepared [1] as shown in Fig. 2. Then, the release agent (wax) was covered on the mold exterior to avert the polymer stitched on the surface [1]. Fibers were cut and placed as per the size of the mold in the form of a chopped components [1], 0^0, 90^0, 45^0, and $0^0/90^0$ as shown in Fig. 3. Then, the fluid polyester resin was prudently combined with a hardener in a 10:1 ratio [1] based on a manual prescription of hardener and dispensed onto the strengthening board. The resin was regularly spread with a roller brush; it is applied to eliminate air and surplus matrix [1]. The thickness of the composite panel was 4±0.15.

a b

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

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921 Ethiopian International Journal of Engineering and Technology (EIJET)
(P): 2959-393X (Provisional) Volume 1, Issue 1, 2023
DOI: https://doi.org/10.59122/134CFC10

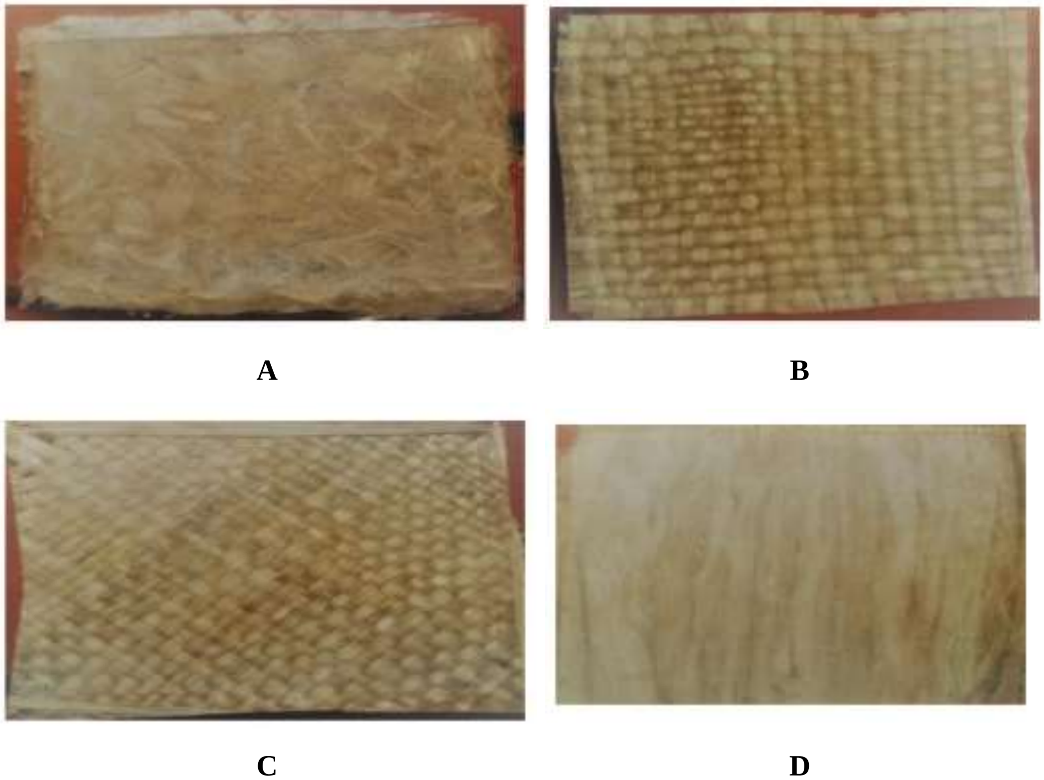


Fig. 3: Composite Products, a) Chopped type, b) Bilateral (0º/90º), c) Bilateral (45º/45º), and d) Unilateral (0º or 90º)

C. Mechanical Properties

The mechanical and physical behaviors of the constructed 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 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 [1].

III. Results and Discussion

Produced composites of the ʾənəsätə fiber are the strengthening while the polyester resin forms the matrix, which cross-links the strengthening fiber and provides its shape with distinct oriented reinforcement. Furthermore, the influence of the strengthening fiber positioning was investigated. 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 [14].

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

A. Tensile Strength Analysis

The definitive tensile strength test analysis is reliant on the fiber positioning as shown in Fig. 4 set up of the Universal Material Testing Machine [1]. The 0º-oriented sample is the highest definitive tensile strength with a score 181.41MPa because fibers are positioned parallel to the direction of applied force as shown in Fig. 6b similar to the findings of [1]. Concerning fiber orientations, tensile strength will be greatest in the loading direction [15],[16]. Similar to the findings of [1], not all specimens broke in mid-section as indicated in the failure mode of the specimen. When the experiments were executed, a substantial difference was observed between specimens with the same build parameters [1]. However, in the same building parameter of the specimen, no significant difference was performed [17].

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)

B. Flexural Strength Analysis

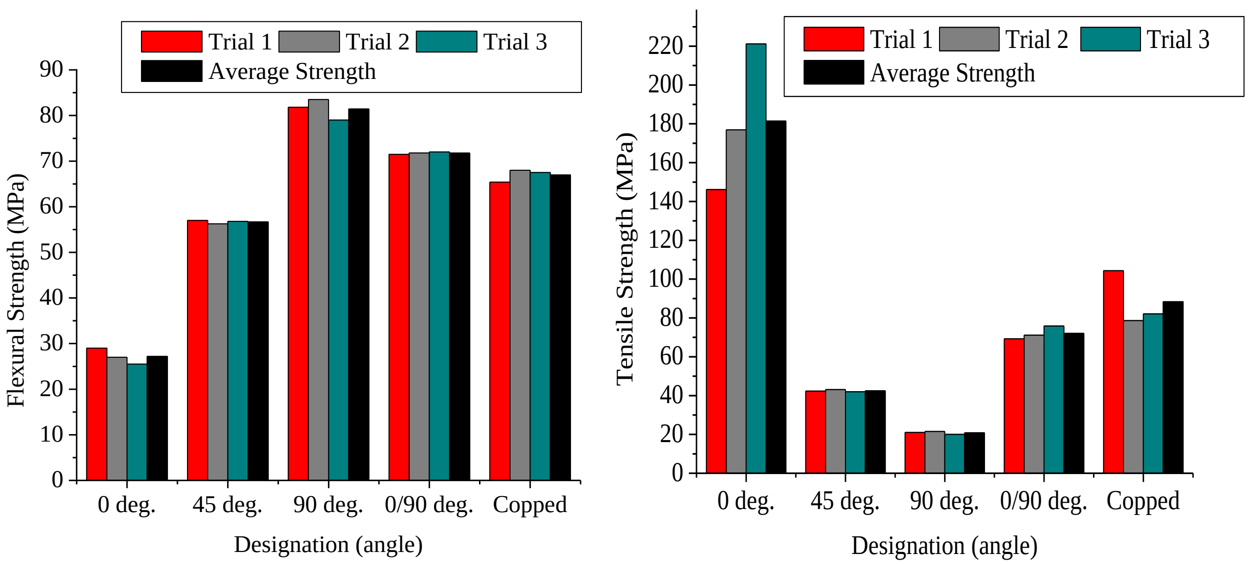
A flexural strength property test was carried out in terms of the force-deflection relationship using the standard method of testing ASTM D790 [18]. Universal Testing Machine (hydraulic universal Amsler testing machine) as shown in Fig. 5 performed the test. Similar to [1], the results have documented the force and deflection with a permanent speed of 0.6 mm/min at room temperature by loading a maximum load cell of 25kN. Flexural strength was improved due to the orthogonality of the fibers loading with a force direction rise [1] as shown in Fig. 6a; similar to [1], the 90º specimen of loading fiber composite was noted for its highest value of 81.43 MPa. The perpendicular direction of loading with the fiber orientation was the higher flexural strength compared to the other [19]. Therefore, as the angle of the fiber loading direction lowers, the flexural strength also lowers. Chopped fiber is created from a maximum 50mm length randomly but still consistently spread as a strand. This is a simpler production method compared the other. Moreover, good strength was noted. Especially, it is very important for preventing surface cracking because it is a control of three-dimensional force [20]. Similar to [1], the failure mode of flexural-tested specimens was

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

noted near the center, but some samples were different due to the thickness and fiber distribution difference over all surfaces. The thickness of the whole area differs 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



a b

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

C. Impact Strength Analysis

The Izod impact test is carried out to find out and compare the hardness or toughness of a material V-notches are used on Izod specimens (Fig. 7) to avoid deformation due to energy [1]. The dimensions of a machine are executed at 30J (model; EKE MAT 20) impact on the specimen in this study. The orientation of fibers is the perpendicular direction from a direction of impact force on the specimen having the highest value [21]. Therefore, the sample 90° oriented fiber scored the highest value which is 9.75 joules. The

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

ISSN (E): 2959-3921
(P): 2959-393X (Provisional)
DOI: https://doi.org/10.59122/134CFC10

45º/45º and chopped fiber positioning showed an elevated energy absorption ability than the 0º/90º orientation as shown in Fig. 8.

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

Fig. 7: Impact testing specimen, a) 90^0 with force direction, b) 0^0 with force direction, c) 0º/9º fiber orientation, d) 45º/45º fiber orientation, and e) chopped fiber

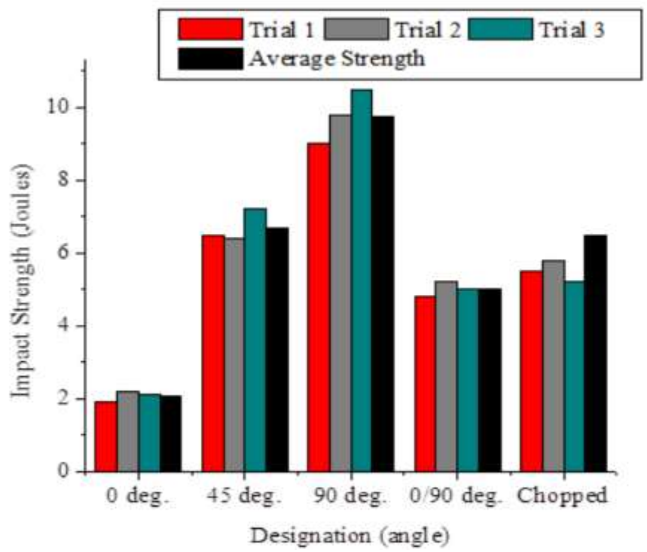


Fig. 8: Impact strength tested analysis

D. Water Absorption Analysis

As suggested in [1] the trial specimens were drenched in cleansed water for 120 hours to examine water absorption property. The water absorption test is used to measure material quality and strength [22]. The 45º oriented fiber's mechanical strength is found to be lower. As depicted in Fig. 8, the biggest proportion of water absorption was by the 45º 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 [23]. Water absorption for ʾənəsätə fiber with unsaturated polyester resin composite was continuous after 72 hours. Wood plastic composites absorb more water as a result of hydrophilic content factors [24] and depicted in Fig. 9.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

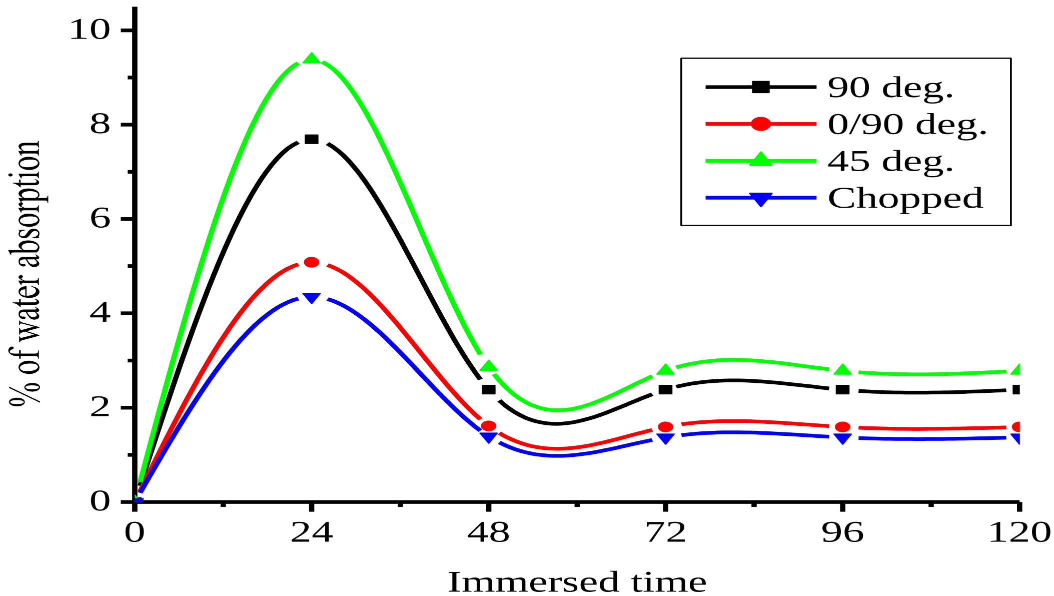


Fig. 9: Rate of water absorption

IV. Conclusion

Samples were efficaciously manufactured by the Hand Lay-up method. The research revealed that even if the quantity of fiber in the composite is identical, they have varying mechanical behaviors because of varying fiber positionings similar to the findings of [1]. The mechanical properties examined are tensile strength, flexural strength, impact strength, and water absorption rate. The results showed that the mechanical behaviors of the composites declined as the degree of fiber positioning rose from the direction of exerted force. The maximum score of tensile strength was 0^{o} positioned fiber which was 181.41MPa due to the orientation of fibers analogous to the path of exerted force. The maximum score of the flexural strength specimen of 90^{o} positioned fiber loading composite was noted at 81.43 MPa, similar to [1]. The chopped fiber was found to be a simpler production procedure compared to the other in agreement with the findings of [1]. Furthermore, decent strength was detected. Particularly, it is highly vital for averting surface cracking since it is a control of three-dimensional force as similarly observed in [1]. The V-notch's impact strength score when arranged in an orthogonal alignment is bigger than the longitudinal alignment of the fiber. The sample of the 90^{0}-positioned fiber functioned at the maximum score of 9.75 joules. The $45^{0}/45^{0}$ and sliced fiber orientations showed a better energy absorption ability compared to the $0^{0}/90^{0}$ orientations. The analysis of water absorption was carried out in distilled water for 120 hours up until it reached the saturation phase. The maximum proportion of water was absorbed in the trial specimen of $45^{0}/45^{0}$ positioned fiber.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

References

1. Wondmagegnehu, B. taye, Alemayehu, Z., Yohannes, G., & Gulte, E. (2022). Development and Characterization of False Banana (Enset) Fiber Reinforced Composite Material. Journal of Natural Fibers, 19(15), 12347–12360. https://doi.org/10.1080/15440478.2022.2057386
2. Verma, D., P. C. Gope, X. Zhang, S. Jain, and R. Dabral., "Green composites and their properties: a brief introduction," *In Green Approaches to Biocomposite Materials Science and Engineering* pp. 148-164. IGI Global. DOI: 10.4018/978-1-5225-0424-5.ch007, 2016.
3. Rangappa, S. M., and S. Siengchin, "Lightweight natural fiber composites." *Journal of Applied Agricultural Science and Technology*, 3(2): 178-178., 2019. doi.org/10.32530/jaast.v3i2.108
4. Motaleb, A. K. Z. M., "Improvement of mechanical properties by alkali treatment on pineapple and jute fabric reinforced polyester resin composites." *International Journal of Composite Materials*, 8(2): 32-37, 2018. DOI: 10.5923/j.cmaterials.20180802.02
5. Susilowati, D. S. S. E., and D. Sumardiyanto, "Assessing mechanical properties of pineapple leaf fibre (plf) reinforced composites for automotive applications," *International Journal of Composite Materials*, 8(3): 57-63, 2018.doi:10.5923/j.cmaterials.20180803.02
6. Ondiek, W. O., H. T. Ngetha, J. N. Keraita, and J. B. Byiringiro, "Investigating the effect of fiber concentration and fiber size on mechanical properties of rice husk fiber reinforced polyester composites," *International Journal of Composite Materials*, 8(5): 105-115, 2018. doi:10.5923/j.cmaterials.20180805.01
7. Pokhrel, S., et al, "Eco-friendly urea-formaldehyde composites based on corn husk cellulose fiber," *International Journal of Composite Materials*, 10(2): 29-36, 2020. doi 10.5923/j.cmaterials.20201002.01.
8. Ridzuan, M.n, et al, "The effects of the alkaline treatment's soaking exposure on the tensile strength of Napier fibre." *2nd International Materials, Industrial, and Manufacturing Engineering Conference,* MIMEC2015, Procedia Manufacturing, *2*, 353-358, 2015. doi.org/10.1016/j.promfg.2015.07.062
9. Pickering, K. L., M. G. A. Efendy, and T. M. Le, "A review of recent developments in natural fiber composites and their mechanical performance," Composites Part A: *Applied Science and Manufacturing*, 83, 98-112, 2016. doi.org/10.1016/j.compositesa.2015.08.038
10. Getu Temesgen, Alhayat, and Omprakash Sahu, "Process ability enhancement of false banana fiber for rural development," *Cellulose,* 67(67.89): 67-63,2014.
11. Davallo, M., H. Pasdar, and M. Mohseni, "Mechanical properties of unsaturated polyester resin," *International Journal of ChemTech Research*, 2(4): 2113-2117, 2010.

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***

12. Sari, N. H., I. N. G. Wardana, Y. S. Irawan, and E. Siswanto. "The effect of sodium hydroxide on chemical and mechanical properties of corn husk fiber," *Oriental Journal of Chemistry*, 33(6): 3037-3042, 2017. DOI: http://dx.doi.org/10.13005/ojc/330642
13. Kashani, A., T.D. Ngo, P. Hemachandra, and A. Hajimohammadi, "Effects of surface treatments of recycled tyre crumb on cement-rubber bonding in concrete composite foam," *Constr. Build. Mater,* 171: 467–473, 2018.
14. Adekomaya, O., and K. Adama, "Glass-fibre reinforced composites: the effect of fiber loading and orientation on tensile and impact strength," *Nigerian Journal of Technology,* (36)3: 782-787, 2017.
15. Madhuri, K. H. Sudha, Rao Raghavender, and B. Chandra Mohan Reddy, "Effect of fiber orientation and loading on the tensile properties of Hardwickia Binata fiber reinforced epoxy composites," *Int J Pure Appl Math* 117: 57-61, 2017.
16. Kumaresan, M., S. Sathish, and N. Karthi. "Effect of fiber orientation on mechanical properties of sisal fiber reinforced epoxy composites," *Journal of Applied Science and Engineering,* (18) 3: 289-294, 2015.
17. Vidakis, N., A. Vairis, M. Petousis, K. Savvakis, and J. Kechagias. "Fused deposition modelling parts tensile strength characterisation," *Academic Journal of Manufacturing Engineering,* 14(2): 87-94, 2016.
18. Mayers, F. A., "Paper no.1-d presented at 37th annual conference SPI," *Washington, DC, January*: 11-15, 1982.
19. Vinod, B., and L. J. Sudev. "Effect of fiber orientation on the flexural properties of PALF reinforced bisphenol composites," *International Journal of Science and Engineering Applications,* (2)7, 166-169, 2013.
20. Wallenberger, F.T., J. C. Watson, and H. Li, "*Glass fibers: ASM handbook* 21,"Composite (06781G), 27–34,2001.
21. Lasikun, D. Ariawan, E. Surojo, and J. Triyono. 2018. "Effect of fiber orientation on tensile and impact properties of Zalacca Midrib fiber-HDPE composites by compression molding," In AIP Conference Proceedings 1931(1), *AIP Publishing LLC*, 2018. doi.org/10.1063/1.5024119
22. Kim, Hyo Jin, "Effect of water absorption fatigue on mechanical properties of sisal textile-reinforced composites," *International Journal of Fatigue,* (28)10: 1307-1314, 2006.
23. Karmaker, A. C., "Effect of water absorption on dimensional stability and impact energy of jute fiber reinforced polypropylene," *Journal of materials science letters*, (16)6: 462-464, 1997.
24. Ab Ghani, M. H., and S. Ahmad, "The comparison of water absorption analysis between counterrotating and corotating twin-screw extruders with different antioxidants content in wood plastic composites," *Advances in Materials Science and Engineering,* 2011. doi.org/10.1155/2011/406284

Received: *23 February 2022;* ***Revised:*** *25 March 2023;* ***Accepted:*** *27 March 2023;* ***Published:*** *30 April 2023.*
Corresponding author- ***Belay Taye Wondmagegnehu***