World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(Research Article)

Influence of drying methods on tensile strength of polyester composites reinforced apus bamboo

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World Journal of Advanced Engineering Technology and Sciences, 2024, 12(01), 245–249

Publication history: Received on 20 April 2024; revised on 31 May 2024; accepted on 03 June 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.12.1.0213

Abstract

In this research, the tensile strength of polyester composites reinforced with apus bamboo fiber (*Gigantochloa apus*/GA) was characterized. The bamboo fiber used does not contain lignin. The lignin removal process is greatly influenced by the chemical processing system and drying method. In this paper, the influence of three drying method systems (air drying, oven dring and freeze drying) on the physical properties of bamboo fiber reinforced polyester is studied comparatively. The matrix used is polyester resin BTQN 157. The volume fractions GA fiber are 15%; 20%; 25%; 30%. Specimens for tensile testing using the ASTM D638-03 Type I. The results of study drying method for GA fiber influences the tensile strength and modulus of elasticity of polyester composite material reinforced with GA fiber. The air drying method provides the greatest increase in tensile strength and Modulus of Elasticity and the freeze drying method is around 180% - 200%. Freeze drying method provides increased tensile strength and the lowest modulus of elasticity is around 4.5 - 5.0%.

Keywords: Polyester composite; Bamboo fiber; *Gigantochloa apus*; Tensile strength; Drying method

1. Introduction

Many environmental problems, the reduction of fossil fuels and climate change, are the main reasons for replacing synthetic fibers in polymer composites with natural plant fibers such as hemp, coir, hemp, flax and bamboo [1]. This natural plant fiber is widely used because of its low density, good thermal insulation and mechanical properties, low price, durability, sustainability and biodegradability [2]. Wood and bamboo, which are rich in cellulose, have attracted widespread attention of researchers in this field. Bamboo is a fast-growing, sustainable and renewable type of plant with rich resources. It is a wood fiber material consisting of three main chemical compositions, namely cellulose, hemicellulose and lignin, which function as a framework, matrix and shell respectively [3]. Known for its fast growth rate and naturally high content of dense cellulose crude fiber, bamboo has been proposed as an alternative natural fiber source. Bamboo fiber can be processed into raw materials for various industrial applications, depending on the processing method. Bamboo fiber has long been used for construction materials, pulp in the paper industry [4].

For example, chemical methods are usually required to remove lignin in bamboo. Chemical methods are applied in the process of making paper, textiles and other fields. Therefore, the lignin removal process is considered important in the preparation and utilization of bamboo fiber. There are two methods commonly used to remove lignin in bamboo fiber, namely delignification and drying. Commonly used delignification methods consist of the sodium chlorite method, alkaline sodium sulfite method, and performic acid method [5]. Drying methods are classified into air drying and freeze drying. Differences in drying process methods will have an impact on the morphology and mechanical strength of the fiber. For example, freeze drying can better preserve the morphology of submicron fibers and reduce fiber shrinkage. In the air drying method, separate large fibers will produce capillary tension, causing the nanofibers that make up the

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fibers to crumble together. The increase in capillary strength will combine with the strength of hydrogen bonds, contributing to the disintegration of cellulose nanofibrils and the self-densification of the corresponding large fibers, thus forming a more stable structure [6].

Although much research has been carried out regarding the functional transformation of materials in the form of wood and bamboo fiber, there are limitations in research regarding changes in the properties of the material itself, especially changes in the tensile strength of bamboo fiber reinforced polyester composites, after the drying process with the aim of removing lignin. Different drying methods will have different effects on the morphology and tensile strength properties of bamboo fiber. By applying two drying methods (i.e. air drying/drying and freeze drying), we studied the comparison of physical properties of bamboo fibers with different processing methods. This article provides effective data for the future processing and utilization of bamboo resources, which is very important for increasing the utilization rate of bamboo, especially apus bamboo (*Gigantochloa apus*).

2. Material and methods

2.1. Materials

The specifications for the bamboo used as reinforcing fiber for polyester composites are: *Gigantochloa apus* which local people call Apus bamboo. The apus bamboo plants used as reinforcing fiber material for polyester composites have an average age of three years. Taken from the people's bamboo plantation of Gangga Village, Gangga District, North Lombok Regency, West Nusa Tenggara Province, Indonesia. Bamboo has an average density of 725 kg/m3 to 730 kg/m3. The modulus of rupture and the modulus of elasticity of the former are 120 N/mm2 and 11.239 N/mm2, respectively. This type of bamboo is medium sized with an average stem diameter of 6–7 cm and wall thickness of 10–11 mm, with an estimated height and length of 15–20 m each and the length of this bamboo segment measuring 40–45 cm, as shown in Figure 1.

Figure 1 a. *Gigantochloa apus* (GA), b. *Gigantochloa apus* (GA) fibers

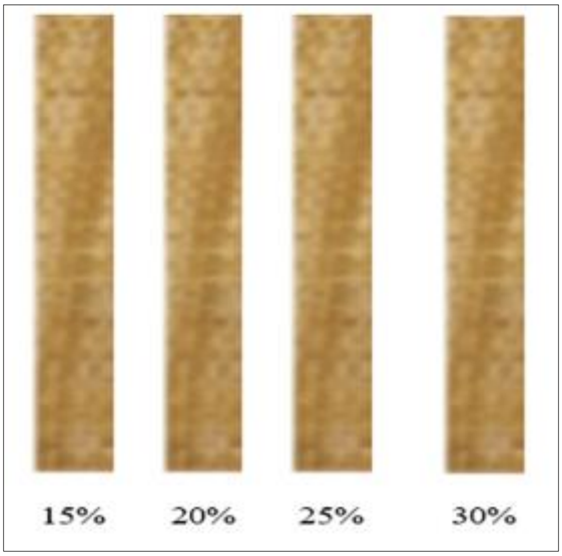

Figure 2 Polyester composite reinforced *Gigantochloa apus* (GA) fibers

2.2. Methods

The material polyester composites reinforced GA fibers were made using the vacuum infusion method. The matrix used is polyester resin BTQN 157. The volume fractions GA fiber are 15%; 20%; 25%; 30%. Specimens for tensile testing using the ASTM D638-03 Type I standard shown in Figure 2. Before being used as reinforcing fiber for polyester composite GA, the fiber was subjected to drying treatment, using two different drying methods, namely air drying, oven drying and freeze drying. In air drying, bamboo fiber is dried at room temperature for 36 hours. In the oven drying process, bamboo fiber is placed in an oven at 60 ∘C for 6 to 8 hours. In freeze drying, the treated bamboo is frozen in a refrigerator at −10 ∘C for 24 hours until completely frozen, then placed in a freeze dryer for 24 hours. To determine the strength characteristics of polyester composite GA, the tensile strength was tested using a universal tensile machine (SHIMADZU Instruments, Kyoto, Japan) at a loading force of 5 KN at a speed of 5 mm/min.

3. Results and discussion

3.1. The tensile strength of polyester composite reinforced *Gigantochloa apus* fibers

Based on the tensile test results graph, it can be seen that the tensile stress value is influenced by the GA fiber drying treatment, for all GA fiber volume fractions. The highest increase was found in test objects with air drying treatment, while the test objects that produced the lowest increase in tensile strength were found in test objects with freeze drying treatment as seen in Figure 3. The increase in PF volume fraction increased the tensile strength of the specimen. The tensile strength with air drying treatment on GA fiber is: 220, 427, 585, 632 MPa, while the tensile strength with freeze drying treatment on GA fiber is: 125, 240, 355, 387 MPA respectively for 15% GA fiber volume fraction, 20%, 25% and 30%.The tensile strength of polyester composites with bamboo fiber reinforcement in freeze-dried samples is only 5.5–9.5% of natural bamboo fiber, but the tensile strength of samples treated with drying and air-drying increases 2 to 3.5 times according to research results [7].

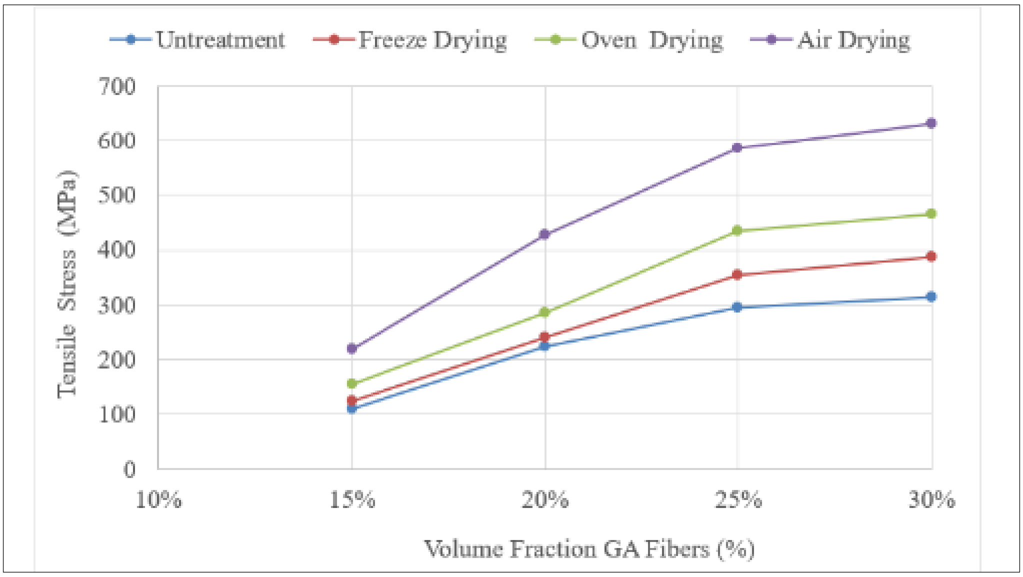

Figure 3 The results of the tensile test of polyester composites reinforced *Gigantochloa apus* (GA) fibers

In addition, the tensile strength of the freeze drying samples was only 4.5 - 5.0% of that of the natural bamboo fibers, but the tensile strength of the samples treated with oven drying increased by 120 - 150% and air drying increased by 180% - 200%

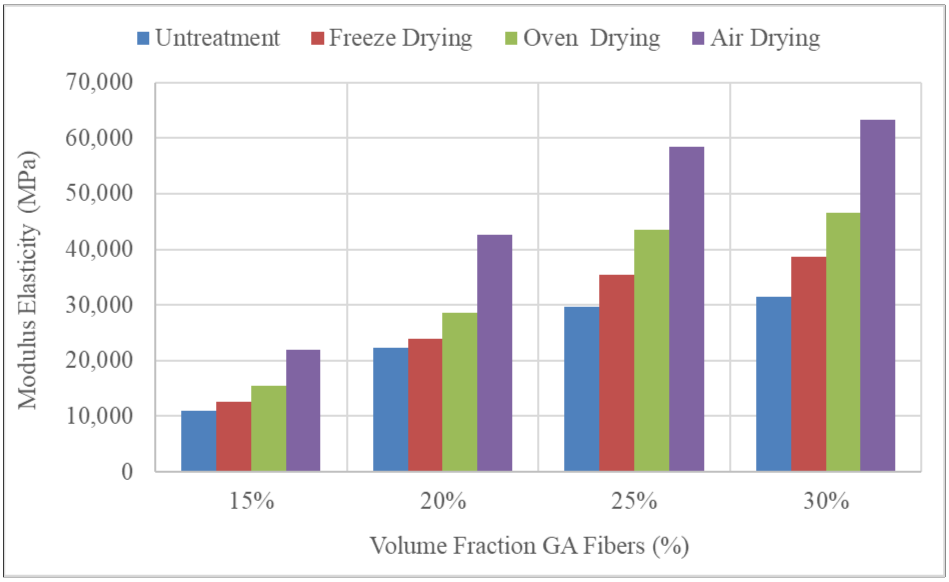

Figure 4 Modulus Elasticiy of polyester composites reinforced *Gigantochloa apus* (GA) fibers

Different GA fiber drying methods (air drying, oven drying and freeze drying) also result in changes in the elastic modulus of the test specimens as shown in Figure 4. The elastic modulus of test specimens treated with GA fiber using the air drying method is 22,000, 42,700, 58,500, 63,200 MPa, with oven drying method 15,500, 28,500, 43,500, 46,500 MPa, with freeze drying method 11,000, 23,300, 29,600, 31,500 MPa respectively for GA fiber volume fractions of 15%, 20%, 25% and 30%. The air drying method provides the largest increase in the Modulus of Elasticity of by 185% - 200%, the freeze drying drying method provides an increase in the Modulus of Elasticity reduced by 14% - 23%..

4. Conclusion

The air drying method on GA fiber provides the greatest increase in tensile strength of around 180% - 200%, the freeze drying method provides an increase in ultimate tensile strength of around 4.5 - 5.0%. The drying method also affects the Modulus of Elasticity of GA fiber reinforced polyester composite materials. The air drying method provides the greatest increase in Modulus of Elasticity of approx 185% - 200%, the freeze drying method provides the lowest increase in Modulus of Elasticity of around 14% - 23%.

Compliance with ethical standards

Acknowledgments

The intellectual and moral contributions of Prof. DR. Ir. Rudy Soenoko, Msc.Eng., Prof. DR. Eng. Ir. IGN. Wardana, Prof. Nasmi Herlina Sari, ST., MT. among others towards the success of this work are deeply appreciated.

Disclosure of conflict of interest

No conflict of interest to be disclsoed.

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