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To cite this article: Nurfajriani *et al* 2022 *J. Phys.: Conf. Ser.* **2193** 012058

Mechanical properties of polyethylene matrix composites with areca fruit peel powder filler (*Areca catechu*) and sugar cane fiber (*Saccharum officinarum L*)

Nurfajriani[1]*, H. Herlinawati[1], M.Yusuf[1], M.I. Siregar[1] , M. Yunus[1], Derlina[2]

[1]Department of Chemistry, Universitas Negeri Medan, Jl. Willem Iskandar Pasar V Medan Estate, Medan, Indonesia, 20221
[2]Department of Physic, Universitas Negeri Medan, Jl. Willem Iskandar Pasar V Medan Estate, Medan, Indonesia, 20221

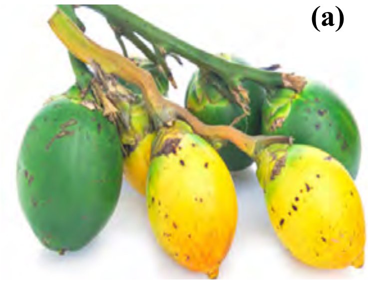
*Corresponding Email : nurfajriani@unimed.ac.id

Abstract. Utilization of betel nut peel waste and sugarcane fiber has not been maximized so that the purpose of this study was to determine the characteristics of the mechanical properties, tensile strength and bending strength of the polyethylene matrix composite with betel nut peel powder and sugarcane fiber filler. In this study, the variation of the ratio of the volume of fiber used is: (0%: 10%), (10%: 0%), (5%: 5%). The fibers used previously were modified with 2% NaOH treatment for each fiber. The results for the tensile test were the variation of 10% sugarcane fiber was 34.876 MPa, 10% variation of areca nut husk powder was 28.109 MPa, 5% variation of areca nut peel powder and 5% sugarcane fiber was 12.104 MPa.

1. Introduction

Materials continue to progress. Basically the use of each material that causes the development and progress of materials, such as the need for materials that are cheap, light, strong, anti-corrosion and easy to obtain [1]. The current development of materials is referred to as composite materials. Composite material is a combination of several types of materials, which have different characteristics from their basic properties (1). The development of the use of natural composite materials (Natural Composite / Naco) in the industrial sector is currently experiencing very rapid development. The use of natural fiber materials is preferred because the cost is relatively cheaper and is also more environmentally friendly [2].

Areca nut plants are found in all corners of Indonesia so that natural products in the form of areca nut in Indonesia are very abundant. Until now, the utilization of waste in the form of betel nut skin fiber is still limited to the furniture and household handicraft industries, not yet processed into technological products. The waste of betel nut peel fiber has the potential to be used as a reinforcement for new materials in composites. Some of the features of using areca nut peel fibers as engineering raw materials include producing new natural composite materials that are environmentally friendly and supporting the idea of using areca nut peel fibers into products that have high economic value and technology. To achieve this goal, it is necessary to conduct research on the utilization of betel rind fiber waste as an alternative material to replace fiber [3]. Areca nut and betel nut skin fibers are shown in Figures 1a and 1b.



(a)

(b)

Figure 1a. Areca nut and **Figure 1b**. Areca nut skin fiber

Sugarcane is one of the major agricultural commodities in Indonesia. In 2013 which refers to statistical data, sugarcane in Indonesia produced 2,517,374 tons [4]. Through the manufacture of sugar from sugar cane, 5% of sugar is produced, 90% of bagasse waste is produced and the rest is water and molasses.

In producing new material products, economic progress from the sugarcane bagasse is needed, the achievements of which can still be engineered. Chemical compounds contained in bagasse are 26 - 43% cellulose, 17 - 23% hemicellulose, 20 - 33% pentosan and 13 - 22% lignin, where these chemical compounds can be used as basic ingredients in making composites. Referring to the results of research from Sudhir Kumar and Chandan Datta, it was explained that the mechanical properties of epoxy composites with bagasse without treatment with an epoxy/bagasse ratio of 70 : 30 had Tensile Strength 9.87 MPa, Flexural Strength 26.78 MPa, and Impact Strength 6.67 kJ/m^2 [5]. Bagasse like Figure 2.

Figure 2. Sugarcane Bagasse

The main content of the composite is fiber which has several advantages, therefore this fiber composite is more widely used. Fiber composite materials consist of fibers bonded by an interconnected matrix. There are two types of this fiber composite, namely long fiber or continuous fiber and short fiber or short fiber and whisker [6]. Polyethylene (PE) is a thermoplastic polymer, is a transparent, white polymer with a melting point varying between 110-1600C. Generally Polyethylene (PE) is resistant to chemicals [7].

ASTM D-638 . tensile strength test, Tensile strength is one of the mechanical properties of a material, from the tensile test data can be obtained in the form of the maximum tensile force of a material and changes in the length of the sample when it is pulled to break [8]. The ASTM D-638 mold specimen is shown in Figure 3.

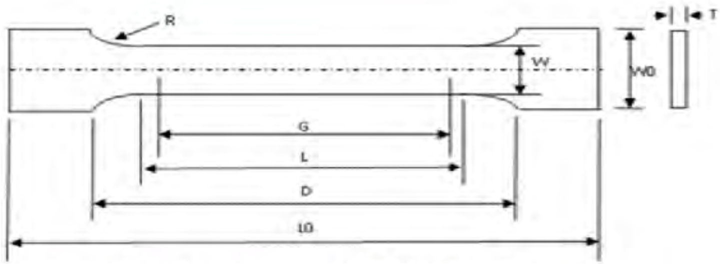


Figure 3. ASTM D-638 mold specimen [9].

2. Experimental

2.1. Materials

Materials and equipment needed in the manufacture of test samples include bagasse fiber (Bagasse) and betel nut skin fiber that has been mashed with a size of 250 mesh. For the alkalization process, 2% and 7% NaOH solutions are needed.

The equipment needed in making test samples includes digital scales, a set of glass equipment, vacuum pumps, hot plates, thermometers, magnetic stirers, dry grinders, 250 mesh sieves, Internal Mixer Brabanders, hot presses, specimen molds, tensile strength test equipment (tensile). strength) ASTM D 638.

2.2. Sample preparation

Bagasse fiber is dried in the sun for 1 day. The old betel nut with brownish red skin is separated from the fruit seeds, then dried in the sun for 4 days. Then the samples were mashed using a dry mill. Bagasse and mashed betel nut skins were filtered using a 250 mesh sieve. Then both samples were added with 2% NaOH solution and 7% NaOH solution for the alkalization process, respectively. Soaking process with NaOH to remove the content of lignin and hemicellulose in the sample. After soaking for 2 hours, the samples were dried and rinsed with water until neutral and then dried in the oven for 2 hours at 105^{o}C [4].

2.3. Composite manufacturing

Comparison of compositions that are varied in the composites are variations in fiber composition and variations in alkalization concentration. The first step in making composite specimens is the mass of sugarcane fiber and the mass of areca nut fibers that are already in powder form, weighed according to the ratio volume has been converted to mass. Then the polyethylene is also weighed according to the mass of each mass variation. Each Polyethylene and fiber is put into the Internal Mixer with a time interval of 5 minutes. Mixing was carried out for 15 minutes with a blend temperature of 1500C. The sample blending process is as shown in Figure 4. After evenly mixed, the composite is removed from the Internal Mixer after which it is flattened and cut into small pieces. Then it was pressed on an ASTM mold for a tensile test on a Hot Press at a temperature of 1500C for 30 minutes, after which the specimen was removed from the mold and the surface was leveled. The finished specimen is a ready-to-test sample. Figure 5 Shows a composite sample for characterization.

Figure 4. Blending samples

Figure 5. Composite Sample

2.4. Composite characterization

The specimens that have been obtained are then subjected to a tensile strength test (tensile strength) ASTM D-638 to determine the maximum tensile strength of the specimen.

3. Result and discussion

The test sample was made with six variations of fiber volume fraction with variations in alkalization concentration. Furthermore, it is characterized and analyzed for differences in the mechanical properties of each sample. The test data obtained include tensile strength test data (tensile strength).
The following is Table 1. Variations in fiber volume fraction and variations in alkalization concentration

Table 1. Variation of Composition of Polymer Composites with 2% NaOH Alkalization

No	Test Sample Code	Fiber Volume Fraction		Polyethylene Matrix (%)	NaOH 2%	Tensile Strength Average (MPa)
		Areca Fiber (%)	Sugarcane Fiber (%)			
1	PE-SP-2	0	10	90	√	34.876
2	PE-ST-2	10	0	90	√	28.109
3	PE SP.ST-2	5	5	90	√	12.111

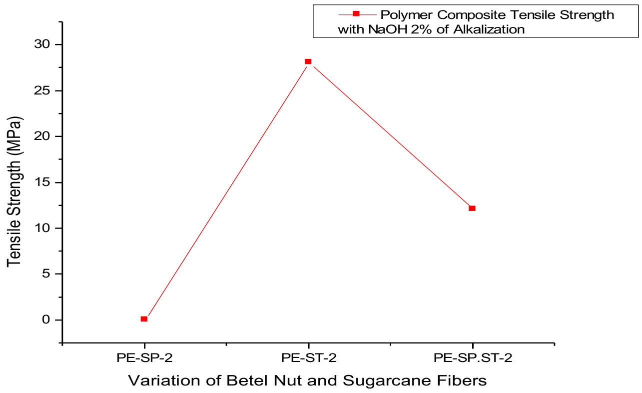


Figure 6. Polymer Composite Tensile Strength with NaOH 2% of Alkalization

In Figure 6. The tensile test of the specimen with 90% LDPE percentage, 10% Pinang Fiber after going through the 2% NaOH alkalization process, the tensile strength obtained was 34,876 MPa. In the tensile test of the specimen with a percentage of 90% LDPE, 10% Pinang Fiber after going through the 2% NaOH alkalization process, the tensile strength obtained was 28.109 MPa. In the tensile test of the specimen with a percentage of 90% LDPE, 5% Areca Fiber and 5% Sugar Cane Fiber after going through the 2% NaOH alkalization process, the tensile strength obtained was 12.111 MPa.
The results of the characterization of variations in the composition of polymer composites with 7% NaOH alkalization are shown in Table 2.

Table 2. Variation of Composition of Polymer Composites with 7% NaOH Alkalization

No	Test Sample Code	Fiber Volume Fraction		Polyethylene Matrix (%)	NaOH 2%	Tensile Strength Average (MPa)
		Areca Fiber (%)	Sugarcane Fiber (%)			
1	PE-SP-7	0	10	90	√	21.124
2	PE-ST-7	10	0	90	√	31.272
3	PE SP.ST-7	5	5	90	√	12.104

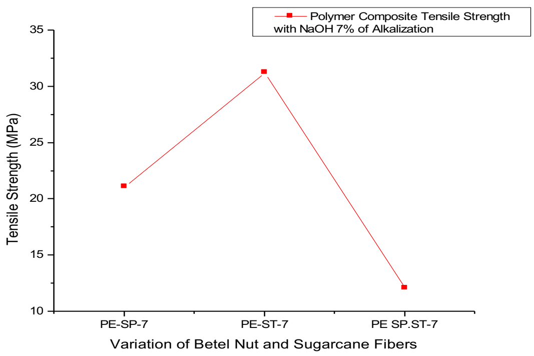


Figure 7. Polymer Composite Tensile Strength with NaOH 7% of Alkalization

In Figure 7. The tensile test of the specimen with 90% LDPE percentage, 10% Areca Fiber after going through the 7% NaOH alkalization process, the tensile strength obtained is 21.124MPa. In the tensile test of the specimen with 90% LDPE percentage, 10% Areca Fiber after going through the 7% NaOH alkalization process, the tensile strength obtained was 31.272 MPa. In the tensile test of specimens with a percentage of 90% LDPE, 5% Areca Fiber and 5% Sugar Cane Fiber after going through the 7% NaOH alkalization process, the tensile strength obtained was 12.104 MPa.

The best tensile strength and strain values were found in the variation matrix specimens of 10% sugarcane fiber and 90% LDPE, namely 34,876 MPa. While the variation of LDPE 90%, Pinang Fiber 5% and Sugar Cane Fiber 5% after going through the 2% NaOH alkalization process became specimens with the smallest tensile strength of 12.104 MPa. Meanwhile, in the 7% NaOH alkalization process, the optimal tensile strength was 10% areca nut fiber and 90% LDPE, the lowest tensile strength was 90% LDPE specimen, 5% areca fiber and 5% sugarcane fiber. SP-ST-2 is caused by the less than optimal distribution of stress received by the matrix to the fiber. This phenomenon can occur when the interfacial bond between the matrix and the fiber is not perfect (debonding) [10]

To be able to clearly determine the interfacial bond between the matrix and the fiber is bonded or debonding, simply the interfacial bond can be seen from the fracture form of the composite after tensile testing. In general, the average fracture in the areca fiber composites studied is brittle fracture. It is characterized by the shape of the fault which tends to be perpendicular to the direction of the stress received [11]

By looking at the phenomenon of changes in the modulus of elasticity that occur, it indicates that the addition of fiber to polyethylene affects the value of the modulus of elasticity. The phenomenon of debonding has a variety of factors, especially in natural fibers, one of the causes is fiber processing that is still not precise. In this study, the researchers carried out alkalization of areca nut fibers at a concentration of 2% and 7%. Excessive alkalizing treatment can cause the fiber to become brittle and brittle so that its strength is reduced. Meanwhile, the inadequate alkalizing treatment was not able to remove all the lignin and hemicellulose content in the fiber and caused a reduction in the interfacial bond between the fiber and the matrix.
In addition to the debonding factor, another thing that can cause a decrease in strength in this areca fiber composite is the number of voids. The presence of voids results in the inhibition of the stress distribution by the matrix. The resulting material will be an environmentally friendly material [12].

4. Conclusion

Based on the results of the research that has been done, it can be concluded In the 2% alkalization process, the optimum tensile strength value for the variation matrix specimens of 10% Sugar Cane Fiber and 0% LDPE is 34.876 MPa, the lowest tensile strength is 12.111 MPa at 90% LDPE, 5% Areca Fiber and 5% Sugar Cane Fiber. Whereas in the alkalization process of 7% specimens with the largest tensile strength at 10% Areca Nut and 90% LDPE, the smallest tensile strength was 12.104 MPa in the variation specimens of LDPE 90%, Areca Fiber 5% and Sugar Cane Fiber 5%.

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Acknowledgments
This research is supported by the Universitas Negeri Medan PNBP Fund grant. In accordance with the Decree of the Head of LPPM Unimed, Number : **0016/UN33.8/PL-PNBP/2021**