Effect of Subang Pineapple Leaf Fiber Loading on Flammability and Mechanical Properties of Pineapple Leaf Fiber Reinforced Polypropylene Composites

Toho Dustin Sutomo, Ariadne L Juwono

Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Kampus UI Depok 16424, Indonesia

E-mail: toho.dustin@ui.ac.id
Corresponding author: ariadne.laksmidwi@ui.ac.id

Abstract. Environmentally friendly composites are composites with one or all of the constituent elements being natural materials. Indonesia with high biodiversity resources produces a lot of various types of natural fibers as reinforcements, one of them is pineapple leaf fiber (PALF). This study aimed to determine the effect of Subang PALF contents on flammability, impact resistance, and hardness of polypropylene (PP) / Subang PALF composites. Three compositions of PALF in PP were fabricated by hot press method. Pristine PP samples were also prepared for comparison. Flammability, impact, and hardness test results showed that composites with 40 wt.% PALF were the best with their respective values of (15.7 ± 0.4) mm/minute, (31.6 ± 4.5) J/cm², and (60.5 ± 2.01) HD.

1. Introduction

Synthetic fibers that have been used for reinforcement in composites cannot be degraded technically. The use of synthetic fibers is not environmentally friendly. This problem attracts attention and environmental issues such as pollution and pollution from fuel. Therefore it is expected that natural fibers can be an alternative material for synthetic fibers and provide better impact on the environment [1]. Indonesia is one of the countries that has a potential to develop natural fibers such as jute, flax, pineapple, cotton, abaca, agave, linum, rosella, and kenaf [2]. Pineapple or Ananas comosus is an alternative fiber-producing plant which has only been used as a textile fiber-producing material [3]. Utilization of pineapple leaf as reinforcing fibers in composites makes pineapple leaf waste has added value, one example is as composite boards [4].

Pineapple leaf fibers (PALFs) have good mechanical properties associated with high cellulose levels [5]. PALFs are used effectively in polymer matrix to develop composites with better mechanical properties [6]. The most common treatment to increase fiber and matrix adhesion interaction is using chemical treatment. The chemical treatment modifies the fiber surface is called alkali treatment using NaOH solution. Alkali treatment on fiber can increase roughness on the fiber surface and remove lignin, wax, and oil from fiber cell walls. Increasing the effective contact area of the fiber creates higher adhesion between the fiber and the polymer matrix and increase the mechanical properties [7,8].
Several previous studies have been conducted to determine the flammability and mechanical properties of natural fiber reinforced polymer composites [9-11]. The impact strength of PALF/PP composites were studied on various fiber loading and showed that the impact strength of the composites increased with fiber loading [9]. Rockwell hardness test was tested on PALF reinforced epoxy resin composites and showed that the hardness of composites increased with the fiber loading [10]. Flammability tests were carried out on PP/sisal composites using horizontal and vertical burning test [11]. There is a lack of study in PP/PALF composites. The aim of this study is to investigate the effect of weight fractions of Subang PALF on the flammability and mechanical properties of PALF/PP composites.

2. Materials and Method

2.1. Materials and Fiber Pre-treatment
Polypropylene resin was supplied by PT Chandra Asri Petrochemical Tbk, Indonesia. The polypropylene used has type B132AN. Pineapple leaf fibers were harvested from Subang, Indonesia. The PALFs were soaked in the 5% of the NaOH solution in water reservoir for 5 hours at room temperature. After that, fibers were rinsed several times with distilled water until the distilled water was colourless and then the fibers were dried at room temperature for 24 hours. PALFs were heated in an oven for 24 hours.

2.2. Preparation of Composites
PP as matrix in the form of pellets were melted into sheet form using a hot press method at 190°C. PP which was already in sheet forms were combined with PALFs based on the variations in fiber weight, namely 20 wt.%, 30 wt.%, and 40 wt.%. PP/PALF composites were fabricated by using a 220 mm x 130 mm x 4.5 mm stainless metal plate. The plate was placed into the hydraulic hot press at 190°C temperature. The stainless steel plate was removed from the hot press machine after 20 minutes and kept in room temperature for cooling.

3. Testing

3.1. Fourier Transform Infrared Spectroscopy
Fourier Transform Infrared Spectroscopy (FTIR) measurement was conducted on PALFs using Parkin Elmer tool. The test was conducted to analyze the organic compounds present in PALFs before and after PALFs alkali treatment. The measurements was carried out in the wavelength region of 500 until 4000 cm⁻¹.

3.2. Flammability Test
Flammability tests were conducted using flammability tester according to UL-94 HB. The dimension of the specimens used was 125 mm x 13 mm x 4.2 mm. The specimen was burnt horizontally from one end of the specimen.

3.3. Impact Test
Impact tests were conducted according to ASTM D 6110-10. The impact strength of the composites was measured using GOTECH GT-7045 impact testing machine. The dimension of the specimen used was 125 mm x 12.7 mm x 3 mm.

3.4. Hardness Test
The hardness of the composites was measured using D shore durometer according to ASTM D2240. Durometer used to measure hardness was attached to the surface of the sample to be measured at room temperature. Hardness test was carried out on composite samples which had a thickness of 4.2 mm.
4. Results and Discussion

4.1. Fourier Transform Infrared Spectroscopy

FTIR spectrum of PALFs before and after alkali treatment were shown in Figure 1. The FTIR spectra showed an interesting comparison about several peaks. The presence of hydroxyl (-OH), C-H stretching of methyl groups and C-H bending vibrations bands can be observed at 3339 cm\(^{-1}\), 2892 cm\(^{-1}\), and 1316 cm\(^{-1}\) respectively. These peaks belong to cellulose [12]. Lignin was indicated by the presence of peaks in the range of 1200-1300 cm\(^{-1}\) [13]. Figure 1 exhibits that the peaks in the range of 1200-1300 cm\(^{-1}\) appeared on the before alkali treatment PALFs spectrum, while these peaks disappeared on the after alkali treatment PALFs spectrum. Comparison of the two FTIR spectra for both PALFs showed that alkali treatment caused a decrease in lignin content in PALFs.

![FTIR spectra of before and after alkali treatment Subang PALFs.](image)

**Figure 1.** FTIR spectra of before and after alkali treatment Subang PALFs.

4.2. Flammability Properties

The horizontal UL-94 tests were conducted to quantify the flame rate of the composites. The results of the UL-94 tests for the polypropylene and PALF/PP composites are presented in the Figure 2. The horizontal test shows that the flame rate of PP is the highest. It is a fact that the PALF/PP 40% composites show the lowest combustion rate. It could be observed that, the flame retardancy of composites increase with the fiber loading. The flame retardancy increased because fibers in the composites inhibit oxygen in the composite combustion process. From this test, it was revealed that the more fiber loading, the less oxygen played a role in composites combustion process. This process agreed well with previous research by Barath et al [14].

![Flammability test results.](image)
Figure 2. Flammability of Subang PALF/PP at different fiber loading.

4.3. Impact Strength Results
Impact strength of PP and PALF/PP composites at different fiber loading are shown in Figure 3. The highest impact strength is found in PALF/PP 40% composites. According to Figure 2, impact strength of PALF/PP composites increases as the fiber loading increases. The increase in impact strength occurred because with increased fiber loading, more energy is needed to hit the sample. From this test, it can be seen that the function of the fiber as the recipient of the load from the matrix takes place well. These results agree well with the previous study about PALF/PP composites [9].

Figure 3. Variation of impact strength at different fiber loading.

4.4. Hardness Results
Hardness test of the PP and PALF/PP composites were determined and shown in Figure 4. The more the fiber loading, the higher the hardness value. PALF/PP 40% composites have the highest hardness number. The increased in hardness of the composites because the higher content of PALF which hold the load. The increment of composites hardness due to fiber loading were confirmed on PALF/epoxy composites as the PALFs had similar function [10].
5. Conclusion
The effects of pineapple leaf fiber loading on flammability and mechanical properties on Subang PALF/PP composites were studied. It was concluded that PALF loading increased the mechanical properties and flame retardancy of Subang PALF/PP composites. Flammability, impact, and hardness test results showed that 40 wt.% Subang PALF/PP composites were the best composites with their respective values of $(15.7 \pm 0.4)$ mm/minute, $(31.6 \pm 4.5)$ J/cm$^2$, and $(60.5 \pm 2.01)$ HD.

6. References
[1] M Haameem J A, Majid M S A, Afendi M, Marzuki H F A, Fahmi I, Gibson A G 2015 Mechanical properties of napier grass fibre/polyester composites Comp. Struct 136 1-10
[2] Sudjindro 2011 Prospek serat alam untuk bahan baku kertas uang. Perspektif. 10 92-104
[3] Hidayat P 2008 Teknologi Pemanfaatan Serat Daun Nanas Sebagai Alternatif Bahan Baku Tekstil Teknoin 13 31-35
[4] Hafizhah R, Juwono A L, Roseno S 2017 Study of Tensile Properties and Deflection Temperature of Polypropylene/Subang Pineapple Leaf Fiber Composites IOP Conf. Series: Journal of Engineering and Technology 7 125-139
[5] Odusote J K, Oyewo A T 2016 Mechanical Properties of Pineapple Leaf Fiber Reinforced Polymer Composites for Application as A Prosthetic Socket Journals of Engineering and Technology 7 125-139
[6] Panyasart K, Chaiyut N, Amornsakchai T 2014 Effect of Surface Treatment on The Properties of Pineapple Leaf Fibers Reinforced Polyamide 6 Composites Energi Procedia 56 406-413
[7] Li Y, Sreekala M S, Jacob M 2009 Textile composite based on natural fibres, in Natural fibbreinforced polymer composites from macro to nanoscales S Thomas, L A Pothan, ed Old City Publishing: Philadelphia chapter 8 pp 202-227
[8] Li X, Canada A, Tabil L 2007 Chemical Treatments of Natural Fiber for Use in Natural Fiber- Reinforced Composites: A Review Journal of Polymers and The Environment 15 25-33
[9] Mochtar M, Rahmat A R, Hassan A 2007 Characterization and Treatments of Pineapple Leaf Fiber Thermoplastic Composite for Construction Application Research VOT 75147 Universitas Teknologi Malaysia chapter 4 pp 51-52
[10] Kumar S, Praveen B A, Aithal K, Keempaiah U N 2015 Development of Pineapple Leaf Fiber Reinforced Epoxy Resin Composites International Research Journal of Engineering and Technology 02 2190-2193
[11] Jeencham R, Suppakarn N, Jarukumjorn K 2014 Effect of flame retardants on flameretardant,mechanical, and thermal properties of sisal fiber / polypropylene composites Compos. Part B 56 249-253
[12] Lojewska J, Miskowiec P, Lojewski T, Proniewicz L M 2005 Cellulose oxidative and hydrolytic degradation: In situ FTIR approach Polymer Degradation and Stability 88 512-520

Figure 4. Variation of hardness at different fiber loading.
[13] Reddy N, Yang Y 2005 Structure and properties of high quality natural cellulose fiber from cornstalks *Polymer* **46** 5494-5500

[14] Bharath K N, Basavarajappa S 2014 Flammability Characteristics of Chemical Treated Woven Natural Fabric Reinforced Phenol Formaldehyde Composites *Procedia Materials Science* **5** 1880-1886

**Acknowledgement**

This research was funded by PITTA 2018 Universitas Indonesia.