A comparison of tensile properties of polyester composites reinforced with pineapple leaf fiber and pineapple peduncle fiber

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Abstract. Pineapple fiber which is rich in cellulose, relatively inexpensive, and abundantly available has the potential for polymer reinforcement. This research presents a study of the tensile properties of pineapple leaf fiber and pineapple peduncle fiber reinforced polyester composites. Composites were fabricated using leaf fiber and peduncle fiber with varying fiber length and fiber loading. Both fibers were mixed with polyester composites the various fiber volume fractions of 4, 8 and 12% and with three different fiber lengths of 10, 20 and 30 mm. The composites panels were fabricated using hand lay-out technique. The tensile test was carried out in accordance to ASTM D638. The result showed that pineapple peduncle fiber with 4% fiber volume fraction and fiber length of 30 mm give highest tensile properties. From the overall results, pineapple peduncle fiber shown the higher tensile properties compared to pineapple leaf fiber. It is found that by increasing the fiber volume fraction the tensile properties has significantly decreased but by increasing the fiber length, the tensile properties will be increased proportionally. Minitab software is used to perform the two-way ANOVA analysis to measure the significant. From the analysis done, there is a significant effect of fiber volume fraction and fiber length on the tensile properties.

1. Introduction
Environmental awareness, new rules, and legislation are forcing industries to seek new materials that are environmentally friendly. Over the past two decades, natural fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements [1-3]. Recently, natural plant fibers have been used in scientific researches as potential alternatives to glass fibers (GF) in fiber-reinforced plastics (FRP). Relative to glass fibers, these lignocelluloses fibers have lower densities, cost relatively lower, consume lesser energies during production, pose no abrasion to machines and have no health risk when inhaled [4-10].

From large selection of plant fibers, pineapple leaf fibers (PALF) have the highest cellulose contents which make the fibers mechanically sound [5]. According to this review, however, PALF are among the least studied fibers especially for reinforcing plastics. PALF come from the leaves of the pineapple plant, Ananas comosus, from Bromeliaceae family. Pineapple is one of the most important tropical fruits in Malaysia. Currently, the main focus of the pineapple industry in this country is the fruits and related foodstuffs leaving the leaves as agricultural wastes [4]. Even though PALF have been used traditionally as threads and textile in this country, works have only just started on studying...
them as commercial textile materials. Pineapple leaves are either composted or burned by farmers thus wasting potential source of good fibers.

There have been numerous studies carried out by researchers on various aspects of PALF. A number of authors analyzed the chemical composition of PALF [11-12]. PALF obtained from plants bearing inedible fruits were examined for textile purposes, and blends of PALF with silk and polyester fibers were studied [13]. Yu [14] studied chemically-treated PALF in terms of their properties and ability to be spun. Chemical treatments carried out on these technical fibers, while improving their fineness, resulted in degradation of their tensile properties [15].

Most of the recent studies, pineapple leaf fiber (PALF) has been used as a reinforcement instead of other part. This presented paper looks at the opportunity to utilise pineapple peduncle fibers (PAPF) as reinforcement in natural fiber composites. The aims of this paper is to compare the tensile properties between pineapple leaf fiber and pineapple peduncle fiber reinforced polyester composites by investigate the effects of fiber loading and fiber length on tensile properties.

2. Material and Methods

2.1. Preparation of Pineapple Leaf and Peduncle Fiber

Pineapple leaf and peduncle showed in figure 1, were obtained from Pekan Nanas, Johore. The pineapple leaf and peduncle fibers were extracted and were cut into 10, 20 and 30 mm of length. The pineapple leaf and peduncle were washed by using reverse osmosis water to remove the dirt and were dried for two days.

![Figure 1: Pineapple leaf and peduncle fiber](image)

2.2. Preparation of Composites

The specimens were manufactured by hand lay-up method, which was commonly used method for small scale composite manufacturing. All composite panels were prepared with various fiber volume fractions of 4, 8, and 12% and various fiber lengths of 10, 20 and 30mm. Polyester resin used as matrix with polyester / hardener ratio of 100: 1. The mixture was stirred until all the fiber was mixed with the polyester. The mixing was poured into mould and was pressed for 24 hours.
2.3. Test Specimen
The composite plates were cured in room temperature. After a week, the plates were cut into simple based on ASTM D638 Type 1 standard by using band saw machine.

2.4. Mechanical Testing
The tensile test was performed at the Fiber and Biocomposite Development Centre (FIDEC) at Olak Lempit, Banting. Tensile test of the specimens was carried out at room temperature with a constant cross-head rate of 10 mm/min using universal testing machine type Gotech model. The load cell that has been chosen is 5 tons. Five specimens were tested for each various fiber loading and fiber length, and the average value was obtained using Gotech software. Result of the tensile properties was analyzed by using analysis of variance (ANOVA). The purpose of this ANOVA analysis was investigated the design parameters significantly affect the quality characteristic of a product or a process.

3. Results and Discussion

3.1. Tensile Strength
Figure 3 shows a comparison of tensile strength between pineapple leaf and pineapple peduncle reinforced polyester composites. Both fiber showed the decreased trend in tensile strength when reached highest volume fraction. Result also shown by increasing the fiber length it also increased the tensile strength value. For overall result, fiber volume fraction at 4% and 30 mm of fiber length gave the highest value of tensile strength. Pineapple peduncle showed a higher tensile strength when compared to the pineapple leaf reinforced polyester composite. The highest value of the tensile strength value is 12.3 MPa which are from the pineapple peduncle while for the pineapple leaf fiber the highest is 10.2 MPa.
The result was agreed with [16] that tensile strength increased with the volume fractions at the beginning and experienced slowly decreased when reach higher volume fraction. The reasons why tensile strength gave lower values for the volume fraction above 4% are possibly due to the fiber-to-fiber interaction, void and dispersion problems. In general, the composites showed an increasing trend in their mechanical properties over the fiber length. In this pineapple fiber, whether leaf or peduncle, increasing the fiber length showed the increasing trend in tensile strength. This is because the interlocked between the long fiber.

### 3.2. Analysis of Variance

An analysis of variance of tensile strength data in three different fiber volume fractions and three different fiber lengths was performed, with the objective of analyzing the influence of fiber loading and fiber length. For this study two away analysis of variance is performed because it involve two independent variable.

Table 1 and 2 show the results of the analysis of variance with the flexural strength in varies fiber volume fraction and fiber length.

In table 1 for pineapple leaf fiber reinforced polyester composites, the significant value of fiber volume fraction (0.00) and fiber length (0.00) are less than the threshold value (0.05), it can be concluded that the influence of fiber volume fraction and fiber length does effect the tensile strength. The interaction between the two factors fiber volume fraction and fiber length (0.084) are more than threshold value (0.05), leading to the conclusion that the combination of fiber volume fraction and fiber length does not significantly affect flexural properties of pineapple leaf fiber reinforced polyester composites.

In table 2, pineapple peduncle fiber reinforced polyester composites show a significant value of fiber volume fraction (0.00) and fiber length (0.00) are less than the threshold value (0.05). Thus, the influence of fiber volume fraction and fiber length did effect the tensile strength. The interaction between the two factors fiber volume fraction and fiber length (0.199) are more than threshold value (0.05), leading to the conclusion that the combination of fiber volume fraction and fiber length does not significantly affect flexural properties of pineapple peduncle fiber reinforced polyester composites.
Table 1. Analysis of variance with the PALF tensile strength in varies volume fractions and fiber length.

| Source             | Type III Sum of Squares | df | Mean Square | F   | P-value |
|--------------------|-------------------------|----|-------------|-----|---------|
| Corrected Model    | 174.374a                | 8  | 21.797      | 7.517 | .000    |
| Intercept          | 2846.657                | 1  | 2846.657    | 981.729 | .000   |
| Volume             | 63.793                  | 2  | 31.896      | 11.000 | .000    |
| Length             | 84.603                  | 2  | 42.301      | 14.589 | .000    |
| Volume * Length    | 25.978                  | 4  | 6.494       | 2.240 | .084    |
| Error              | 104.387                 | 36 | 2.900       |      |         |
| Total              | 3125.418                | 45 |             |      |         |
| Corrected Total    | 278.761                 | 44 |             |      |         |

a. R Squared = .626 (Adjusted R Squared = .542)

Table 2. Analysis of variance with the PAPF tensile strength in varies volume fractions and fiber length.

| Source             | Type III Sum of Squares | df | Mean Square | F   | P-value |
|--------------------|-------------------------|----|-------------|-----|---------|
| Corrected Model    | 105.132a                | 8  | 13.141      | 8.541 | .000    |
| Intercept          | 4364.043                | 1  | 4364.043    | 2836.401 | .000   |
| Length             | 35.271                  | 2  | 17.635      | 11.462 | .000    |
| Volume             | 60.100                  | 2  | 30.050      | 19.531 | .000    |
| Length * Volume    | 9.762                   | 4  | 2.440       | 1.586 | .199    |
| Error              | 55.389                  | 36 | 1.539       |      |         |
| Total              | 4524.564                | 45 |             |      |         |
| Corrected Total    | 160.521                 | 44 |             |      |         |

a. R Squared = .655 (Adjusted R Squared = .578)

The values shown in this table are p-values of the two-way ANOVA tests. A p-value smaller than 0.05 indicates significant influence of the corresponding tensile on the corresponding property at the 5% significance level.

4. Conclusion
In this paper, the tensile strength of pineapple leaf fiber and pineapple peduncle fiber reinforced polyester composites was measured. Based on the results, it was found that the tensile strength showed an increasing trend as the fiber length increased but decreased when increasing the fiber volume fractions. The optimum of fiber volume fractions and fiber length in polyester resin to obtain the highest tensile strength was found at 30 mm in fiber length and 4 % fiber volume fractions. In the analysis of variance, the interaction effect of fibre volume fraction and fiber length not significantly affect the tensile strength for both fibers. Pineapple peduncle fiber reinforced polyester composites showed a higher tensile strength compared to pineapple leaf fiber reinforced composites. The results
confirmed that more studies are needed to determine the beneficial and cost effective applications of the pineapple peduncle fibre in composites.

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