Investigation of Single Fibre Tensile Properties of the Pineapple Leaf (PALF)

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Abstract. Recently, natural fibres composite is rigorously explored as alternative fibres due to the source depletion of petroleum. This research was focusing on pineapple leaf (PALF). The purpose of this research was to study the single fibre tensile properties of PALF. The single fibre tensile test was conducted via the universal testing machine following ASTM D3379 – 89 standards. The result shows that the Ultimate Tensile Strength (UTS) and Young's Modulus of PALF were 141.093 MPa and 89.073 MPa, respectively. This research's benefits include reducing agriculture waste of pineapple leaf, which is commonly being thrown out by the farmers when the fruits are harvested. It focuses not only on waste reduction but also on economic factors when other industries fully utilise the pineapple leaf.

1. Introduction
The natural fibres materials are being used from the early ages, such as for shelters and clothes but slowly decreasing since synthetic fibres. However, due to the depletion of sources, natural fibres' importance arises and influences the researchers and industries to consider using them instead of synthetic fibres. One of the examples of natural fibres is the plant fibres which generally classified into two types of plant which are the primary plants, those the fibre from a plant grown such as kenaf [1–3] and the secondary plants which the fibres come from other utilities such as the pineapple [4–6]. Aside from the natural fibre, there are also synthetic fibres, a human-made fibre mostly from petroleum and used in the fabric. Some of the synthetic fibres include carbon fibre [7,8], fibreglass [7], and Kevlar [9,10]. Due to their advantages such as high elasticity, high durability, soft, and can sustain the heavy load, synthetic fibres are among the main components in composite industries [11]. Natural fibres such as cotton [12], sisal [3,13], jute [12,14], pineapple leaf fibre (PALF) [15,16] and kenaf [17] are considered the primary natural fibre that is being used in the world. The hybridisation of two different natural fibre material may improve the material properties.

Interestingly, pineapple is one of the main commodity plantations in Malaysia. However, the research of pineapple leaf hybridisation still in the early stage. Pineapple belongs to the Bromeliaceae family, known as the “Queen of Fruit Crops”, and considered one of the world's tropical fruit. Aside from banana and citrus fruits, pineapple is the third most cultivated, and its diverse variety affects its yield. However, the pineapple leaves are often considered waste, which increases the volume of post-harvest waste due
to the quantity of approximately forty to fifty leaves per shoot. The pineapple plant has a short stem, and each full-grown pineapple has approximately eighty leaves with a variety of shapes and lengths. According to pineapple leaves’ anatomy, there are two types of fibre: the vascular bundles, found under the top lamina and the finer fibre, found in the bottom laminar [5]. In fibre processing, the fibre from pineapple leaves is acquired by mechanical or retting in water.

Moreover, the pineapple leaf fibre filament that is finer and stronger than jute can also be spun successfully using jute machinery. The pineapple leaf fibre is considered more quality than jute in terms of structure because it is without mesh. As for the pineapple leaf fibre, the cellulose was also the dominant content in the natural fibre where according to the previous researchers, their cellulose content was about 70 ± 10 %, its hemicellulose content was about 10 ± 10 %, and the lignin content was about eight ± 8 %. Based on previous researchers such as Mahardika [18] and Fareez [19], the treated pineapple leaf fibre possesses higher cellulose content than the raw fibre, promoting higher tensile strength. The leaves of pineapple contain strong, white silky fibre, and due to its limited quantity of fibre, there has been no grading of these fibres [4,5,20]. The fibre comparison between the raw and treated is tabulated in Table 1.

### Table 1. Chemical composition of raw and treated pineapple leaf fibre.

| Author          | Condition | Cellulose       | Hemicellulose | Lignin       |
|-----------------|-----------|-----------------|---------------|--------------|
| S. Jose [21]    | Raw       | 80.00 – 81.00 % | 16.00 – 19.00 % | 4.60 – 12.00 % |
| Z. Daud [22]    | Raw       | 66.20 %         | 19.50 %       | 4.20 %       |
| M. Mahardika [18]| Raw      | 62.50 %         | 13.90 %       | 15.9 %       |
| S. Mishra [20]  | Raw       | 70.00 – 82.00 % | -             | 5.00 – 12.00 % |
| Z. Daud [23]    | Raw       | 66.20 %         | 19.50 %       | 4.28 %       |
| M. Mahardika [18]| Treated  | 81.30 %         | 2.90 %        | 1.50 %       |
| I. Fareez [19]  | Treated   | 85.53 ± 2.30 %  | 0.30 ± 0.90 % | 0.40 ± 0.30 % |

With the above concern, this study's objective is to determine the single fibre tensile properties of the PALF. The output of the research may help to understand the characteristic of the PALF for further application.

2. Methodology

2.1. Pineapple Leaf Sample Preparation

The pineapple leaf fibres obtained for this study was in bundle form, as shown in Figure 1 after the extraction process. The PALF was obtained from pineapple leaf extraction from a pineapple farm in Pontian, Johor, using the Pineapple Leaf Fibre (PALF) Machine 1 located in Universiti Tun Hussein Onn Malaysia. A single fibre of the PALF was extracted from the bundle for sample preparation.
The sample preparation was following the ASTM D3379 – 89 standards. The single fibre was attached to a paper frame of 60 mm in height with 20 mm width, with a hole of 20 mm height and 10 mm width at the centre frame, as shown in Figure 2. Six samples were prepared following the standard for better accuracy.

2.2. Single Fibre Tensile Test

The sample was mounted to the universal testing machine's grip. The paper frames will then be cut on the cut line, allowing the tensile forces from the universal test machine to be acting only on the single fibre. After that, the machine's pulling force exerted at the rate of 0.5 mm/sec until the fibre was break up. The data was recorded automatically in the machine software, and analysis was conducted after the test finished.
3. Result and Discussion

Figure 3 shows the mean data for force versus stroke data of pineapple leaf fibre. The force is gradually increased as the stroke increases to 0.936 mm before it starts to drop. The maximum force achieves in this graph is at 2.279 N at the stroke of 0.927 mm.

![Graph](image)

**Figure 3.** The mean data for the single pineapple leaf fibre tensile test.

The maximum forces obtained from the tensile test is then be calculated their maximum stress or strength, in Megapascal (MPa), by using the formula that relates the stress $f$, the density $\rho$, and the specific stress, $\sigma$:

$$f = \sigma \times \rho \tag{1}$$

In the equation, the stress $f$ is in the unit of Gigapascal (GPa), the specific stress $\sigma$ is in the unit of Newton per tex (N/tex) and the density in the unit of gram per centimetre cubic (g/cm$^3$). By using this formula, the maximum forces for each sample can be calculated their tensile strength by using the linear density of 9.000 tex and the density of 1.200 (g/cm$^3$) [24].

A stress-strain diagram is constructed using the formula above and shown in Figure 4. The ultimate tensile strength of the PALF is 141.093 MPa at a strain of 1.560 %. As for Young's Modulus, which is the slope of the graph is 89.073 MPa.

As for the previous research, such as S. Jose [21] and M. Asim [16], their tensile strength was 413 – 1627 MPa and 170 MPa, respectively, higher than this research 141.093 MPa. Their average Young's Modulus were 34.5 – 85.2 MPa and 62.1 MPa, which are lower than this output, 89.073 MPa. The difference in their chemical composition and the pineapple tree's origin can cause differences in their mechanical properties, resulting in the difference in experimental data.
4. Conclusion

The objective of the research is to determine the tensile properties of single fibre PALF. The Ultimate Tensile Strength and the Young Modulus was obtained successfully. The data of Ultimate Tensile Strength (UTS) and Young's Modulus of PALF are 141.093 MPa and 89.073 MPa, respectively. This primary data is needed as a reference for future enhancement in the following research.

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**Acknowledgement**

The authors would like to thank the Universiti Tun Hussein Onn Malaysia for supporting the research activity through research grant TIER 1: H773.