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Tensile strength study of mensiang (*scirpuss grossus*) fibre composites with unsaturated polyester resin matrix

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Abstract: The mensiang (scirpuss grossus) is a plant that grows on moist and watery land. Mensiang plants are commonly used by the society to produce mats or bags that have a strong and durable texture. This mensiang plant has fibres that can be used as reinforcement in polymer composites as a substitute for synthetic fibres. In composite manufacturing, one of the important factors in determining strength is the fraction between fibre and matrix. This study was conducted to determine the effect of different volume fractions of composites on the tensile strength of mensiang fibre reinforcement. Extraction of fibre from the stem of the mensiang plant was done manually by combing, so that the fibre was obtained. The fibres were then naturally dried by the sun for 2-3 days. The composite manufacturing process was carried out by using the hand lay-up method. Specimens and tensile testing procedures refer to the ASTM D638 standard. Several specimens were made by varying the fibre and matrix fractions. The test results showed that the 12.5% fibre volume fraction had the highest tensile strength. In this study there was no chemical treatment on the fibres before the lamination process, thus, this can be suggested for future researchers to study on the effect of chemical treatment on mensiang fibres on fibre bonding with the matrix.

Keywords: mensiang fiber; natural fiber; nature composite; renewable material

1. Introduction

The use of composite materials is increasing, because of the advantages in terms of a fairly high ratio of strength and lightness (Makruf et al., 2024). In the manufacture of composites, synthetic fibers are still widely used because of their ability to withstand water, chemicals and higher heat resistance (Rajak et al., 2022). However, the use of synthetic fibers has an impact on the environment because it cannot be recycled (Park & Kim, 2001). Various studies continue to be conducted to find natural materials that can replace synthetic fibers and improve their performance (Mohammed & Dauda, 2014). The use of natural materials can save resources and reduce environmental pollution (Kim et al., 2016).

Composites are a combination of two or more different materials that have properties that are superior to the properties of each constituent material (Hodkinson et al., 2011). Composites have the advantages of being easy to manufacture, relatively low cost, and environmentally friendly (Nurdin et al., 2023). One of the materials from natural fibres that can replace the use of synthetic fibres is fibres found in mensiang plants. Mensiang fibre has the advantages of being easy to obtain, easy to decompose naturally and non-toxic. In addition, mensiang fibre can grow and spread well in wastewater (Darajeh et al., 2014). The potential of mensiang fibre is very interesting and needs to be investigated further. For example, the type of matrix suitable for use, the volume fraction of fibre and matrix, the additives that can be used and the chemical treatment of mensiang fibre before use as a reinforcement.

Mensiang (*Scirpuss grossus*) plants contain 61.8% cellulose, 26.1% lignin, 21.2% pentosan, 11.5% ash, and 8.3% silica (Brink & Escobin, 2003). The plant has been widely distributed from Southeast Asia, India, China, Indonesia, Malaysia, Philippines, Sri Lanka, and Thailand (Suhaeri et al., 2024). This mensiang plant is often regarded as a nuisance weed and not useful (Lerdluksamee et al., 2013). Previous research on the manufacture of particle composite boards made from mensiang fibre and coconut fibre using 7% by weight adhesive for particle board construction has the highest elastic modulus value of 360.20 MPa and the highest rupture modulus of 21.60 Mpa (Kongkaew et al., 2019) In the research, the mesiang plant taken is the fibre for making fibre composites. This research was conducted by varying the volume fraction between fibre and matrix. This research is expected to be the basis for future research in the use of mensiang plants for fibre composites.

2. Material and methods

2.1 Preperation of mensiang's fiber

This study used mensiang (Cyperus rotundus) plants obtained from Tunggul Hitam Subdistrict, Padang City, West Sumatra Province, Indonesia. Previously, this mensiang plant was used by the community as a material for making mats. However, currently there are no more community businesses that produce mats from mensiang plants, so this plant is now a wild plant that is no longer used. The process of extracting fibre from the mesiang plant is presented in Figure 1.

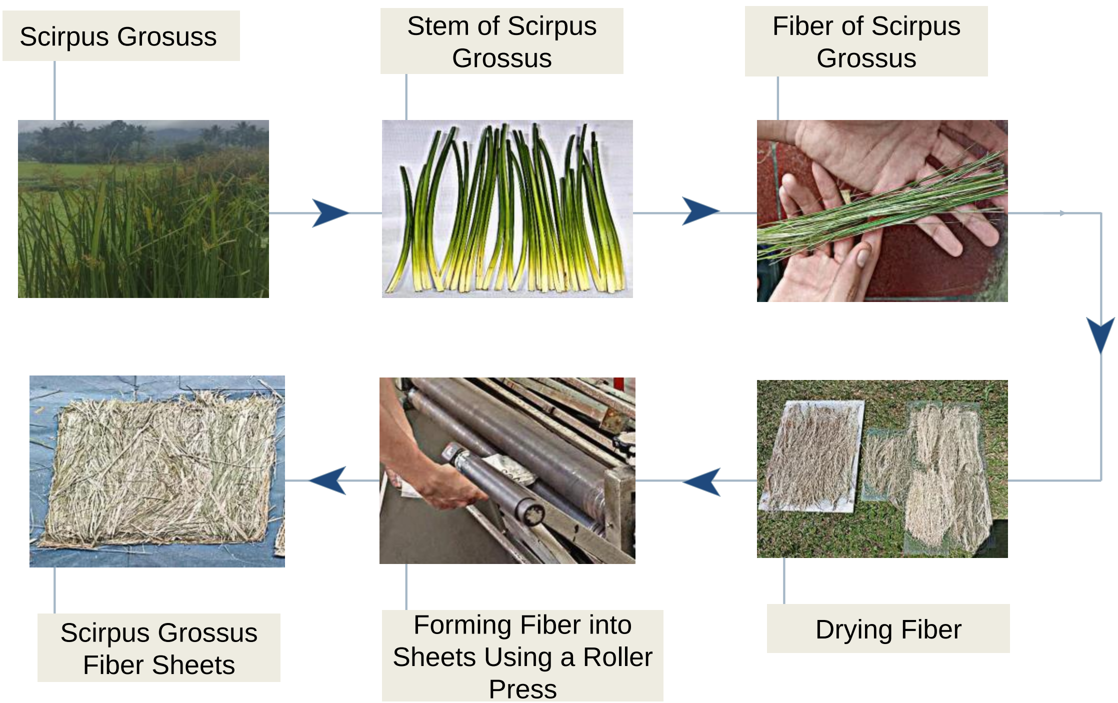

Figure 1. Fibre preparation process

The fibers are extracted from the plant stem by combing with a steel wire comb. Next, the fibers are dried in the sun for 2-3 days. This process is done to strengthen the bond between the fiber and the polymer matrix and reduce residual stress (Ming et al., 2023). The dried fibers were cut according to the size of the prepared mold and then the fibers were formed into sheets using a roller press to make it easy to flatten the fibers in the mold.

2.2 The composite lamination process

The manufacture of this mensiang fiber-reinforced composite uses the hand lay-up method. The mold is made of glass with dimensions of 250 mm x 140 mm x 8 mm. The composite manufacturing process is carried out by the hand lay-up method, which is the process of

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laminating resin on the fiber using a brush (Jamir et al., 2018). The type of resin used is unsaturated polyester resin. The stages of the composite lamination process are presented in Figure 2.

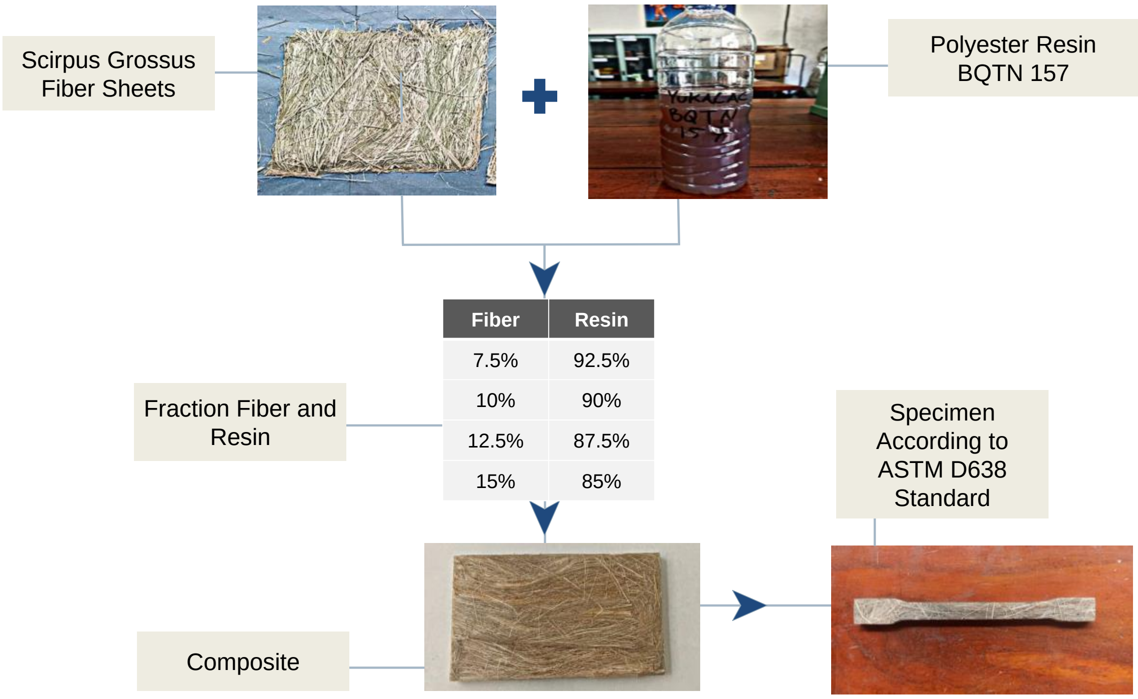

Figure 2. The composite lamination process

The composites were molded using 4 variations based on the fraction of fiber and resein. The printed composite is then cut according to ASTM D638 standard with the size in Figure 3. The fiber weight used is obtained from the percentage of fiber volume in the composite (Table 1).

Table 1. Fiber composition

Weight composition of mensiang fiber (%)	Total fiber weight (Gram)
7.5% mensiang fiber	19 Gram
10% mensiang fiber	25 Gram
12.5% mensiang fiber	30 Gram
15% mensiang fiber	35 Gram

2.3 Tensile testing and SEM

Tensile testing was conducted using a Universal Testing Machine (UTM) to analyze the mechanical strength of the samples. This test refers to the ASTM D638 standard, which is a standardized procedure for measuring the mechanical properties of materials, especially on plastic or composite samples. Each type of specimen was tested for three samples to ensure consistency and accuracy of the test results. In addition, a Scanning Electron Microscope (SEM) was used to examine the surface structure and interactions between material components. SEM allows observation of the surface morphology of mesiang fibers at the microscopic level, and facilitates evaluation of the bonding quality between the fibers and the composite matrix. The use of SEM is important to obtain a more detailed picture of the distribution and density of bonds, which affect the mechanical properties and overall durability of the material.

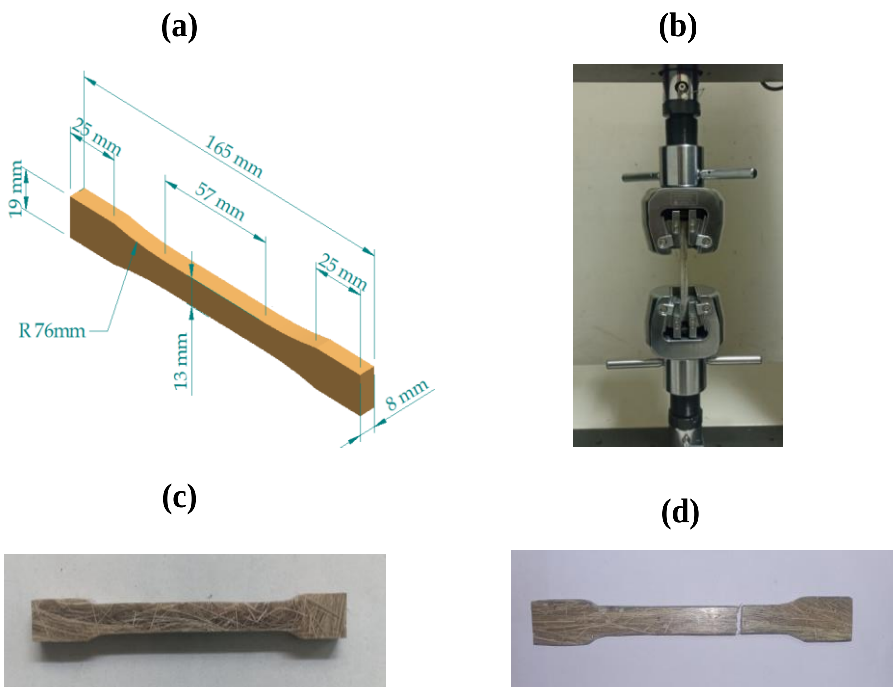

Figure 3. (a) Design tensile test specimens according to ASTM D638 Type 1 standard, (b) Tensile testing, (c) Tensile test specimen before breaking, and (d) Tensile test specimen after breaking

3. Results and discussion

Based on the results obtained on tensile test samples that were not treated with alkali with different fiber fractions in Figures 4 and 5. The tensile test results show differences in tensile strength and elastic modulus of mensiang fiber composites with different fiber fractions. With the increase of fiber fraction, the tensile strength also increases. Tensile test results for each specimen with different fiber fractions.

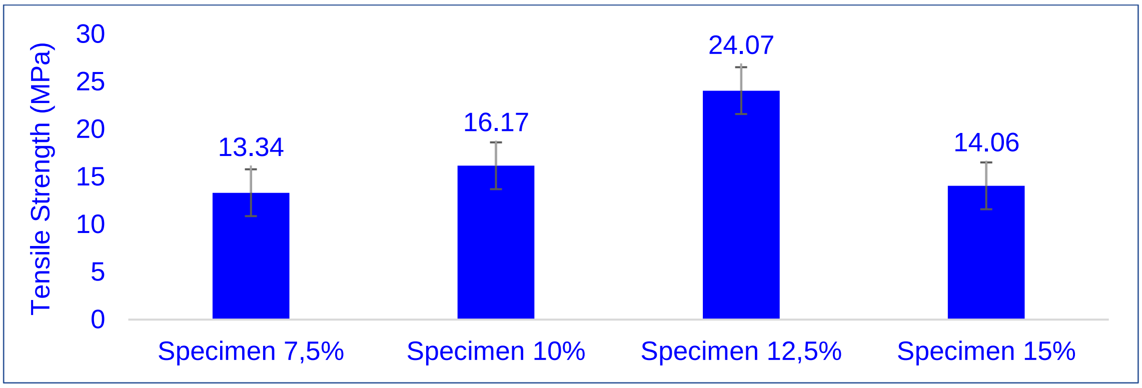

Figure 4. Tensile strength

Figure 4 the maximum value of tensile strength is at a fraction of 12.5% with a value of 24.07 MPa. When the percentage of fiber increases the orientation can become non-uniform reducing the effectiveness of load-bearing and tensile strength. The 15% fraction has a decreased tensile strength value compared to the 12.5% fraction. If the fiber orientation is uniform at a higher percentage, the tensile strength can increase again. The 12.5% fraction experienced an increase in tensile strength value compared to the 7.5%, and 10% fractions. In theory, the effect of fiber orientation and distribution by Gibson (2016) explained that fiber orientation and distribution affect the strength of composites. In composites with optimal fiber percentage, the fiber distribution tends to be more uniform, supporting maximum tensile strength. This shows that there is an increase in the tensile strength of fiber composites along with the increase in fiber fraction up to a certain limit (Gong et al., 2023; Singh et al., 2020; Ziaee et al., 2024).

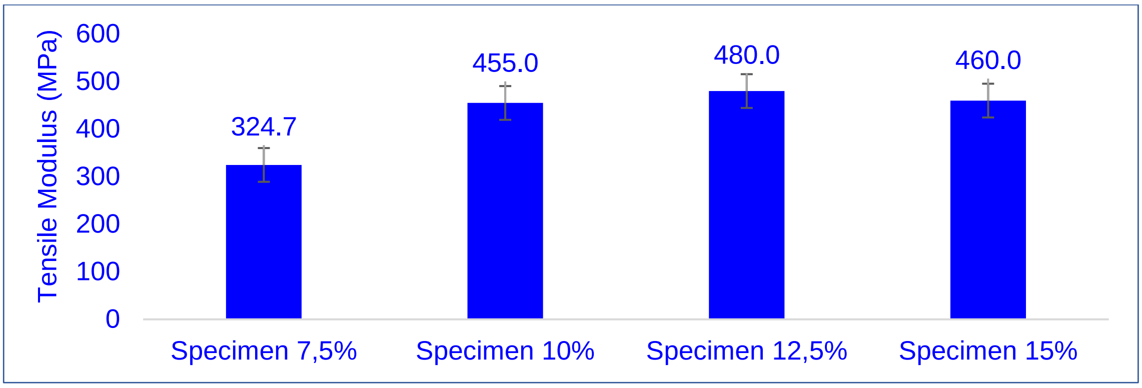

Figure 5. Modulus of elasticity

The obtained elastic modulus values are shown in Figure 5. The mensiang fiber composite shows the highest elastic modulus value at 12.5% fiber fraction with a value of 480 MPa. The lowest tensile modulus value was at 7.5% fiber fraction with a value of 324.7 MPa. However, the 15% fraction experienced a decrease from the increase in the graph in the 7.5% - 12.5% fraction. At 15% fiber fraction, it is because the matrix can no longer support the role of fiber reinforcement optimally and the stress concentration increases, thereby reducing the total stiffness of the composite. In previous research Ku et al. (2011) showed that the elastic modulus of the highest ramie fiber was 128 GPa. The value of young's modulus increases with increasing fiber volume fraction. Giving a large percentage of alkali treatment and a long soaking time can reduce the modulus of elasticity in fiber composites (Du et al., 2015).

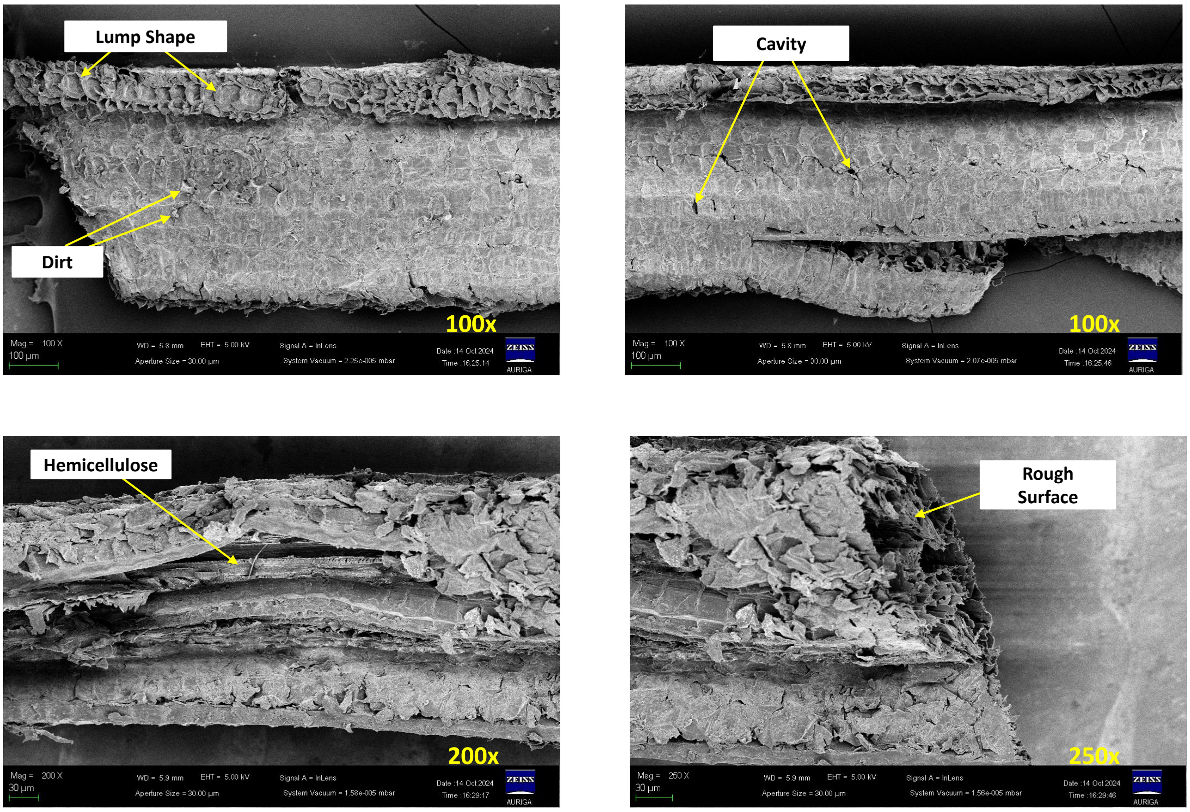

Figure 6. SEM results of mensiang fiber with magnification (a) 100x, (b) 100x, (c) 200x, (d) 250x

Observations using a Scanning Electron Microscope (SEM) show that the fibers contain various impurities, such as lignin, hemicellulose, and other compounds. The presence of these substances can affect the quality of the fibers, so that their durability as a reinforcing material is not optimal. To improve the performance of natural fibers, further research is needed that includes chemical treatment to remove these impurities. This chemical treatment is expected to produce fibers with better mechanical properties and adhesion, so that they can be maximally utilized as reinforcing materials in a wider range of applications.

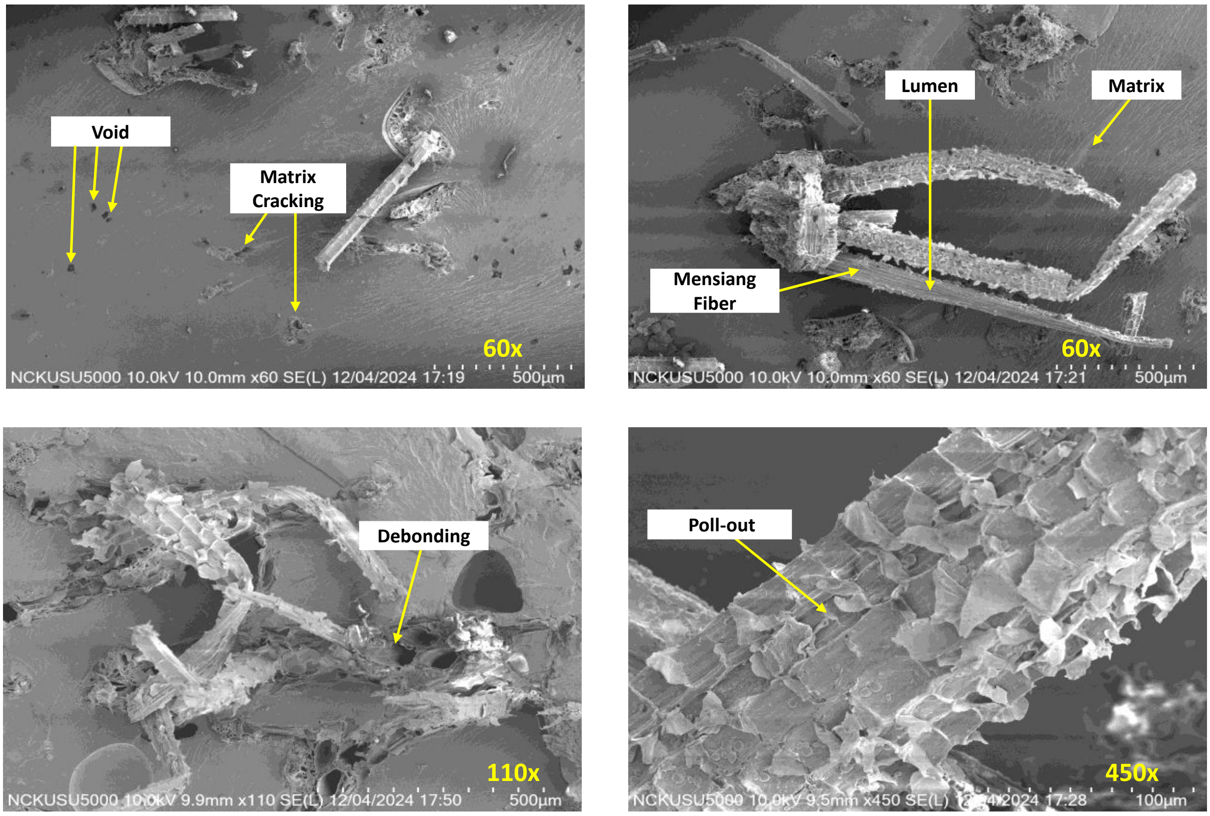

Figure 7. SEM results of the Composite with magnifications of 60x, 60x, 110x and 450x

SEM observations revealed the presence of matrix cracking, which is the cracking of the matrix due to the brittle nature of the matrix. This needs to be a concern because although the brittle nature causes the strength to increase, if the cracks that occur exceed the limit, it can cause debonding. Debonding is the loss of binding force between the fiber and the matrix. Debonding occurs because there is no strong binding force between the fibers and the matrix so that during testing the matrix is separated from the fibers. In mensiang fiber composites, poll-out is likely to occur due to the absence of alkali treatment on mensiang fibers. Poll-out is caused by the binding force between the fiber and the matrix which is less than perfect so that when testing is carried out, the fiber is separated from the matrix. This greatly affects the tensile strength of the composite. In addition, there is a lumen that can maintain the fiber structure and the shape of the cell wall that is still intact and smooth indicates that there is still lignin and hemicellulose in the fiber used.

4. Conclusion

Mensiang plants have the potential to be used as reinforcement in fiber composites. Based on the test data, the volume fraction of fiber and matrix used for making composites affects the tensile strength and elastic modulus. The highest tensile strength and highest elastic modulus are at 12.5% fiber composition while the minimum tensile strength and minimum elastic modulus are at 7.5% fiber composition. This study did not use chemical treatment on fibers from mensiang plants before being used as reinforcement in fiber composites. Further research needs to be done to test the effect of chemical treatment on the fiber, whether it will affect the fiber bond with the matrix so that it has an impact on improving mechanical properties.

Author's Declaration

Author contribution

Evan Hakiim: Conceptualization, Methodology, Writing- Original draft preparation. **Hendri Nurdin**: Supervision, Investigation, Data curation, Validation. **Zainal Abadi**: Data curation, Validation, Writing- Reviewing and Editing. **Wei-Ting Zhuang**: SEM observations.

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Competing interest

The authors state that there is no conflict of interest.

Ethical Clearance

This research does not involve humans or animals as subjects.

AI Statement

The language structures used in this article were checked by using Grammarly and has been verified by an English language expert. In addition, none of the sentences and figures in this article was AI tool-generated. All the data were obtained from the process of the study, and authors' and previous research review.

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Researcher and Lecturer Society as the publisher and Editor of Journal of Engineering Researcher and Lecturer state that there is no conflict of interest towards this article publication.

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