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# Manufacturing and Characterization of Composite Boards from Corn Husk Fiber, Water Hyacinth Fibers, and Sawdust Using Epoxy Resin

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**ABSTRACT**
Composite board has been made with corn husk fiber (CHF), water hyacinth fiber, and wood sawdust using epoxy resin as an adhesive. The composition of each fiber was varied, and physical tests (density, porosity, water absorption, and thickness expansion) and mechanical tests (modulus of elasticity (MOE), modulus of rupture (MOR), and compressive strength) were carried out, and microstructure was analyzed using SEM-EDX. The results of testing the physical and mechanical properties with optimum results were density of 1.03 g/cm$^3$, porosity of 10.48%, water absorption capacity of 10.22%, thickness expansion of 2.91%, MOR 256.05 kgf/cm$^2$, MOE 228 kgf/cm$^2$ and compressive strength of 3.19 MPa. The results showed that the physical (porosity, absorption, and thickness expansion) and mechanical (MOR and compressive strength) tests met the standards of SNI 03-2105-2006, while the MOE test did not meet the standards. For density testing, it complies with SNI 01-4449-2006 standards. The composite board can be used as a substitute for wood for furniture materials.

**Keywords:** Composite Board, Corn Husk Fiber, Epoxy, Sawdust, Water Hyacinth Fiber

**ABSTRAK**
Papan komposit telah dibuat dengan serat kulit jagung (CHF), serat eceng gondok, dan serbuk gergaji kayu menggunakan resin epoksi sebagai perekat. Komposisi setiap serat divariasikan, dan tes fisik (kepadatan, porositas, absorpsi air, dan ekspansi ketebalan) serta tes mekanik (modulus of elasticity (MOE), modulus of rupture (MOR), dan kekuatan tekan) dilakukan, dan struktur mikro dianalisis menggunakan SEM-EDX. Hasil pengujian sifat fisik dan mekanik dengan hasil optimal adalah kepadatan 1.03 g/cm$^3$, porositas 10.48%, kapasitas absorpsi air 10.22%, ekspansi ketebalan 2.91%, MOR 256.05 kgf/cm$^2$, MOE 228 kgf/cm$^2$, dan kekuatan tekan 3.19 MPa. Hasil penelitian menunjukkan bahwa tes fisik (porositas, absorpsi, dan ekspansi ketebalan) dan mekanik (MOR dan kekuatan tekan) memenuhi standar SNI 03-2105-2006, sementara tes MOE tidak memenuhi standar. Untuk pengujian kepadatan, papan komposit ini sesuai dengan standar SNI 01-4449-2006. Papan komposit dapat digunakan sebagai pengganti kayu untuk bahan furnitur.

**Kata kunci:** Epoksi, Papan Komposit, Serat Eceng Gondok, Serat Kulit Jagung, Serbuk Gergaji

## 1. Introduction

The manufacture of composite boards from natural fibers is essential because the availability of wood as a raw material for buildings and furniture is decreasing [1]. Natural fiber-reinforced composite materials are being considered more significantly than synthetic fiber-reinforced composites. Natural fibers offer various benefits over synthetic fibers, including being more affordable, lightweight, and plentiful [2].

Composite materials are defined as a mixture of multiple substances with contrasting shapes and chemical compositions, and they do not dissolve each other, where one material acts as a reinforcement and the other as a binder. Composites are composed of two components, namely the matrix in the form of resin and reinforcement or reinforcement, or some call it filler [3].

Maize is one of the most abundant crops in Indonesia. The Ministry of Agriculture (MOA) recorded that the production of maize with a moisture content of 25% in the country was 23 million tons in 2021. Maize in Indonesia is mainly grown in the lowlands in Tagelan, rain-fed and irrigated rice fields. Some are also found in mountainous areas 1000-1800m above sea level [4]. With the abundance of corn plants in Indonesia, corn plants must produce a lot of waste. Corn husk is widely used as animal feed in the community, especially in rural areas. However, if processed properly, the skin of this corn plant can be appropriately utilized and has a high selling value [5]. Corn husk waste is known to have a reasonably high cellulose content. The content of corn husk consists of 44.08% cellulose, 5.09% ash, 15.7% lignin, and 4.57% alcohol-cyclohexane [6].

Water hyacinth plants belong to a very high aquatic weed group, especially in tropical and subtropical regions. The rapid growth rate of water hyacinth is that one water hyacinth stem within 52 days can produce new plants covering an area of 1,000 hectares [7]. The water hyacinth plant stem (petiole) is round and bulging, filled with air spaces that float above the water surface [8]. Water hyacinths in water cause nuisance problems for local communities and aquatic animals. Water hyacinth (zirconia crassipes) is a weed whose development is challenging to control. Because water hyacinth grows to fill the surface, sunlight will not penetrate and enter below the surface [9]. This is an excellent potential for water hyacinth to be utilized in the manufacture of composites in the world of composite manufacturing. Furthermore, water hyacinth contains a chemical composition of 5.77% ash, 0.68% silica, 8.93% lignin, 18.14% pentose, and 72.63% cellulose [10].

On the other hand, wood waste, either in the form of chips or sawdust, is hardly optimally utilized; efficient utilization of sawdust can help overcome several problems related to the environment [11]. Wood sawdust may be used as a raw material to create composite boards, increasing the economic worth of wood waste. 49% of the wood sawdust is cellulose, while 26.8% is lignin, 15.6% pentose, 0.2% silica, and 0.6% ash [12].

Based on the content of the three materials, the composite board's quality is anticipated to improve in its physical and mechanical properties. The composite board can be used as building materials and furniture for tables, cabinets, and other wood-based products. Based on previous research, no research has combined the three materials. Therefore, this research aimed to manufacture and characterize composite boards made of wood sawdust, water hyacinth fiber, and corn husk fiber using epoxy resin.

## 2. Method

### *2.1. Treatment of Corn Husk*

High-quality corn husks were selected, and any dirt adhering to them was meticulously removed. Subsequently, the corn husks were washed and immersed in a 2% NaOH solution for one hour. Following this, they were thoroughly rinsed again. The corn husks were then carefully combed using an iron comb until they were shaped into strands. Next, these strands were left to dry under the sun. Once dried, the corn husk fibers were cut into 1 cm pieces. Consequently, the corn husk fiber was prepared for use.

### *2.2. Treatment of Water Hyacinth*

High-quality water hyacinth stems were carefully chosen, and any dirt adhering to them was thoroughly cleaned. The water hyacinth stems were then dried under sunlight until fully dry. Once dried, they were ground into fine water hyacinth powder using a blender. Subsequently, the ground sawdust was sieved using a 120 mesh sieve to ensure uniformity. Finally, the water hyacinth fiber was prepared and ready for use.

### *2.3. Treatment of Sawdust*

The sawdust was washed and cleaned to eliminate dirt contaminants before being sun-dried. To prepare it for use, the dried sawdust was blended and sifted through a 120-mesh sieve to achieve a refined texture.

### *2.4. Mixing of Raw Materials*

The sifted and cut supplies were weighed according to the specified composition. Subsequently, they were thoroughly mixed using a mixer for 5 minutes to achieve a homogeneous sample mixture. The combined raw components were then placed in a mold coated with wax and lined with aluminum foil. The mold was left to air out on an electric compressor for 20 minutes at an ambient temperature of 100°C.

Table 1. The composition of composite board-making materials.

| Sample | MaterialI | | | | |
|---|---|---|---|---|---|
| | *Epoxy* Resin (wt%) | Hardener (wt%) | CHF (wt%) | Water hyacinth fiber (wt%) | Sawdust (wt%) |
| A | 25 | 25 | 0 | 20 | 30 |
| B | 25 | 25 | 5 | 20 | 25 |
| C | 25 | 25 | 10 | 20 | 20 |
| D | 25 | 25 | 15 | 20 | 15 |
| E | 25 | 25 | 20 | 20 | 10 |
| F | 25 | 25 | 30 | 20 | 0 |

In the composite board standards issued by several countries, there may still be differences in criteria, testing methods, and requirements. However, they are primarily the same. The composite particleboard is characterized by determining and analyzing the mixture of polymers with fibers. Table 2 shows the standards BSN [13] and JIS [14] for particleboard testing.

Table 2. The standards of particleboard testing.

| No. | Physical and Mechanical Properties | SNI 03-2105-2006 | JIS A 5908-2003 |
|---|---|---|---|
| 1. | Density ($g/cm^3$) | 0.5 – 0.9 | 0.4 – 0.9 |
| 2. | Moisture content (%) | < 14 | 5-13 |
| 3. | Water absorbency | - | - |
| 4. | Thickness development (%) | Max 12 | Max 12 |
| 5. | MOR ($kgf/cm^2$) | Min 82 | Min 80 |
| 6. | MOE ($kgf/cm^2$) | Min 20,400 | Min 20,000 |
| 7. | Internal adhesive strength ($kg/cm^2$) | Min 1.5 | Min 1.5 |
| 8. | Screw holding force(kg) | Min 30 | Min 30 |

*2.5. Density Testing*

The principle of implementing theoretical density is by weighing the composite sample's weight and then determining the composite's volume value according to the visual appearance seen by measuring the sides of the composite [15].

## 3. Results and Discussion

*3.1. Density Test Results Analysis*

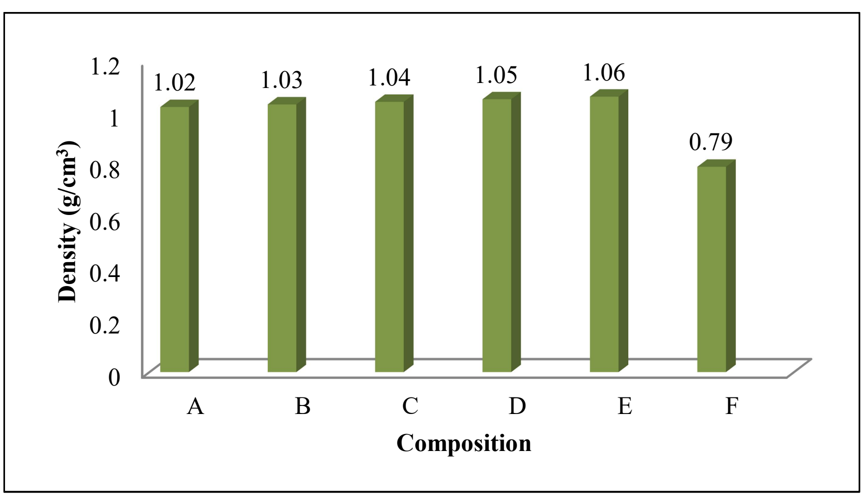



Figure 1. Density test results.

Figure 1 shows that the optimum density value is found in the composition of the E board sample, which is 1.06 g/cm$^3$. Meanwhile, the minimum density value found in the composition of the F board sample is 0.79 g/cm$^3$. The optimum density value can be obtained from the composite board sample composition, found in composition E, 1.06 g/cm$^3$. Furthermore, the minimum density is found in the F composition of 0.79 g/cm$^3$. The addition of each wood powder composition and reduction in the composition of each corn husk fiber resulted in a decrease in the density of the composite board.

According to BSN, composites can be classified based on their density, namely low-density fiberboard, which has a high density $< 0.40$ g/cm$^3$, medium-density fiberboard, namely fiberboard with a density of 0.40−0.84 g/cm$^3$, and high-density fiberboard with a density$>$ 0.84 g/cm$^3$ [16].

Similar research was also carried out by Desiasni et al., which showed the results of the density of composite boards with a corn husk fiber composition of and polyester resin (25:75) had a density value of 0.85 g/cm$^3$ and the density of a board with a corn husk fiber content of and Polyester resin (75:25) has the most negligible density, namely 0.51 g/cm$^3$ [17]. So it can be concluded that the lower the corn husk fiber content and the more resin in the composite, the lower the absorption and the higher the density value, and conversely, the greater the corn husk fiber content and the less resin in the composite, the greater the absorption and the lower the density value.

### *3.2. Porosity Test Results*

Porosity testing is carried out to determine the pores or air cavities in particle boards [18]. Data from research on dry sample mass and wet sample mass, as well as sample volume, are used to look for porosity. Figure 2 displays the porosity test's findings.

Figure 2 shows that the higher the porosity value, the more maize husk fiber is utilized. The largest porosity was obtained in sample F, namely 24.31%. This is because, in sample F, the composition of wood sawdust is 0% while the composition of corn husk fiber is 30%, giving rise to many voids and making the composite board have the highest porosity value.

The porosity value of a material is inversely proportional to the density of the composite material because porosity is the cavity found in the composite material and will affect the density of the material. The denser a material is, the higher the density and the smaller the porosity, and vice versa [15].

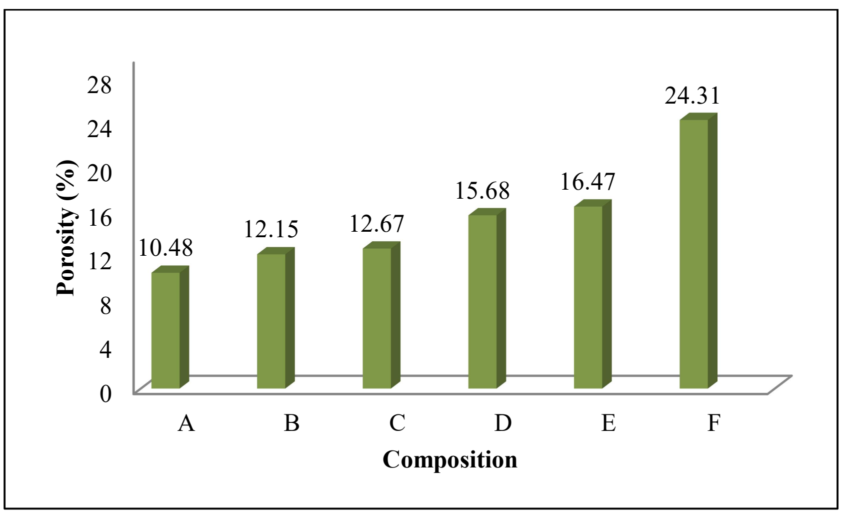



Figure 2. Porosity test results.

### *3.3. Water Absorption Testing*

Absorption testing aims to determine the amount of water samples soaked for 2-4 hours at ambient temperature. Figure 3 displays the water-absorbing test results.

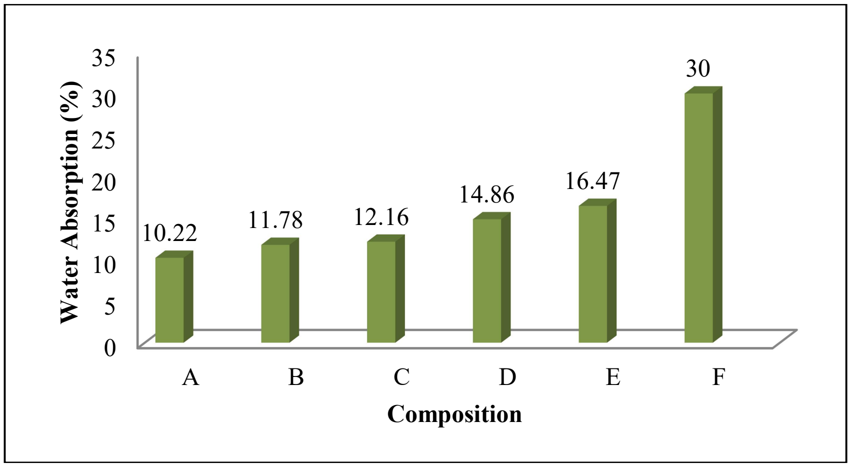



Figure 3. Water absorption test results.

Figure 3 shows that composition A's minimum water absorption value is 10.22%. The highest water absorption value is 30% in composition F. Based on the graph above, the more maize husk fiber utilized, as may be observed, the higher the absorption capacity value. The water will get higher, too. The more corn husk fiber is used, the more cavities will form, so the higher the water absorption [5].

Based on the research by Chairunnisa, the maximum absorption capacity of composite boards is 14% [12]. Thus, it can be inferred that samples A, B, and C meet this standard, while the remaining three samples do not.

### *3.4. Thick Development Testing*

Thickness expansion is the increase in board thickness after being soaked for 24 hours. When the sample is soaked, water will enter the pores of the composite board material. Measurements of sample thickness were carried out before immersing the sample thickness and after immersion.

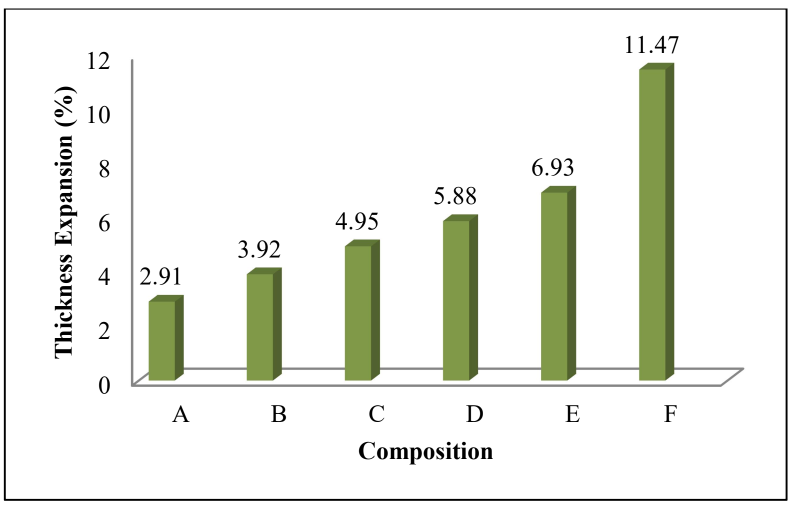



Figure 4. Thickness expansion test results.

Figure 4 demonstrates that composition A has an initial water absorption value of 2.91% and a maximum water absorption value of 11.47% in composition F. Thickness development is related to water absorption by the composite board. With the higher water absorption, the corn husk fibers absorb water, making the composite board expand, meaning that more changes in the dimensions of the composite board occur. The large amount of corn husk fiber makes the resulting thick development even greater.

According to BSN, the maximum expansion value for composite board thickness is 12% [13]. So, it can be concluded that all composite board samples meet the standards.

### 3.5. Modulus of Rupture (MOR) Testing

Modulus of Rupture (MOR) testing measures a material's strength and ability to withstand bending or flexural loads without breaking. Based on Figure 5, the MOR value above shows that various data results are obtained, namely around 123.61 kgf/cm $^2$ – 228 kgf/cm$^2$. Meanwhile, according to BSN, the MOR value of composite boards is at least 82 kgf/cm$^2$ [13]. So it can be concluded that all composite board samples have met SNI standards. The MOR value of composite boards is related to the matrix and fiber bonding process. The stronger the bond between the matrix and the fiber structure, the better the MOR value of the composite board produced. The compression temperature factor also has an authentic influence on the MOR value [19].

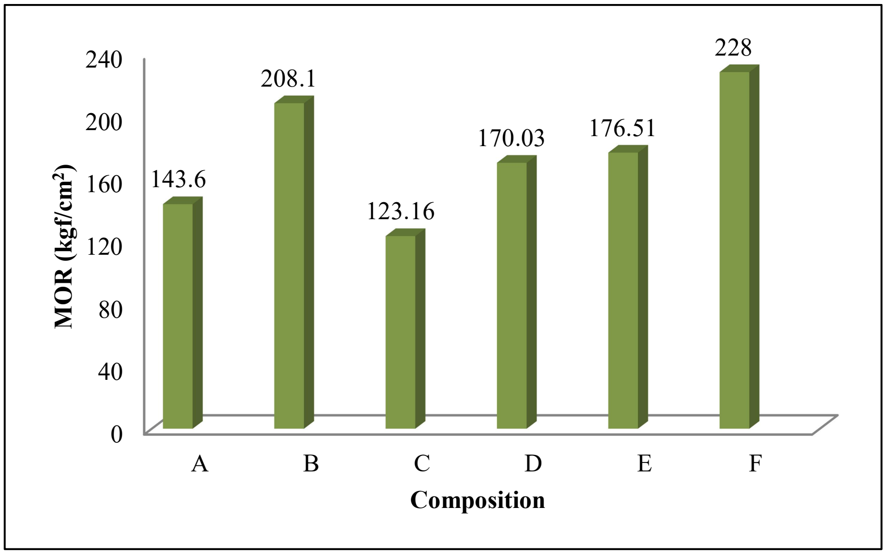



Figure 5. MOR test results.

### 3.6. Modulus Testing of Elasticity (MOE)

Modulus Testing of Elasticity (MOE) testing is carried out to determine the resistance of a material to experiencing elastic deformation when force is applied to the object. The results of the tensile strength test can be seen in Figure 6.

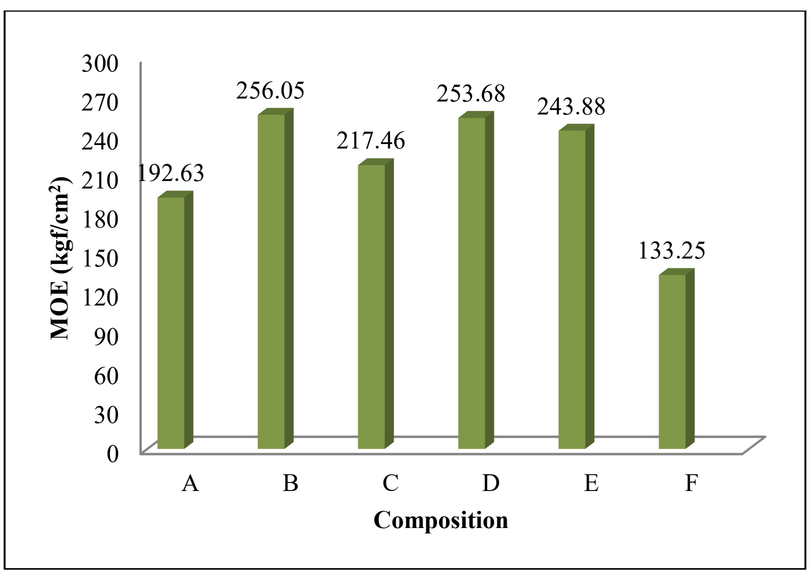



Figure 6. MOE test results.

According to BSN, the minimum MOE value of composite boards is 20400 kgf/cm$^2$ [13]. Meanwhile, according to Figure 6, the MOE value ranges from 133.25 kgf/cm$^2$ to 256.05 kgf/cm$^2$, so none of the tested samples met the standard [13]. This is thought to be due to the uneven distribution of fibers at the sample-making stage during the composite board-making process, even though efforts have been made so that each material can be mixed evenly. The unequal distribution of fibers in the sample means that during the compression process, the pressure received causes the pressure received on each composite board to be unequal.

### *3.7. Compressive Strength Testing*

Compressive strength testing is carried out to determine the material's resistance to withstanding loads/forces until failure occurs. The results of the Compressive Strength test can be seen in Figure 7.

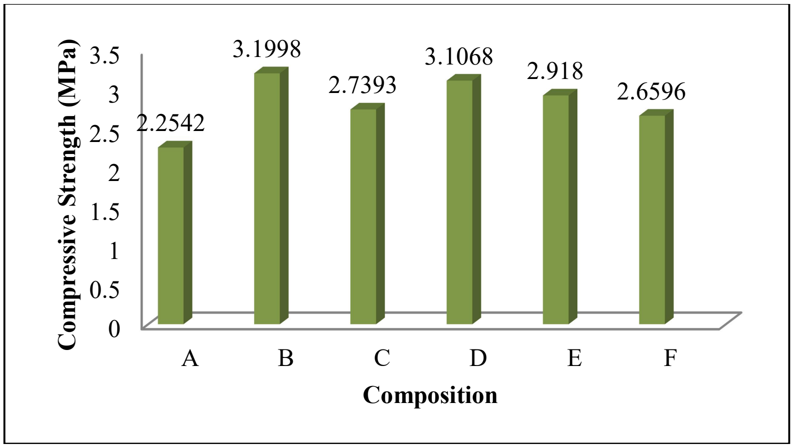


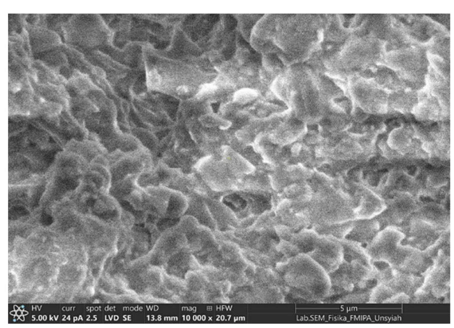

Figure 7. Graph of results composite board compressive strength testing.

The tests obtained a maximum compressive stress value of 3.1998 MPa in sample B with a composition of 5% corn husk fiber, 20% water hyacinth fiber, and 25% wood sawdust using 25% epoxy resin. According to BSN, the compressive strength value obtained in this study meets the standard with a 6 kg/cm$^{-3}$ value, which, if converted, becomes 0.59 MPa [13]. The compressive strength value obtained in this study was lower than that obtained by research on composite boards from a mixture of palm frond waste and polypropylene matrix [20], 6.72 MPa – 13.43 MPa. This is due to the uneven distribution of fibers at the sample-making stage during the composite board-making process, even though efforts have been made so that each material can be mixed evenly.

### *3.8. Microstructural Testing*

The SEM-EDX test results of composite board sample B with a composition of 5% corn husk fiber, 20% water hyacinth fiber, and 25% wood sawdust using 25% epoxy resin with a heating temperature of 100°C for 20 minutes are shown in Figure 8.

(a)



(b)

Figure 8. (a) SEM-EDX test of sample B (5:20:25) 1000× magnification, and (b) SEM-EDX test of sample B (5:20:25) 10000× magnification.

Figure 8. (a) shows the SEM-EDX test results on sample B with 1000× magnification with a composition of (5:20:25) and the addition of 25% resin; it can be seen that there are still some air voids in the sample. This is due to the uneven mixing of each material at the sample-making stage in the composite board-making process, although it has been attempted so that each material can be mixed evenly (homogeneous). Figure 8. (b) shows the SEM - EDX test results on sample B with 10000× magnification with a composition of (5:20:25). Moreover, 25% resin was added. At 10000× magnification, it can be seen that the air voids are more clearly visible.

## 4. Conclusion

In conclusion, the addition of corn husk fiber, water hyacinth fiber, and wood sawdust significantly impacts the mechanical properties, including Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and compression strength. The mechanical test values increase with higher wood sawdust composition and lower corn husk fiber composition. Similarly, the addition of these fibers affects the physical properties, such as porosity, water absorption, and thickness expansion. There is an increase in the physical test values with changes in corn husk fiber composition, while those of the other fibers decrease, particularly wood sawdust. The optimal composition, when using epoxy resin as a compatibilizer, consists of 5% corn husk fiber, 20% water hyacinth fiber, and 25% sawdust, along with 25% epoxy resin. This composition yields the best results, with a density of 1.03 g/cm$^3$, porosity of 10.48%, water absorption capacity of 10.22%, thickness expansion of 2.91%, MOR of 256.05 kgf/cm$^2$, MOE of 228 kgf/cm$^2$, and compressive strength of 3.19 MPa.

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