# Evaluation of the Effect of Coconut Coir Fiber Addition on Polypropylene Matrix Composite Properties

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**Abstract.** Research has been conducted on coconut coir fiber composites with a polypropylene matrix. The aim of this study is to examine the effect of adding coconut coir fiber to the polypropylene matrix on the physical and mechanical properties of the composite. The method used is the hand lay-up method, which is carried out in the laboratory by initially preparing coconut coir fibers and polypropylene matrix, then mixing them and placing them into molds. Subsequently, hot pressing is performed at a pressure of 38 atm and a temperature of 150°C for 30 minutes. After being cooled to room temperature, the composite is tested according to testing standards. The results obtained are the density values of the coconut coir fiber (CCF) and polypropylene (PP) composites ranging from 0.543-0.7 g/cm3, water absorption capacity ranging from 0.5-16.45%, moisture content ranging from 0.14 – 0.22%, and thickness swelling value ranging from 0.76 - 15%. For mechanical properties, the MOR value ranges from 11.22 – 19.20 MPa and the MOE value ranges from 220 – 350 MPa.

**Keywords:** coconut coir fiber, polypropylene, composite.

## INTRODUCTION

Indonesia's tropical rainforest is the third largest in the world, after Brazil and the Congo. About 59% of Indonesia's land area is tropical rainforest, which contributes 10% of the total global forest area, approximately 126 million hectares. However, the area of forests in Indonesia continues to decline at a very concerning rate along with population growth. Uncontrolled deforestation over several decades has also significantly contributed to the reduction of forest area. As a result of this damage, it can be seen that the forest's carrying capacity is unable to meet the wood demand in line with population growth. [1].

According to data from the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry (KLHK) in 2022, input from 202 regencies/cities across Indonesia recorded the national waste accumulation reaching 21.1 million tons. Of this total waste production, 65.71% (13.9 million tons) can be managed, while the remaining 34.29% (7.2 million tons) has not been well managed. In response to this crisis, there are efforts to find innovative solutions in the management and mitigation of plastic waste. This plastic waste can be reused by recycling it and turning it into new products, one of which can be used as a substitute for wood/board. One of the most commonly found plastic wastes is polypropylene.

Polypropylene (PP) is the main material in the production of plastic products. The characteristics of polypropylene include: an elastic modulus of 1400 MPa, tensile strength of 35 MPa, and elongation of 10 to 500%, and polypropylene has a latent heat of 210 J/g [2].

Composites made from Polypropylene (PP) reinforced with Coconut Fiber have been extensively researched for various applications[3][4][4]. Based on this, research on the use of composites with cultivated natural fibers is increasing because consumers are aware of the need to preserve the environment.

Coconut coir waste is a material that contains lignocellulose and can be utilized as an alternative raw material for the production of particle boards that can conduct heat [3][5][6][7]. One of the factors that affects the quality of composite boards is density.

In general, the higher the density of particleboard, the better its mechanical physical properties will be. However, the more raw materials are needed, the higher the production costs will be. Therefore, research is necessary to determine the optimum density. Particle size greatly affects the physical and mechanical characteristics of composite boards. As the investigation of wood waste in fine and coarse sizes has affected its characteristics. Coarse particle sizes can increase its MOR and MOE values, and the variation in fiber sizes used in this study also significantly influences the results obtained. The hardness of the composite is directly proportional to its density, where the density of each composite depends on the fiber mesh size. For 40 mesh bamboo fiber particle size, it has the lowest hardness value, while 80 mesh has the highest hardness value [8].

The purpose of this research is to examine the effect of adding coconut coir fiber on the physical and mechanical properties of polypropylene matrix composites compared to the SNI 03-2105-2006 standard.

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## METHODS

### A. Material

Coconut Coir Fiber (CCF) functions as a reinforcement. CCF is collected from coconut coir collection points around Lhokseumawe. Polypropylene (PP) waste is collected from aqua glass waste around Lhokseumawe. Alkali for soaking the fibers to remove the wax layer present on the CCF particles. The coupling agent functions as an enhancer of the bond between the matrix (PP) and Coconut Coir Fiber (CCF).

### B. Treatment of Coconut FiberTreatment of Coconut Coir Fiber (CCF)

SSK as a composite filler undergoes pre-treatment before use. The pre-treatment process of the fibers affects their characteristics, namely the physical and mechanical properties of the composite [9]. CCF was cleaned and sized to a uniform 4 mesh. It was then soaked in a 5% NaOH solution for 2 hours. SSK was then washed with running water until neutral pH and dried under sunlight.

### C. Treatment of Polypropylene Waste (PP)

PP is taken from glass aqua waste, cleaned, and cut into pieces measuring 1x1 cm². Mix PP with xylene and reflux it at a temperature of 1700°C until it becomes liquid PP, then dry it in an acid cabinet for 3 days until it becomes dry PP. Then, this dry PP is ground into ready-to-use PP powder.

### D. Composite Manufacturing

CCF composite is mixed with ready-to-use PP according to its composition and placed into a mold. Then, the mold is inserted into a hot press machine with a pressure of 38 atm and a temperature of 150°C for 30 minutes. The pressed result is removed from the machine and dried at room temperature for 1 day.

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**Table 1.** Composition of Coconut Coir Fiber/PP Waste Composite

| Type komposit | Rasio CCF : PP |
|---|---|
| | |
| A1 | 30:70 |
| A2 | 40:60 |
| A3 | 50:50 |
| A4 | 60:40 |

### E. Testing of Density

In the density test, three specimens were cast with dimensions of 10x10x1 cm in an air-dry condition, then their length, width, and thickness were measured to determine their volume. The density test used Equation 1.

$$K = \frac{B}{V} \quad (1)$$

Where,
K = Density (g/cm3)
B = Dry air weight (g)
V = dry air volume (g)

**F. Testing of Water Absorption**

In the water absorption test, three specimens were cast with dimensions of 50x50x10 mm. The specimens were dried by leaving them at room temperature for 14 days. After drying, they were weighed. The specimen is then soaked in water for 24 hours. The water absorption test refers to ASTM D 785. Water absorption is calculated using Equation 2.

$$DSA = \frac{m_2 - m_1}{m_1} x100 \quad (2)$$

Where,

DSA = water absorption capacity (%)
$m_1$ = weight of the specimen before immersion (g)
$m_2$ = weight of the specimen after immersion (g)

**G. Testing of Water Content**

The moisture content is one of the physical properties of composite boards that indicates the water content of the composite board in equilibrium with its surrounding environment. The moisture content is calculated using equation 3.

$$KA = \frac{m_{ku} - m_{ko}}{m_{ko}} x100\% \quad (3)$$

Dimana:

KA = moisture content (%)
$m_{ku}$ = Dry air mass (gr)
$m_{ko}$ = Oven dry mass (gr)

**H. Testing of swelling thickness**

Thickness swelling is an increase in the dimensions of the board with increasing thickness of the board. The equation for the thickness swelling value can be seen in equation 4.

$$PT = \frac{t_2 - t_1}{t_1} x100\% \quad (4)$$

Dimana ,

PT =Thickness swelling (%)
$t_1$ = Thickness before soaking in water (mm)
$t_2$ = Thickness after soaking in water

**H. Testing of the Modulus of Rupture**

Modulus of fracture (MOR) is the strength of fracture of a beam expressed in the amount of stress per unit area, which can be calculated by using the amount of stress on the top and bottom surfaces of the beam at maximum load. The equation for the thickness swelling value can be seen in equation 5.

$$MOR = \frac{3PL}{2bd^2} \quad (5)$$

Dimana,
MOR = Modulus of Rupture (kgf/cm$^2$)
L = Length of span(kgf)
d = Thickness of the test sample(cm)
b = Lebar contoh uji (cm)

**I. Testing of the Modulus of Elasticity (MOE)**

The modulus of elasticity is a value indicating stiffness properties which is a measure of the material's ability to withstand changes in shape or bending that occur during loading at the proportion limit. The equation used is shown in equation 6.

$$MOE = \frac{\Delta PL^3}{4\Delta Ydb^3} \quad (6)$$

Where,
MOE = Modulus of Rupture ($kgf/cm^2$)
ΔP = Difference from load (kgf)
L = Distance from support (cm)
d = Thickness of the test sample(cm)
b = width of the test sample (cm)

## RESULTS AND DISCUSSION

### THE RESULTS DENSITY

Density indicates how dense a material is within a certain volume. Figure 1 shows the effect of the type of composite board on its density. Testing the value of density uses equation 1.

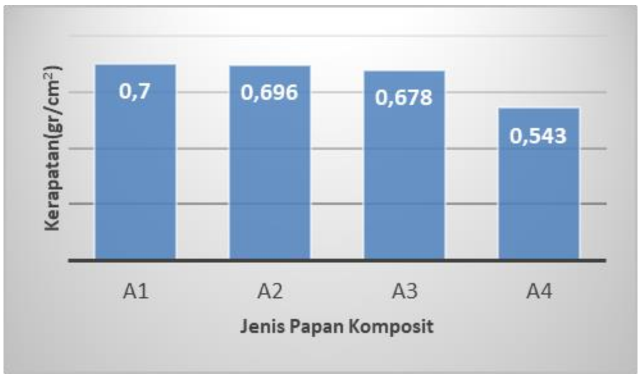


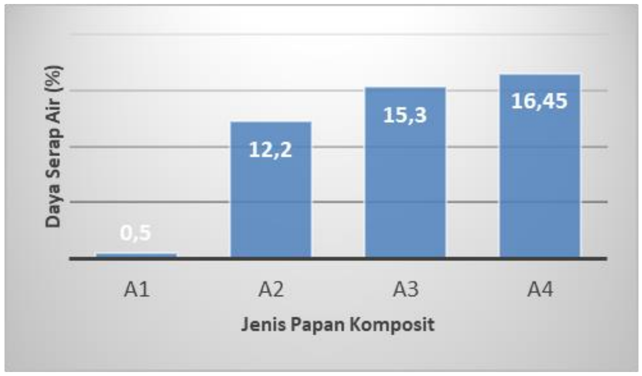

**Figure 1.** Type of Composite Board Against Density Value

In Figure 1, the performance of the composite against density is shown. The density value of the coconut coir fiber (CCF) and polypropylene (PP) composite ranges from 0.543-0.7 $g/cm^3$. The highest density value is found in sample A1 with a 30% SSK percentage of 0.7 g/cm3. In this sample, the composite is still dominated by the polypropylene matrix. Coconut coir fibers have a lower density than the polypropylene matrix, so a higher proportion of fibers can result in a lower density. Meanwhile, the lowest density is found in sample A4 with 60% coconut coir fibers at 0.543 $g/cm^3$.

The higher the fiber content percentage in the composite, the lower the density value. This occurs because the increasing amount of fiber, while the percentage of the polypropylene matrix decreases, causes a compositional imbalance. As a result, the matrix is unable to fully wet the fibers. The numerous cavities that formed caused the density of the composite to decrease [10][11] . All specimens meet SNI 03-2105-2006 for density, which is 0.4-0.9 $g/cm^3$.

### THE RESULTS OF WATER ABSORPTION

Water absorption is the ability of a material to absorb and retain water. Figure 2 shows the water absorption values of the composite samples. esting the water absorption value using equation 2.

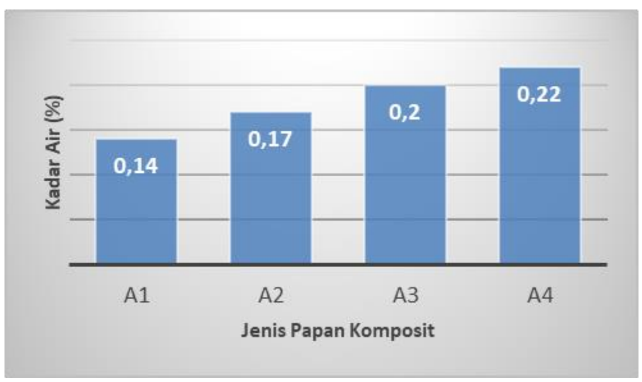



**Gambar 2.** Type of composite board in relation to water absorption

Figure 2 shows the performance of the composite in terms of water absorption. Water absorption ranges from 0.5-16.45%. The A1 type composite, which consists of 30% coconut coir fibers, has a water absorption of 0.5%. Meanwhile, the A2 type has a water absorption of 12.2%. The A4 type composite, with a matrix content of 60%, has the highest water absorption performance at 16.45% compared to the other types. The increase in the amount of coconut coir fibers in the composite results in a higher water absorption capacity of the composite. This phenomenon is accompanied by the amount of matrix, where the gradual reduction of the matrix percentage has improved the water absorption performance of the composite. The higher the fiber percentage and the lower the polypropylene matrix percentage, the more cavities are formed in the composite specimens, allowing water to easily enter and become trapped inside. The findings are consistent with those of previous researchers [9][12].

## THE RESULTS OF WATER CONTENT

The moisture content indicates the amount of moisture contained in the material. This is the most important parameter that can affect the physical and mechanical properties of the material. Figure 3 shows the moisture content value in the composite. testing of water content uses equation 3.

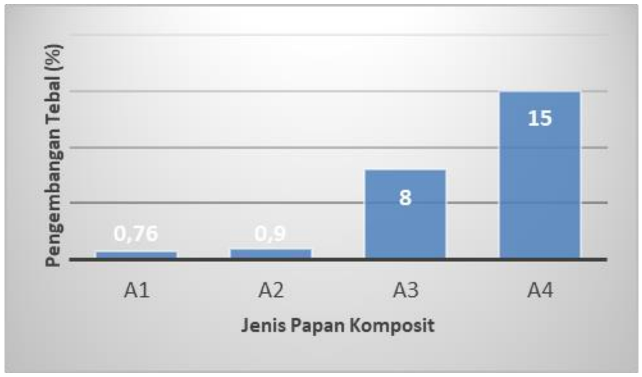



**Gambar 3.** Type of composite board in relation to moisture content

In Figure 3, it can be seen that the moisture content values range from 0.14% to 0.22%. The lowest moisture content is found in A1 with 30% coconut coir fiber. This is followed by A2 with 40% coconut coir fiber, resulting in a moisture content value of 0.17%. Similarly, A3 with 50% coconut coir fiber results in a moisture content of 0.2%, and A4 with 60% coconut coir fiber results in the highest moisture content value of 0.22%. It turns out that the higher the percentage of coconut coir fiber in the polypropylene matrix, the higher the moisture content value. Materials with high moisture content tend to be more susceptible to damage due to humidity, and fluctuating moisture levels can cause dimensional changes in the material, such as swelling or shrinkage, which can affect the structural integrity and performance of the product [13].

## THE RESULTS OF THICKNESS SWELLING

Thickness swelling is a property of board particles related to their ability to absorb air. The thickness development of this composite can be seen in Figure 4. Testing of thickness swelling uses equation 4.

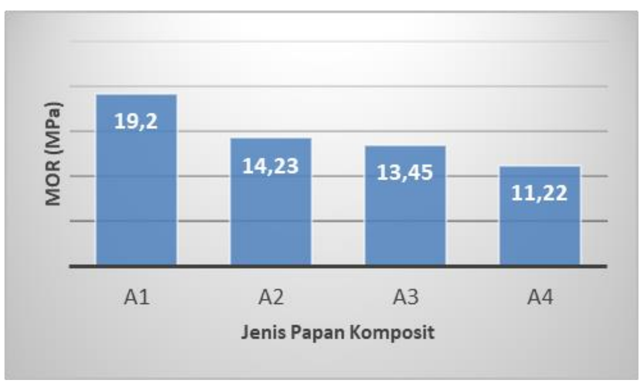



**Gambar 4.** The type of composite is related to the swelling thickness.

In Figure 4, the swelling thickness values of the composite range from 0.76% to 15%. Sample A1 with 30% coconut coir fiber shows a thickness expansion value of 0.76%. An increase in coconut coir fiber within the polypropylene matrix by 40% also increases the thickness expansion value to 0.9%. Similarly, sample A3 with a 50% addition results in a thickness expansion value of 8%. The addition of 60% coconut coir fiber causes the largest increase in thickness expansion, reaching 15%. It turns out that the increase in the percentage of coconut coir fiber within the polypropylene matrix leads to an increase in the thickness expansion value. This is related to the decreasing density value and the increasing volume addition. The increasing proportion of coconut coir fibers can cause a decrease in density due to the reduction of the polypropylene matrix that binds the fibers [14][15].

## THE RESULTS OF MODULUS OF RUPTURE

Modulus of Rupture (MOR) is a measure of a material's strength under bending load, describing the material's ability to withstand force before breaking or failing. Testing of the Modulus of rupture uses equation 5. The value of MOR on the composite board can be seen in Figure 5.

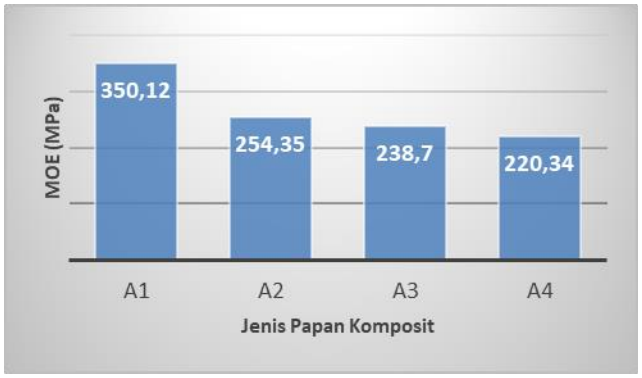



**Gambar 5.** The type of composite is related to the MOR value.

In Figure 5, the MOR values range from 11.22 to 19.20 MPa. For A1, the highest MOR value is 19.2%, obtained with a composition of 30% coconut coir fiber. Meanwhile, for A2, the MOR value is 14.23 MPa with a composition of 40% coconut coir fiber. For A3, the MOR value is 13.45 MPa with a composition of 50% coconut coir fiber. In A4, the lowest MOR value is 11.22 MPa with a composition of 60% coconut coir fiber. From the test results, it is evident that as the composition of coconut coir fiber increases, the MOR value decreases. If coconut coir fibers are added without enhancing the bond between the fibers and the polypropylene matrix, this can result in a decrease in strength [16]. Thus, samples A1, A2, and A3 meet the SNI 03-2105-2006 standard, which is a minimum of 13.0428 MPa.

**THE RESULT VALUE OF THE MODULUS OF ELASTICITY (MOE)**

The Modulus of Elasticity is a measure of a material's ability to return to its original shape after experiencing elastic deformation. Testing the modulus of elasticity uses equation 6. The elasticity value can be seen in Figure 6.




**Gambar 6.** The type of composite is related to the Modulus of Elasticity.

In Figure 6, the modulus of elasticity (MOE) values of the composites are shown. The values range from 220 to 350 MPa. The highest value was obtained from sample A1 at 350.12 MPa, which contains 30% coconut coir fiber composition. Sample A2, with a 40% coconut coir fiber composition, resulted in an MOE value of 254.35 MPa. Sample A3, with a value of 238.7 MPa, contains 50% coconut coir fiber composition, and the lowest MOE value of 220.34 MPa was obtained with a 60% coconut coir fiber composition. It is evident that as the coconut coir fiber composition increases, the MOE value decreases. This is because the fibers are not well bonded with the polypropylene matrix, which can cause instability and reduce the material's ability to transfer loads effectively, thereby decreasing its stiffness [17]. In this sample, none meet the SNI 03-2105-2006 standard, which is a minimum of 1961 MPa.

## CONCLUSIONS

The results of the study show the physical characteristics, including the density value of the coconut coir fiber (CCF) and polypropylene (PP) composites ranging from 0.543-0.7 g/cm³, water absorption ranging from 0.5-16.45%, moisture content ranging from 0.14 – 0.22%, and thickness swelling ranging from 0.76 - 15%. For mechanical properties, the MOR value ranges from 11.22 – 19.20 MPa and the MOE value ranges from 220 – 350 MPa. The addition of coconut coir fiber in the polypropylene matrix can reduce its physical and mechanical properties.

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