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Effect of corn stalks and palm fibers ratio on physical, mechanical, and durability properties of particleboard

Effect of corn stalks and palm fibers ratio on physical, mechanical, and durability properties of particleboard

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Abstract. Corn stalk and palm fiber are potential non-wood material as a raw material in the manufacture of particleboards. The purpose of this study was to analyze the corn stalk and palm fiber ratio to the physical, mechanical, and durability properties of particleboard. In this study, corn stalk and palm fiber were made into particles with a length of 7 cm respectively. Isocyanate adhesive content used in board manufacturing was 10% with a solid content of 97%. The process of making boards using a hot press machine was set at a temperature of 160ºC, the pressure of 30 kg/cm² for 5 minutes. The result showed that the higher proportion of palm fiber to decrease in the thickness swelling value indicates an improvement in the dimensional stability value even though it has not yet met the standards. The mechanical parameters of the board showed a tendency to decrease with the increasing composition of the palm fiber. The durability test of particleboard showed that the board given the palm fibers were more resistant to termite attack.

1. Introduction

Non-wood lignocellulosic material is suitable for used material for particleboard. Several studies have been conducted previously related to the characteristics of particleboards made of non-wood material [1-5]. The advantage of non-wood lignocellulosic material mainly from crops is the abundance of material. This is because the life cycle of crops is shorter compared to forestry plants. This is what drives efforts to use agricultural crop waste as material in particleboard manufacturing.

One of the agricultural commodities in Indonesia is corn. Corn is a strategic commodity after rice. East Java is one of the corn production centers with a contribution of around 27.7% of the total, followed by Central Java (15%), Lampung (8.4%), and South Sulawesi (7.9%). Corn plants after harvested, the stalk can be used as particleboard materials. Corn stalks are lignocellulosic wastes that are still underutilized. Another agricultural commodity that has the opportunity as a raw material for particleboard is a palm plant. This plant produces a hydrophobic material, ijuk (palm fiber). Palm fiber has advantages such as being flexible and not easily brittle, which is very resistant to acids and high salt content [6].

It is expected that the use of palm fibers mixed with corn stalks can improve particleboard weaknesses, especially those related to low dimensional stabilization rates. The purpose of this study was to analyze the corn stalk and palm fiber ratio to the physical, mechanical, and durability properties of particleboard.

2. Materials and Method

2.1. Materials
Corn stalks and palm fiber are cut using a chopper to 7 cm in length. Furthermore, the corn stalks are dried until they reach a moisture content of 9%. The fibers are cut with a length of 7 cm.

2.2. Methods

2.2.1. Raw materials preparation
Corn stalks are dried and then cut to particle size with a chopper, then dried again to 9% levels. Black fibers cut with a length of 7 cm.

2.2.2. Board making
Particleboards were made with targets for density and thickness of 0.7 g/cm³ and 1 cm, respectively. The first stage of board making was the mixing process of particles with adhesives. The adhesive used in this study was isocyanate with a 10% adhesive level (SC: 97%). After the adhesive had been mixed evenly into the particles, the next step is to make sheet boards. Particles were inserted into a mold measuring 25 x 25 cm^2. Then the sheet formed was pressed by using a hot press. Pressing was set at a temperature of 160^{o}C, pressure 30 kg/cm² for 5 minutes. Particleboards were made of 3 replications for each treatment. The last step in the board manufacturing process is board conditioning. The board is conditioned in a room with room temperature conditions around 25^{o}C.

2.2.3. Durability test of particleboards against termite attacks
Particleboard testing parameters consist of density and Moisture Content (MC), Water Absorption (WA), Thickness swelling (TS), Internal Bond (IB), Modulus of Elasticity (MOE), and Modulus of Rupture (MOR). Dimensions of samples for testing physical and mechanical properties include density and MC (10 cm x 10 cm), WA, TS and IB (5 cm x 5 cm), MOE and MOR (20 cm x 5 cm). Testing the physical and mechanical properties of particleboard refers to [7]. While for the durability test of the board is done using the grave test [8]. The sample used for this test measures 20 x 5 cm.

2.3. Data analysis
This research uses a non-factorial complete randomized design (CRD). As treatment is the ratio of corn stems and palm fiber consisting of 6 levels (100/0, 80/20, 60/40, 40/60, 20/80, 0/100) with 3 replications so that the total number of boards made is 18 boards.

3. Results and Discussion

3.1. Physical properties

3.1.1. Density and moisture content
The density value and moisture content of the particleboard were shown in Figure 1. The density value of the board ranges from 0.53 - 0.68 g/cm^3. The highest density value was produced from boards that have a ratio of 100/0 and the lowest values from boards with a ratio of 0/100. The board density value has fulfilled JIS A 5908 (2003) which requires density values ranging from 0.40 to 0.90 g/cm^3 [7], but the density value has not met the specified target (0.70 g/cm^3). The target density was not achieved because during the process of mixing the adhesive and making the sheet there were wasted particles. According to [9] stated that not achieving the specified target density was due to the loss of particles during the board manufacturing process. Besides this, spring back also becomes one of the causes of not achieving the target density. Springback occurs because the two materials used were bulk, corn stalks and palm fiber are non-wood materials that have a low density.

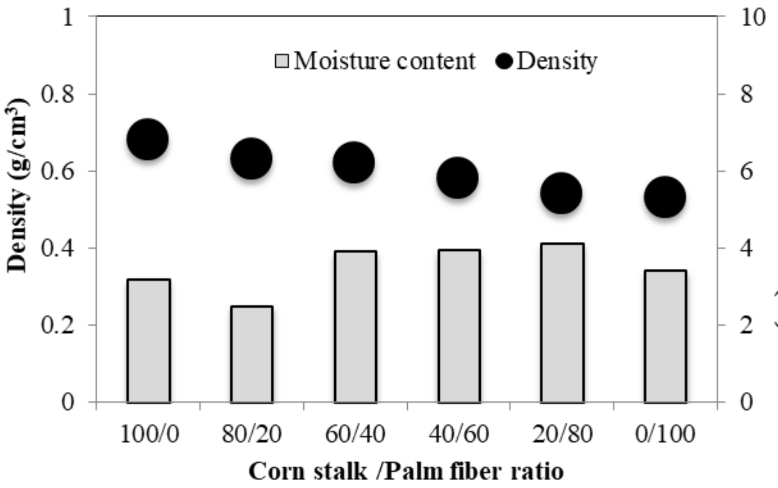

Figure 1. Density and moisture content of particleboard

The highest moisture content value was produced from the board with a ratio of 20/80 of 4.12% and the lowest at an 80/20 ratio of 2.48%. Boards with an 80/20 ratio have the lowest moisture content, this was presumably due to the predominance of palm fibers where the fibers have hydrophobic characteristics so that they cannot absorb the adhesive well so that chemical bonds with isocyanate adhesives do not occur. The trend in Figure 2 shows that decreasing board density results in increased moisture content. A high-density board has a bond between particles with a good adhesive so that water molecules are difficult to fill the cavity contained in the composite board. Analysis of variance showed that the ratio of corn stems and palm fiber significantly affected the density and moisture content of particleboards at 95% confidence intervals.

3.1.2. Water absorption

The water absorption value for 2 hours and 24 hours was presented in Figure 2.

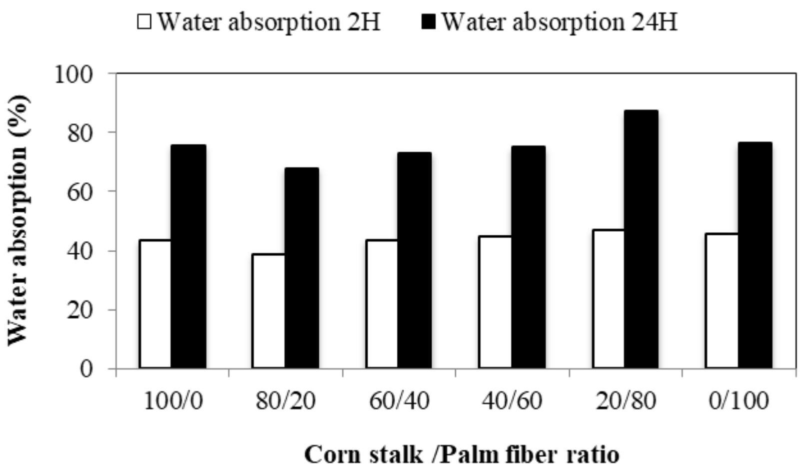

Figure 2. Water absorption of particleboard

The water absorption value for 2 and 24 hours ranges between 38.86% - 47.12% and 68.09% - 87.35% respectively. The highest water absorption for 2 hours and 24 hours was obtained on boards with a ratio of 20/80 and the lowest on boards with a ratio of 80/20. As with moisture content, water absorption value trends show similar things. Increasing the proportion of palm fiber causes an increase in the value of water absorption. The hydrophobic nature of the palm fiber is thought to be one of the causes, thereby reducing the adhesive ability of the isocyanate adhesive. The analysis of variance showed that the amount of palm fiber had no significant effect on the water absorption value for 2 and 24 hours at a 95% confidence interval.

3.1.3. Thickness swelling (TS)
The thickness swelling value for 2 and 24 hours was presented in Figure 3.

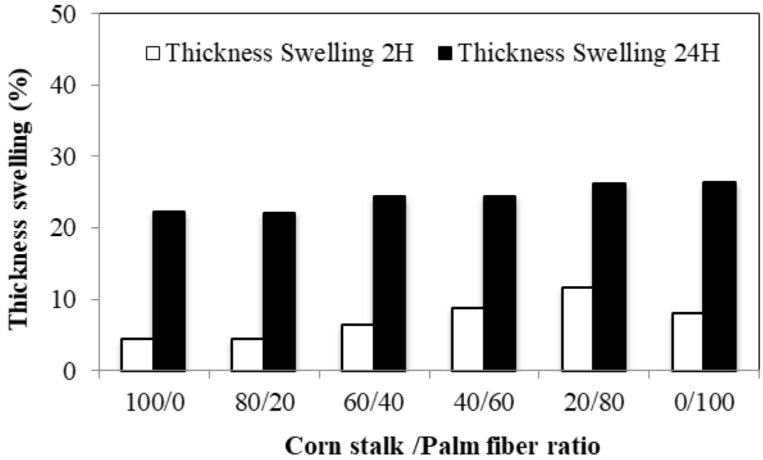

Figure 3. Thickness swelling of particleboard

The thickness swelling for 2 and 24 hours in Figure 3 ranges between 4.42% - 11.71% and 22.16% - 26.47% respectively. The highest values of thickness swelling were on the board with a ratio of 0/100 and the lowest at 80/20. Trends show that increasing the ratio of palm fiber results in an increase in the value of thickness swelling. The hydrophobic character of palm fiber causes the adhesive to not adhere properly so that the bond between particles becomes weak.

The thickness swelling value is also influenced by spring back [2,5]. Springback values in this study ranged from 10-28% where the highest value was produced on boards with a ratio of 20/80 and the lowest at an 80/20 ratio. The higher spring back value causes the thickness swelling value to increase. Analysis of variance showed that the ratio of corn stalk and palm fiber significantly affected the thickness swelling of the board for 2 hours at 95% confidence intervals, and did not significantly affect for 24 hours. In general, the resulting board did not meet the standards of JIS A5908 (2003) which requires a maximum thickness swelling value of 12% [7].

3.2. Mechanical properties

3.2.1. Modulus of elasticity (MOE) and Modulus of rupture (MOR)
The mean values of MOE and MOR particleboards were shown in Figure 4.

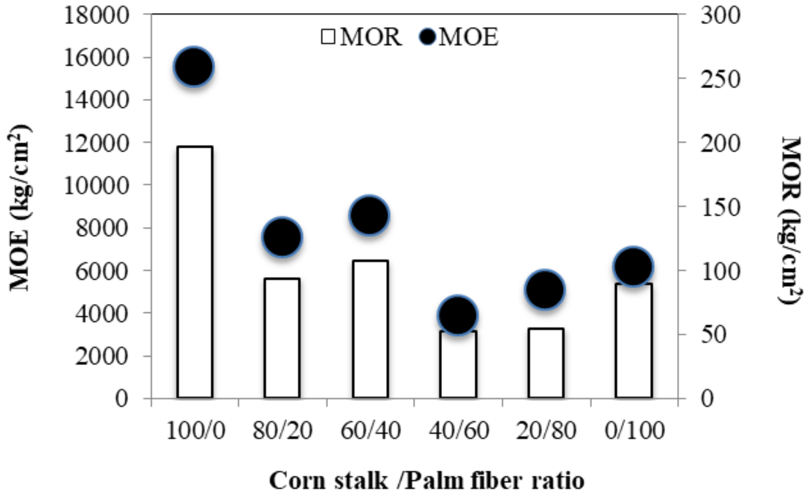

Figure 4. The MOE and MOR of particleboards

According to Figure 4, the MOE and MOR values of particleboards range between 3833 - 15511 kg/cm^2 and 52.76 - 196.44 kg/cm^2 respectively. The highest MOE and MOR values are on the board with a ratio of 100/0 and the lowest at a ratio of 40/60. The trend in Figure 4 shows that the increase in the composition of palm fiber results in a decrease in the value of MOE and MOR. The board density factor also influences this trend. According to [10] that the higher the density of particleboards will be followed by MOE and MOR boards. The Analysis of variance showed that the ratio of corn stalk and palm fibers significantly affected the MOE and MOR values of particleboards at 95% confidence intervals. The MOE value of the particleboard produced in this study did not meet the standards of JIS A 5908 2003 which require a minimum MOE value of 20,400 kg/cm^2 [7]. Meanwhile, for the MOR value, only the ratio of 40/60 and 20/80 did not meet the standards.

3.2.2. Internal bond (IB)

The Internal Bond (IB) values of particleboard were shown in Figure 5.

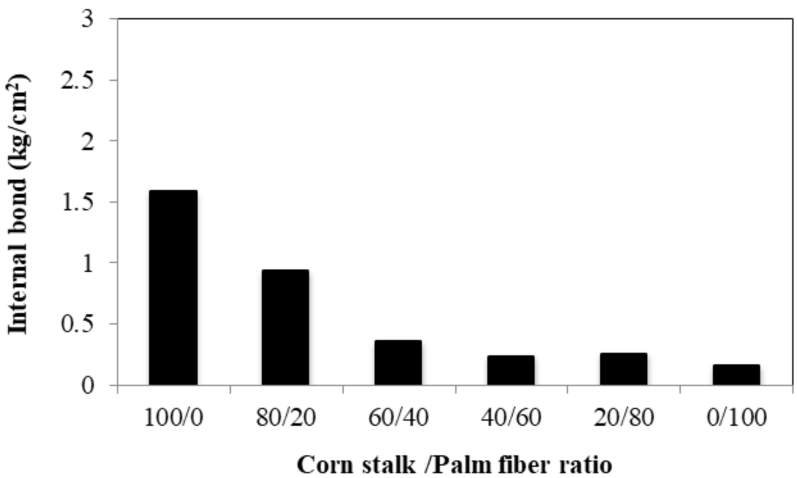

Figure 5. Internal bond of particleboards

Based on Figure 5, IB values range from 0.16 - 1.59 kg/cm². The highest IB is on the board with a ratio of 100/0 and the lowest is on the board with a ratio of 0/100. Most of the IBs produced did not meet JIS A 5908-2003 standards which required a minimum IB value of 1.5 kg/cm^2 [7], except for boards with a ratio of 100/0 that had met these standards. The hydrophobicity of palm fiber particles causes the adhesive to not be able to glue optimally so that the bond between the particles becomes weak. The next possibility was that the corn stalk has a slippery bark that is difficult to penetrate. This is similar to a study conducted by [11] who reported that sorghum bark is slippery and hydrophobic so that it inhibits the performance of adhesives resulting in weak bonding. The Analysis of variance showed that the ratio of corn stalk and palm fibers significantly affected the IB values of particleboards at 95% confidence intervals.

3.2.3. Particleboards durability

Particleboard weight loss value is presented in Figure 6. Based on Figure 6, the particleboard weight loss value ranges from 3.18 - 49.62%, where the highest value is found on boards with an 80/20 ratio, and the lowest is on boards with a 0/100 ratio.

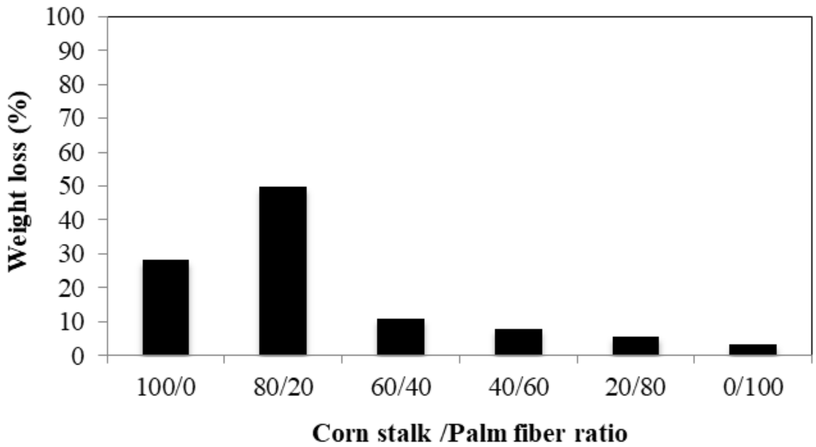

Figure 6. Weight loss of particleboards

Based on Figure 6, it can be seen that the increasing proportion of palm fiber results in a decrease in the value of loss of board weight. Long-lasting palm fiber affects the termite attack. This is following the statement of [12] palm fiber has several advantages, which are durable and not easily rot in the soil. The Analysis of variance showed that the ratio of corn stalk and palm fibers significantly affected the weight loss values of particleboards at 95% confidence intervals.

4. Conclusions

Based on the test results of the thickness swelling value, particleboard from a mixture of corn stalk and palm fiber still has a low dimensional stability value. However, there is a tendency for the higher proportion of palm fiber to decrease in the thickness swelling value, this indicates an improvement in the dimensional stability value even though it has not yet met the standards. The mechanical parameters of the board showed a tendency to decrease with the increasing composition of the palm fiber. The results of the durability test of particleboard showed that the board given the palm fibers were more resistant to termite attack.

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