International Journal of Applied and Physical Sciences
volume 4 issue 2 pp. 50-58 doi: https://dx.doi.org/10.20469/ijaps.4.50003-2

# The Effect of Size and Composition Variation of Cacao (*Theobroma Cacao*) Peels Powder with Bagasse Fillers on Physical And Mechanical Properties of Particle Board

**Yuli Yetri***
Mechanical Engineering Department,
Padang State Polytechnic,
Padang, Indonesia

**Sukatik**
Civil Engineering Department,
Padang State Polytechnic,
Padang, Indonesia

**Ruzita Sumiati**
Mechanical Engineering Department,
Padang State Polytechnic,
Padang, Indonesia

**Rahmi Hidayati**
Civil Engineering Department,
Padang State Polytechnic,
Padang, Indonesia

***Abstract:*** The research was conducted about the effect of size and composition variation of cacao peels powder with bagasse fillers on particleboard's physical and mechanical properties. The physical and mechanical properties tested are density, water absorption, compressive and flexural strength. Variations of cacao (*Theobroma cacao*) peels powder size used is 8, 10, 20, and 30 Mesh, while the variation of cacao peels powder and the bagasse composition used is (100: 0)%, (80: 20)% and (60:40)%. Testing of mechanical properties used a *Universal Testing Machine (UTM)*. The calculation result of physical properties of particleboard got standard JIS A 5908-2003, but the mechanical properties did not get the standard of JIS A 5908-2003. The optimum value of density resulted at size 10 Mesh with the composition (100:0)%, (80:20)% for water absorption, an optimum value of the mechanical properties of the cacao peels powder resulted at size 20 Mesh with the composition of the material (60:40)%.

***Keywords:*** *Particle board, cacao peels powder, physical properties, mechanical properties*

***Received:*** 20 February 2018; ***Accepted:*** 23 May 2018; ***Published:*** 13 July 2018

## I. INTRODUCTION

The particle board is a product made by mixing materials containing lignocellulose with adhesive and hot forged at a certain temperature. Particle board can be used as an alternative to wood, so it can help reduce the use of wood. Excessive logging in addition to destroying forests also adversely affects the environment and human survival.

One of the plants that contain lignocellulose is bagasse, which has potential as a particle board raw material. Sugar cane is the main raw material in the manufacture of sugar. This plant is a kind of grasses and thrives in tropical climates such as Indonesia. So far, sugar cane utilization is still limited to sugar processing by taking only water. While the bagasse is about 35-40% of the weight of sugar cane is only used as an industrial material or may be disposed to waste. Unused bagasse can damage the environment and if burned also cause new problems of air pollution. The bagasse has a fiber length between 1.7 and 2 mm with a diameter of about 20 micrometers. This fiber is not soluble in water, so it meets the requirements to be processed into an artificial board. The water content in bagasse is about 48-52%, and an average of 3.3% sugar content, and fiber averaging 47.7%

*Correspondence concerning this article should be addressed to Yuli Yetri, Mechanical Engineering Department, Padang State Polytechnic, Padang, Indonesia E-mail: yuliyetriyetri@gmail.com

[1, 2, 3]. The bagasse fibers contain 62.78% insoluble silica so that the bagasse particle can function as a heat insulator [4]. The weakness of sugarcane particles has poor strength and MOR (Modulus of Rupture) adhesion [5, 6]. Therefore, to improve the quality of particle board produced, bagasse is given another mixture such as cacao peels powder [7, 8].

Cacao is one of the national export commodities with a wide spread of planting and growing well in Indonesia. Cacao has a substantial contribution in generating foreign exchange and contributes to the development of regions and agro-industries. In 2015, Indonesia's cacao plantation area is 1 million ha spread from Sabang to Merauke. The largest component of cacao peels waste comes from the skin of the fruit, which is 75% of the total fruit [2]. Utilization of cacao peels waste is still very limited; people use cacao peels waste only as animal feed and compost only. However, in general, cacao peels waste produced is simply left to rot just around the plantation area, so the economic value obtained from the utilization is still quite low. The peels of cacao fruit have high cellulose, hemicellulose, and lignin content. The properties of cellulose are insoluble in water, allowing the peels of the cacao fruit to be good for particle board [2]. A previous study on thermal conductivity value of particle board with a composition ratio of bagasse and sawdust, it was found that the smaller the composition of the bagasse, the greater the thermal conductivity value [9, 10]. The particle board is good as a heat insulator and has the lowest thermal conductivity value that is on a particle board without a sawdust mixture [9, 11]. [6] made a particle board using raw husk and fine husk raw materials with 60:40 raw material ratio and a comparison of Urea Formaldehyde (UF) mass adhesive variation. The results obtained that the physical properties that meet the standard of JIS A 5908-2003 are particle board with a density of 0.703 gram/cm$^3$ to 0.709 gram/cm$^3$ and water content with the value of 8.75% to 9.92% [6]. However, the mechanical properties of the particle board do not meet the Japanese Industrial Standard (JIS) A 5908-2003 standard.

Based on these studies, it will be researched for water absorption, density, compressive strength and flexural strength of particle board made by using bagasse and cacao peels powder. Cacao peels powder is varied in size and composition, whereas bagasse is only in composition. It is hoped that these variations will produce better physical properties and mechanical properties and conform to the standards set by JIS A 5908-2003 [12].

## II. RESEARCH METHOD

This research was conducted in the Physics Laboratory of Materials Department of the Physics Andalas University of Padang. Particle board sample is made in the Laboratory of Technology and Process Engineering of Agricultural Product Department of Agricultural Product Technology. The sample test is done in Mechanical Metallurgy Laboratory, Mechanical Engineering Department, State Polytechnic of Padang. Cacao peels used as the base material is taken from Pariaman and bagasse took from sugarcane merchant traders, as well as the polyester resin used as adhesive. The sample is made with size (20 x 20 x 1) cm using hot and cold presses. Then, the mechanical properties test such as compressive strength and flexural strength using the Galdabini Universal Testing Machine (UTM) and physical properties tested were water absorption and density test.

## III. RESEARCH PROCEDURE

The bagasse is cleaned with water until clean, then dried in the sun for two days. It is then coated with a wire brush to remove the cork that is still attached to the bagasse, then cut along 5 cm. Cacao peels are cut thinly and dried for 14 days. After drying it is smoothed with blender and sieved with sieve size 0.59, 0.84, 2.0, and 2.38 mm. All prepared ingredients are then weighed with compositions can be seen in Table 1.

### A. *Particle Board Manufacture*

Particle board is done in 2 stages. First, mixtures of the ingredients (bagasse and cacao peels) are in accordance with the composition with adhesive/resin (16% of sample weight) and catalyst (1% by weight of the resin), stirring until well mixed in the bucket. The second stage is mixed feedstock is fed into a place with size (20 x 20 x 1) cm. Further, cool forged for 20 minutes and hot forged for 10 minutes with a temperature of 140°C. The very hot particle board sheets were removed from the forged machine and left for about 2 minutes. After that, it is removed from the mold and dried for seven days. For the purpose of characterization, cutting the particle board with a hacksaw based on the desired size. Then, physical properties test and mechanical properties can be done. Flow diagram work sequence can be seen in Figure 1.

TABLE 1
SIZE AND COMPOSITION VARIATIONS ON PARTICLE BOARD

| No | Fiber Cane Length (cm) | Cacao Peels Powder (mesh) | Composition (%) | |
|---|---|---|---|---|
| | | | Cacao peels powder | Fiber cane |
| 1 | 5 | 0.59 | 100 | 0 |
| | | | 80 | 20 |
| | | | 60 | 40 |
| 2 | 5 | 0.84 | 100 | 0 |
| | | | 80 | 20 |
| | | | 60 | 40 |
| 3 | 5 | 2.00 | 100 | 0 |
| | | | 80 | 20 |
| | | | 60 | 40 |
| 4 | 5 | 2.38 | 100 | 0 |
| | | | 80 | 20 |
| | | | 60 | 40 |

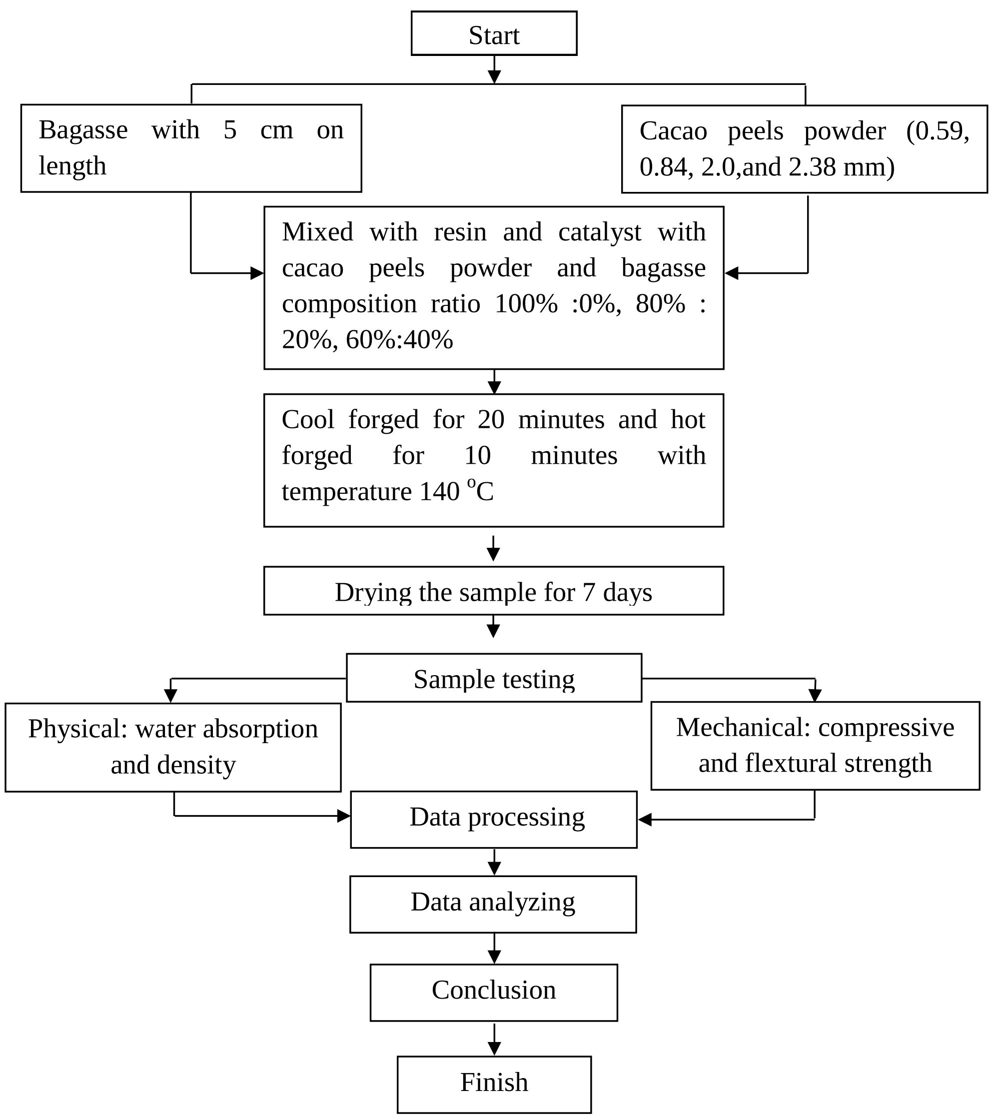


Fig. 1. Flow diagram

## IV. RESULTS AND DISCUSSION

### A. Density

The results of particle board density calculations with a variation of powder size and material composition (cacao peels powder and bagasse) can be seen in Table 2. The density values obtained ranged from 0.584 to 0.76 $gr/cm^3$. The result of particle board test obtained has been according to JIS A 5908-2003 standard that is in the range 0.4-0.9 gram/cm$^3$. Based on the resulting density, the particle board is a medium-density particle board of 0.40-0.80 $gr/cm^3$ [13].

TABLE 2
RESULTS OF PARTICLE BOARD DENSITY CALCULATIONS

| No | Cacao Peels Powder Size (mm) | Material Composition (%) | Density ($\rho$) ($gr/cm^3$) |
|---|---|---|---|
| 1 | 0.59 | (100:0) | 0.735 |
| | | (80:20) | 0.739 |
| | | (60:40) | 0.745 |
| 2 | 0.84 | (100:0) | 0.757 |
| | | (80:20) | 0.750 |
| | | (60:40) | 0.748 |
| 3 | 2.00 | (100:0) | 0.769 |
| | | (80:20) | 0.662 |
| | | (60:40) | 0.661 |
| 4 | 2.38 | (100:0) | 0.737 |
| | | (80:20) | 0.727 |
| | | (60:40) | 0.584 |

The graph of the effect of cacao peels powder size variation on particle board density can be seen in Figure 2. Based on Figure 2, the optimum density value is found on 2 mm cacao peels powder size, while the minimum density value is 2.38 mm. At cacao peels powder size of 0.84 mm and 0.59 mm, the particle board density is higher and constant than other cacao peels powder size. Powder size of 2 mm of cacao peels powder on each ingredient composition decreased. The size of the cacao peels powder 2.38 mm increased the density value of the material composition (100: 0)% to (80:20)% then in the ingredients composition (80:20)% to (60:40)% decreased the density value.

Variations in cacao peels powder size cause changes in the density values of each particle board. The increase in density value occurs because the air cavity or porosity contained on particle board is smaller whereas the decrease in particle board density is due to the air cavity or porosity found on larger particle board [14].

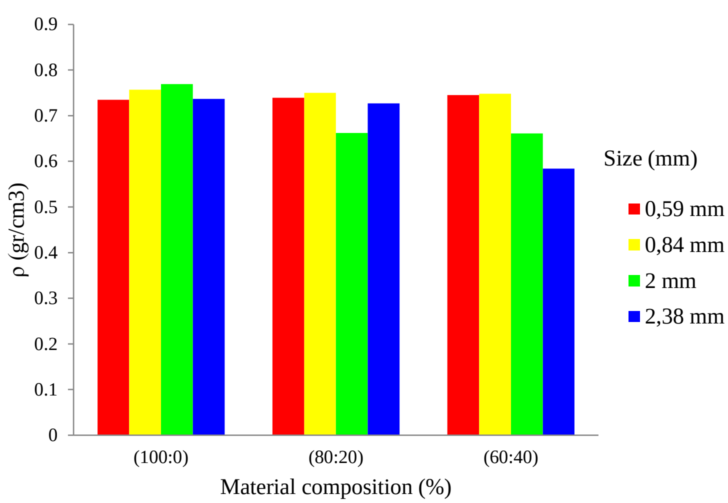


Fig. 2. Graph of effect of cacao peels powder size variation on particle board density

The magnitude of the particle board density value is not only influenced by the particle size but also the material composition on the particle board [15]. The graph of the effect of material composition variation between cacao peels powder and bagasse to particle board density can be seen in Figure 3. In Figure 3, it can be seen that the particle board density values obtained ranged from 0.584 to 0.76 gram//cm$^3$. The optimum density value was obtained on the composition of cacao peels powder and bagasse (100:0)% with a 2 mm cacao peels powder, while the minimum density value of the material composition (60:40)% with the cacao peels powder size was 2.38 mm. Addition of bagasse in the particle board composition results in degradation of the density value, due to the air space or porosity caused by bagasse thus affecting the particle board density value. The more air cavities or porosity on the particle board, the smaller the density you get.

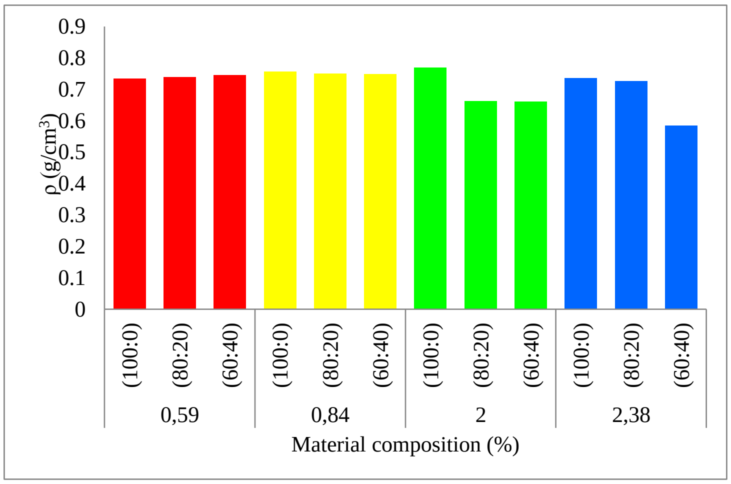


Fig. 3. Effect of material composition variation between cacao peels powder and bagasse on particle board density

Decreasing the density values in each of the material composition ratios may be due to unequal pressures when printing particles, and the amount of adhesive. The more adhesive used the air cavity on the particle board is filled by the adhesive so that the density increases [11]. On the size of cacao peels powder 0.59 mm with the material composition (100:0)%, (80:20)% and (60:40)% there was an increase in particle board density value, because the distribution of cacao peels powder on the particle board was evenly distributed so that the cavity which is filled with cacao peels powder and adhesive.

## B. Water Absorption

The results of particle water absorption calculations on the variation of cacao peel powder size and bagasse can be seen in Table 3.

Based on Table 3 it can be seen that the particle water absorption value is between 16.60-62.70%. The optimum water absorption value is 62.7% while the minimum water absorption value is 16.60%. The graph of the effect of cacao peels powder size variation on particle water absorption can be seen in Figure 4.

In Figure 4, it can be seen that the optimum water absorption rate is present at 2 mm cacao peels powder size, while the minimum water absorption value at the cacao peels powder size is 0.59 mm. Cacao peels powder size 2 mm water absorption value is higher than other cacao peels powder size. The size of cacao peels powder of 0.59 mm and 2.38 mm increased the water absorption capacity of the ingredients (100: 0)% to (80:20)%, then the composition (80:20)% to (60:40) % water absorption decreased. The size of 0.84 mm cacao peels powder has increased in each ingredient composition.

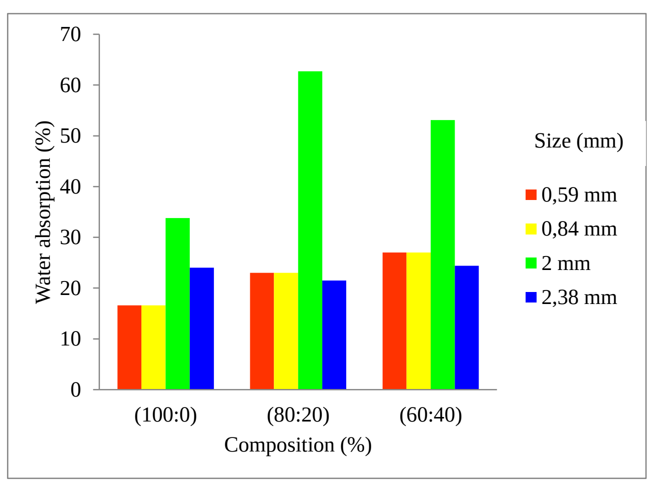


Fig. 4. Graph of the effect of cacao peels powder size variation to water absorption

TABLE 3
PARTICLE BOARD WATER ABSORPTION

| No | Cacao Peels Powder Size (mm) | Composition (%) | Water absorption (%) |
|---|---|---|---|
| 1 | 0.59 | (100:0) | 19.80 |
| | | (80:20) | 18.00 |
| | | (60:40) | 18.02 |
| 2 | 0.84 | (100:0) | 16.60 |
| | | (80:20) | 23.00 |
| | | (60:40) | 27.00 |
| 3 | 2.00 | (100:0) | 33.80 |
| | | (80:20) | 62.70 |
| | | (60:40) | 53.10 |
| 4 | 2.38 | (100:0) | 24.00 |
| | | (80:20) | 21.50 |
| | | (60:40) | 24.40 |

A significant increase in water absorption occurs at 2 mm in size due to variations in cacao peels powder size. The greater the size of the cacao peels powder the greater the absorption of water produced due to the number of air cavities contained on the particle board filled by water, resulting in increased water absorption. Similarly, the smaller the size of cacao peels powder the smaller the water absorption capacity is obtained. The standard water absorption test of JIS A 5908-2003 does not exist, because each test standard has an absorbency value of each. The substantial increase in water absorption is due to several factors: particle size, adhesive count and other materials. The addition of other materials will lead to greater absorption of water obtained such as bagasse. The larger the composition of bagasse is made, the greater the water absorption is obtained and vice versa [5].

### C. Mechanical Properties

*1) Compressive strength:* Compressive strength is the force per unit area. Strong compressive tests were performed on particle board with variations in cacao peels powder size and material composition between cacao peels powder and bagasse. The result of particle board compressive strength showed in Table 4.

TABLE 4
CALCULATION RESULTS OF PARTICLE BOARD COMPRESSIVE STRENGTH

| No | Cacao Peels Powder Size (mm) | Material composition (%) | Compressive strength ($kg/cm^2$) (%) |
|---|---|---|---|
| 1 | 0.59 | (100:0) | 3.7 |
| | | (80:20) | 20.0 |
| | | (60:40) | 27.5 |
| 2 | 0.84 | (100:0) | 33.7 |
| | | (80:20) | 18.7 |
| | | (60:40) | 60.0 |
| 3 | 2.00 | (100:0) | 39.0 |
| | | (80:20) | 33.7 |
| | | (60:40) | 46.2 |
| 4 | 2.38 | (100:0) | 15.0 |
| | | (80:20) | 18.0 |
| | | (60:40) | 20.0 |

Based on Table 4, it can be seen that the value of compressive strength is between 0.37-6 $kg/cm^2$. The optimum compressive strength value is 60 kg/cm$^2$ in the cacao peels powder size of 0.84 mm with the composition of the material (60:40)% while the minimum compressive strength value is 0.37 $kg/cm^2$ on the cacao peels powder size of 0.59 mm with the composition material (100: 0)%. The results of the compressive strength test of particle board obtained have not met JIS A 5908-2003 standard with urea formaldehyde adhesive that is at least 80 $kg/cm^2$.

The size of the cacao peels powder greatly affects the value of the compressive strength of the particle board. Particle size not only affects the particle board, but there is another factor that is the adhesive level, where the higher the adhesive content used, the better the particle board properties are produced [5, 9]. The effect of material composition variation between cacao peels powder and bagasse can be seen in Figure 5. Based on Figure 5 it can be seen that the optimum compressive strength value is the material composition (60:40)% with the cacao peels powder size 0.84 mm, while the minimum compressive strength is the material composition (100: 0)% with the cacao peels powder size 0.59 mm. Addition of bagasse fibers causes the distribution and distribution of the load evenly toward the other fibers when given the compressive strength of the particle board so that the compressive strength particle board increases.

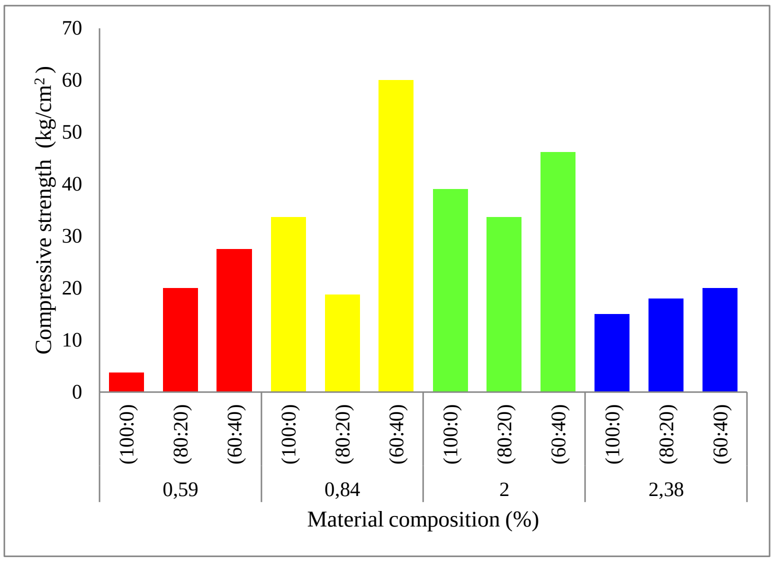


Fig. 5. Effect of material composition variation between cacao peels powder and bagasse on compressive strength, particle board

2) *Flexural strength:* The results of the flexible calculation of flexural, particle board with the variation of cacao peels powder size and the material composition between cacao peels powder and bagasse can be seen in Table 5.

Based on the calculations in Table 5 of the flexural strength, particle board with the variation of Cacao peels powder size and the ratio of material composition between cacao peels powder and bagasse, the value of flexural strength, particle board, ranged from 1.87-27.6 $kg/cm^2$. The optimum value of strong flexural is 47.6 $kg/cm^2$ with a cacao leaf powder size of 0.84 mm and the material composition (60:40)%. It is seen that the variation in the size and composition of the material to the particle flexural strength of particles, the smaller the particle size, the greater the resulting average flexural strength value [9]. The smaller the percentage of the comparison between cacao peels powder and bagasse, the higher the resulting strength of flexural strength. The result of the flexural strength test obtained did not meet JIS A 5908-2003 standard which is at least 80 $kg/cm^2$.

The table shows the effect of cacao leaf size variation on the flexural strength of the particle board. The optimum flexural strength value of cacao peels powders size was 0.84 mm, while the minimum flexural strength with the cacao peels powder size was 2.38 mm. The larger the size of the cacao peels powder, the smaller the strength of the resulting flexural. The optimum flexural strength value is 47.6 $kg/cm^2$ in the material composition (60:40)% at the size of 0.84 mm, while the minimum flexural strength value is 1.87 $kg/cm^2$ with the material composition (100: 0)% on the size 2.38 mm. The greater the ratio of cacao peels powder and bagasse, the greater the flexible flexural value, the resulting.

The addition of bagasse on the particle board has an effect on its flexibility. The bagasse is flexible, the more bagasse it becomes, the more flexible the particle board is produced. The low flexural strength is influenced by the amount of air cavity present on the cacao peels powder particles. However, the addition of more bagasse fibers

TABLE 5
RESULTS OF PARTICLE BOARD FLEXURAL CALCULATIONS

| No | Cacao Peels Powder Size (mm) | Material composition (%) | Flexural Strength ($kg/cm^2$) |
|---|---|---|---|
| 1 | 0.59 | (100:0) | 28.70 |
| | | (80:20) | 38.36 |
| | | (60:40) | 45.00 |
| 2 | 0.84 | (100:0) | 32.50 |
| | | (80:20) | 39.18 |
| | | (60:40) | 47.60 |
| 3 | 2.00 | (100:0) | 32.50 |
| | | (80:20) | 37.18 |
| | | (60:40) | 39.96 |
| 4 | 2.38 | (100:0) | 21.87 |
| | | (80:20) | 29.18 |
| | | (60:40) | 37.92 |

causes the compressive strength of the particle board to increase; this is the maximum amount that can be loaded as an amplifier in the matrix [13, 14]. The amount of fiber that exceeds the maximum limit will make the particle board brittle, due to the small density that causes the flexural strength testing the flexing stretch to shrink. The method of preparing randomly used fibers so that the percentage of fibers loaded in the printed particle board should be taken into account and performed evenly while composing it.

## V. CONCLUSION

From the results of the tests conducted can be concluded that:

1. Variations in cacao peels powder size and the material composition between cacao peels powder and bagasse affect the physical and mechanical properties of particle board.

2. Physical properties of particle board obtained with a variation of cacao peels powder size and variation of material composition between cacao peels powder and bagasse have complied with JIS A 5908-2003 standard, while particle mechanical properties do not meet JIS A 5908-2003 standard.

3. Optimum value of physical properties of particle board obtained was density on cacao skin powder size 2 mm with comparison of material composition between cacao peels powder and bagasse (100:0)%, while water absorption was also obtained at 2mm cacao peels powder with comparison of material composition between cacao peels powder and bagasse (80:20)%.

4. Optimum value of mechanical properties of particle board obtained with the size of 0.84 mm cacao peels powder on the ratio of material composition between cacao peels powder and bagasse (60:40)%.

5. Polyester resin can only be used as adhesive for interior that is not waterproof.

## REFERENCES

[1] A. A. Husin, "Waste utilization for building materials: Development of utilization of mining and industrial waste for building materials, modules 1-3," Bandung Settlement Research and Development Center, Bandung, Indonesia, Tech. Rep., 2002.

[2] R. Ashadi, "Liquid sugar from pod chocolate by using sulfuric acid, enzyme, and combination both," Faculty of Agricultural Technology, Bogor Agricultural University, Bogor, Indonesia, Unpublished thesis, 2008.

[3] P. H. F. Pereira, T. Í. S. Oliveira, M. F. Rosa, F. L. Cavalcante, G. K. Moates, N. Wellner, K. W. Waldron, and H. M. Azeredo, "Pectin extraction from pomegranate peels with citric acid," *International Journal of Biological Macromolecules*, vol. 88, pp. 373–379, 2016. doi: https://doi.org/10.1016/j.ijbiomac.2016.03.074

[4] H. Wibowo, T. Rusianto, and M. Ikhsan, "Effect of density and thickness on the properties of rice husk particle heat insulation board," *Jurnal Teknologi*, vol. 1, no. 2, pp. 107–111, 2008.

[5] M. Krisna, "Utilization of sugar cane as raw material in making particle board," Unpublished thesis, 2009.

[6] Fauziah, D. Wahyuni, and B. P. Lapanporo, "Anal-

ysis of physical and mechanical properties of rice-based particle board," *Positron*, vol. 4, no. 2, pp. 60–63, 2014. doi: https://doi.org/10.26418/positron.v4i2.8728

[7] S. Noura, K. Mohamed, A. Mohammed, and B. Annick, "Extraction of residual sugars from sweet pearl millet and sweet sorghum bagasse for an eventual production of bioethanol," *International Journal of Applied and Physical Sciences*, vol. 1, no. 1, pp. 14–18, 2015. doi: https://doi.org/10.20469/ijaps.50002

[8] N. Lefebvre, M. Khelifi, and Y. De Ladurantaye, "Design of a prototype press for in-field pressing of sweet sorghum and sweet pearl millet biomass," *Journal of Advances in Technology and Engineering Research*, vol. 1, no. 1, pp. 29–32, 2015. doi: https://doi.org/10.20474/-japs1.1.5

[9] F. Maiwita, Y. Darvina, and dan Yulkifli, "Influence of variation of saw and powder safety composition on the thermal conductivity board of particles," *Pillar of Physics*, vol. 1, pp. 41–48, 2014.

[10] V. T. Nguyen, "Mass proportion, proximate composition and effects of solvents and extraction parameters on pigment yield from cacao pod shell (T heobroma cacao L.)," *Journal of Food Processing and Preservation*, vol. 39, no. 6, pp. 1414–1420, 2015. doi: https://doi.org/10.1111/jfpp.12360

[11] G. Tsoumis, *Science and Technology of Wood: Structure, Properties, Utilization*. New York, NY: Van Nostrand Reinhold, 1991, vol. 115.

[12] Japanese Standard Association, "Japanesse Industrial Standard Particle Board JIS A 5908," Japanese Standard Association, Tokoyo, Japan, Tech. Rep., 2003.

[13] T. M. Maloney, *Modern particleboard and dry-process fiberboard manufacturing*. San Francisco, CA: Miller Freeman Publications, 1977.

[14] F. Mahdi and W. Julianto, "Physical and mechanical properties of Rumbia Midrib particle board (Metroxylon sagus Rottb)," Tech. Rep. 18, 2006.

[15] A. H. Iswanto, F. Febrianto, Y. S. Hadi, S. Ruhendi, and D. Hermawan, "Physical and mechanical properties of particleboard made from Jatropa (Jatropha curcas) fruit hulls reinforced with wood particles," *Journal of Wood Science and Technology*, vol. 10, no. 2, pp. 103–111, 2012.