Investigation on the feasibility of coffee husk (endocarp) as efficient filler material for enhancing physical and mechanical properties of styrofoam based particleboard

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Abstract. This research focuses on introducing a coffee husk as viable and efficient filler for enhancing physical and mechanical properties of Styrofoam based particleboard. Heat treatment method was adopted to produce the particleboard from the mixture of coffee husk (CH) with Styrofoam (PS). Styrofoam is material derived from polystyrene. The aim of this research is to get the appropriate weight composition between coffee husks with PS and to identify the physical and mechanical properties of the produced particleboard. The composition of coffee husk varies between 0-90% wt. The manufacture of particleboard i.e. coffee husk milled with size 20/10 mesh then soak with 10% NaOH for 2 hours, rinsed with clean water and dried and weight according to the composition. The mixture of CH and PS is inserted into mold and put into hot-press. The result shows from physical properties that density, water absorption and thickness development test corresponding with SNI 03-2105-2006 standard, the mechanical properties shows MOR test meets the standard on the addition of CH 10-50%, while the MOE test has not meet the standard.

1. Introduction
Central Aceh is the largest Arabica coffee-producer region in Indonesia [1]. The abundance of waste of coffee processing (endocarp) is a huge potential that has only been burned for free. The use of coffee husk (endocarp) as a raw material for making particleboard is considered as one of the best choice. The particleboard is a board product that is produced by compressing the wood particles and simultaneously binding with an adhesive [2].

The development of particleboard technology is now beginning to shift from composite materials to synthetic fibres to natural fibre-making materials [3]. Natural fibre-reinforced particleboard began to be observed by various industries, such as railway industry, ships, automotive, sports, and construction of civil buildings even to household industries. Consideration of fibre selection for composites is strongly influenced by several parameters such as strength and modulus of elasticity, elongation when fracture, thermal stability, bonds between fibres, matrix, dynamic behaviour, density, price, process cost, availability and ease of recycle [4].

Styrofoam made from raw polystyrene (PS) is an inelastic plastic, so it is able to obtained that is not vulnerable essential plastic addition. Styrofoam, which was originally fragile has made it more plastic with the addition of plastic material that is dioctyl phthalate (DOP) [5].

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The fundamental of this study was conducted to examine the extent to which coffee husk and PS can be used as a new material particleboard. Particleboard of fibre reinforced coffee husk and PS as a matrix; it is used as an engineering material, in terms of physical and mechanical properties. The purpose of this research is to make particleboard material with Styrofoam binder. In addition to obtaining a suitable weight volume composition between the husk fibre and Styrofoam fibres which will serve as particleboard that meets JIS A 5908; 2003 standards.

2. Experiment
This section briefly discusses the preparation of specimen and the procedure of the research, which are including the provision of CH, provision of PS and finally the preparation and testing of the samples.

2.1 Specimen Preparation
The used materials in this study are Styrofoam (PS), toluena, coffee husk (endocarp), and clean water (distilled water). While the used the equipment are 500 ml beaker glass, sieves, spatula, analytical balance, hot plate, moulds, electronic system universal tensile machine type SC-2DE, and aluminum foil.

2.2. Research Procedure
The Preparation of Material Composition: the percentage of Coffe husks weighed (0,10,20,30,40,50,60,70,80,90) %. The percent of PS weighed (100,90,80,70,60,50,40,30,20,10) %.

2.2.1. Provision coffee husk (CH) Coffee husk was left in open air for one week, and then soaked in the 10%NaOH then it was washed with water until its pH is neutral. Additionally, it was dried in 800°C oven. After that it was milled (20/10 mesh) and sieved so it was already-made coffee parchment skin. Alkali treatment improves the mechanical bond better [8].

2.2.2. Provision of Styrofoam (PS) The used Styrofoam obtained from the packaging waste is washed and dried then cut to size 0.5 x 0.5 cm and weighed according to the composition, then dissolved with toluene and then added 5% MEXPO catalyst. This mixture is stirred using mixer until evenly distributed.

2.2.3. Preparation of Samples The mixture is between coffee husks and was ready to use PS. The PS was stirred until it was homogeneous. Then put in mould. The samples were in hot-press at a temperature of 170°C and pressure 25 kgf/cm². Once it was completed, the hot press was turned off and the samples were removed and conditioned at room temperature for 7 days and cut to its standard.

2.2.4. Testing Physical testing was performed to test the density, water absorption and the thick development and mechanical testing including the Mechanical of Rapture (MOR) and Modulus of elasticity (MOE) were done by mean of the Electronic System Universal Testing Machine Type SC-2DE MFG No.6079 ASTM D 3039 [9].

3. Results and discussion
The effect of added composition of coffe husk weighted the percentage on physical and mechanical properties such as density, water absorption, tick development, modulus of rapture (MOR) and modulus of elasticity (MOE), respectively as follow,

3.1 Density
The test results of the density is illustrated in Figure 1.
Figure 1. Graph of the density of the weight percent of the coffee husk

Figure 1 shows that the presence coffee husk influenced its density value, including the value of density was lowest for the 90% CH of 0.51 g/cm³, while the value of the highest densities obtained in the composition 0% CH by 0.68 g/cm³. The density value was affected by the volume fraction of the sample, a decrease in density along with weight reduction of pp and additional of husks particles coffee resulted in the addition of a volume fraction, this is due to differences in density PP and shell of coffee beans (endocarp), with the same mass between PP and coffee husks but the second volume was different therefore PP reduction and the additional of coffee husks in the same weight fraction can increase the volume of the resulting particleboard, and this would affect the value of density. The greater volume produced, the density value would be diminished.

Density of the particleboard tends to increase along with the addition of adhesive, this occurs due to physical force between the adhesive interactions with the filler through cavities that filled it. Moreover, the results indicate that the presence of the addition coffee husk (CH) can improve the physical properties of the resulting particleboard, but if the particles used has exceeded the limits of the binding matrix to fiber, composites produced is damaged. All composition have met the SNI 03-2105-2006 standard [10].

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3.2. Water Absorption

The water absorption resulting samples ranged 0.01-7.6 %. Figure 2 illustrates the results of the water absorption weighted the coffee husk percentage.

Figure 2. Graph of water absorption towards the shell weighted the percentage of coffee beans (endocarp).

Figures 2 illustrates that the minimum water absorption in 0% CH in this sample it still dominated by the adhesive properties of density Styrofoam and its high density was 0.9 g/cm³. It was difficult to make it into the water between the particles. Moreover, the effectiveness of the used of Styrofoam as
the matrix is suitable, this is due to the hydrophobic properties of Styrofoam. The particleboard is not easy to absorb water from the environment. The slightly increased of water content occured in the 10-90% so that the content of the particles reduced the resistance of PS mixture which caused erosion. So with reduced Styrofoam materials, the percentage of water absorption becomes smaller.

Water absorption is highest in the 90% CH, where coffee husks a material that tends to absorb water, therefore the increase in the percentage of coffee husks lead to the increasing of water in the sample during the manufacturing process. Water absorption increases with the addition of skinweight percentage of the coffee, this is because the skin of coffee is a lightweight aggregate that has many pores, so that the water absorption percentage is greater than the water absorption without fiber. SNI 03-2105-2006, particleboard, requires the water absorption value for all samples <14%. From the test results indicated that all particleboard produced met the standards. This result is very suitable to use for interior or exterior panels since the water content is very low.

3.3 Thick Development
Development of a minimum thickness of 0.4% was in 0% CH and a maximum of 0.04% was in the sample 5. When it is compared with SNI 03-2105-2006, thick indigo development of the required maximum was 12%, it is thus the particleboard can be said to have fulfilled standard for all compositions on the test thickness swelling as illustrated in Figure 3.

![Graph of thick development and weight percentages of coffee husk](image)

Figure 3. Graph Relations of thick development and weight percentages of coffee husk (CH).

Figure 3 illustrates that the thick development particleboard tends to increase with the increasing weight percentage of coffee husk (endocarp). This is because the nature of coffee husk that absorbs water (hydrophilic) so the amount of water absorbed more and more resulted in the development of particleboards. However, if it is compared to the SNI 03-2105-2006 standard, which requires maximum thickness development value more than 12%, then the rate of progression thickness development of particleboard have met the standard.

3.4. Modulus of Rapture (MOR)
The value of the maximum MOR is 40% CH, which amounted to 99 kgf/cm² and the lowest flexural strength values obtained in 90% CH is 90 kgf/cm². Figure 4 illustrates that the addition of particle composition of CH tends to increase MOR strength. This suggests that the presence of CH may increase the MOR of the particleboard material. The maximum MOR strength results on samples is 40% CH due to the adhesive force strong enough on Styrofoam, which creates better bonding. In composition of 60-90% CH MOR values begin to decrease; this occurs due to not maximal PS binds the CH. The bond between the particle and matrix PS is easily discharge. Resulting in the emergence of shear stress. The failure is dominated by loose bonding of particles and matrix. This is often called "fibre pull out". Particleboard with 10-50% CH composition meets SNI 03-2105-2006 standard. The particleboard requires minimum MOR value of 82 kgf/cm². The probability SEM viewing on the board at its breaking section explains the increase in mechanical properties.
3.5. Modulus Of Elasticity (MOE)

MOE maximum possible value currently on the sample 5 with a composition of 70:30, in the amount of 27987.90 kgf/cm² and the lowest value of MOE obtained on the sample 1 with a composition of 30:70 is 25416.67 kgf/cm².

Figure 5 illustrates the MOE that tends to increase with the increasing percentage of heavy CH. This is caused by the skin effect of coffee, which is natural fibber that has good elasticity. The increase in MOE value tends to increase until the composition of 40% CH. However, at 50% interval MOE value decline, this is due to the gap on the particles so that when the composite is loaded then the tension moves the void area and reduces the strength of particleboard. All samples have not met the requirement of SNI i.e., minimum 20.400 kgf/cm².

4. Conclusion

The results obtained from present work can be summarized as follow; Physical test results such as density, water absorption and thickness development of coffee husk (CH) and Styrofoam (PS) particleboard have met the SNI 03-2105-2006 standards. Increased coffee husk percentage composition indicated that the addition of particle composition CH tends to increase MOR strength. This suggests that the presence of CH may increase the MOR of the particleboard material. The maximum MOR strength results on samples 40% CH due to the adhesive force strong enough on Styrofoam, which creates better bonding. In composition 60-90% CH MOR values begin to decrease. This occurs due to not maximal PS binds CH. The bond between the particle and matrix PS is easily discharge. Resulting in the emergence of shear stress. The failure is dominated by loose bonding of particles and matrix. This is often called "fibre pull out". Particleboard with 10-50% CH composition has met the SNI 03-2105-2006 standard.

In addition, the increase in water content and thickness development decrease the value of MOR and MOE. Finally, The result of mechanical test of bending strength of CH-PS particleboard fulfilling SNI 03-2105-2006 standard is 10-50% KTBK composition, while 60-90% KTKB has not met the standard.
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