Properties of Particleboard Made from Rice Husk and Coconut Husk in Relation of Varying Resin Content and Board Density

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Abstract

Rice husk and coconut husk a potentially cheap raw material are available in large quantities but are currently discarded as agriculture residues. The rice husks and coconut husks are burned after harvest. Hereby, I propose the usage of these "waste" as potential raw material for particleboard so as to provide an alternative source as of replacement depleting wood particles. This study determined the properties of particleboard made of a mixture of rice husks (50%) and coconut husks (50%). The 50:50 mix were investigated for the effects of board densities (600kg/m^3, 700 kg/m^3 and 800 kg/m^3) and varying phenol formaldehyde resin contents (8, 10 and 12 %). Based on the results, the modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB) were increased by increasing resin contents and board densities. For thickness swelling (TS) and water absorption (WA) the values decreased for each increasing board densities and resin contents. In this study the highest value of MOR (11.12 MPa) and MOE (1238.51MPa) is obtained from 800 kg/m^3 with 12% of resin content. The best value of IB is 0.125 MPa from 700 kg/m^3 at 10% resin content. The particleboards were evaluated according to the European Standard (EN 312:2003) requirements.

Keywords: particleboard, Phenol formaldehyde, density, rice husks, coconut husks

1. INTRODUCTION

Malaysia is one of the world's largest tropical timbers/timber products exporter and the 10th largest exporter of furniture with over 160 destinations. In Asia, Malaysia is the second largest. One of the divisions of timber industries is composite sector. Composite, begin a long time ago, is a resultant material with entirely different properties compared to those two or more distinct individual component once combined together (Fowler, Hughes, & Elias, 2006).

These days, the developments of composite industry are becoming attracted toward bio-based composite in both commercial and non-commercial applications (Ndazi et al., 2006). Bio-composite are composite materials comprising one or more phases derived from a biological origin (Fowler et al., 2006). In recent years, wood based industries all over the world are facing difficulties in obtaining wood raw material. The use of renewable resources such as agricultural residues in the production of composite panels is now gaining interest.

Particleboard panel is a common and widely used composite products in furniture manufacturing and house construction (Youngquist, 1999). Bono et al., (2010) described that particleboard production involved wood particles compression at high pressure with other lignocelluloses materials and adhesive made from natural or synthetic products to bind wood pieces. Particleboard is usually produced from wood particles. Nowadays, particleboard ought to be produced by using alternative material in order to decrease deforestation issues, for example in Malaysia. Solid waste material, agriculture residues such as rice husks and coconut husks are examples of alternative materials that have potential to be used as bio-based composite product.

In Malaysia, study done by Chan Chee Wan & Cho Meng Chang (2012) stated that paddy (*Oryza sativa*) is the third most important crop grown after oil palm and rubber in term of acreage. Rice husk is the outer covering of rice grain obtained during milling process. Currently, this agriculture residue is burned and left in the field after harvest (Ciannamea, Stefani, & Ruseckaite, 2010). However, rice husks have very high external surface area, unusually high in ash which is 92% to 95% silica. It is light weight and can be potentially used for making particleboard (Suleiman, 2013).

At the same time, the fourth most popular crops after paddy is coconut (*Cocos nucifera*). Coconut produced natural organic fiber that can be extracted from outer skin coconut (Rozli et al., (2011). Generally, only small percentage of coconut husks are used for making ropes, yarn, mats or brushes. The advantages of this natural fiber are tough, durable, inexpensive, resistance to fungi and rot and not easily combustible. Hence, the combination of these both residues has the potential to make particleboard. This will utilize the waste and with likely reduce cost of raw materials (Hemsri et al., 2012).

In this project the properties of particleboard made from rice husk and coconut husk was investigated, by determining the physical and mechanical properties and the effects of resin contents and board densities on the particleboard properties. The information gained from the study can be used to propose the usage of waste like rice husk as potential raw material for particleboard.

2. MATERIAL AND METHODS

2.1 Material preparation

The rice husk and coconut husk were screened to remove fines. This process to make sure the particles obtained do not involved any unwanted particles. Gilson Screen Testing machine was used to separate the materials. The average length for the rice husk is around 5mm to 10 mm. The coconut husks were cut by scissor into required form. Then, the raw materials are ready for the next process. Figure 1.0 shows the stages of particleboard manufacturing.

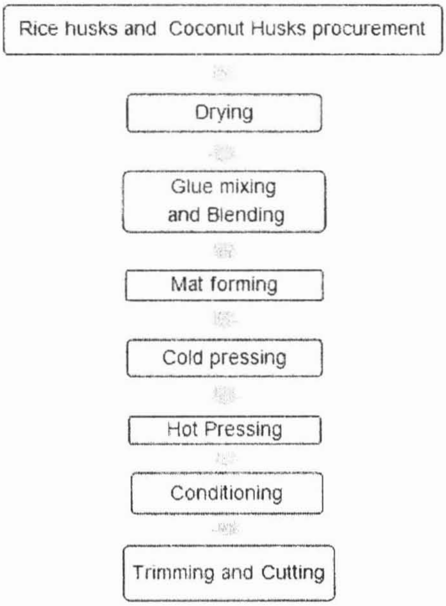

Figure 1: Stages of particleboard manufacturing

2.2 Drying

The raw materials were dried under the sun before the oven drying. The materials were oven-dried at 80°C for 24 hours or until the moisture content of the raw material constant and the percentage of moisture content reach less than 5%. This drying process is very important part to make sure no blows or moisture affect while making the particleboard.

2.3 Glue mixing and blending

Dried particles were mix together with the ratio of 50:50 for both rice husks and coconut husk. The phenol formaldehyde (PF) resin was used as a binder. The PF resins were sprayed onto the particles and blended using Particleboard Mixer Machine. The same blending procedure was repeated for all resin content and board density. Amount of resin and particles were calculated by using specific formula.

2.4 Mat Forming

After resin mix and blend, the particles were formed in a box mould with size 340 mm x 340 mm. The box mould has been cleared from all unwanted substances for a smooth process. Then, before being pressed, the mould release agents were sprayed on the tray to avoid the particles sticking on the tray.

2.5 Cold pressing and hot pressing

The most important process in particleboard manufacturing is pressing. It is done to initiate the bonding between particles. The processes were divided into two stages. First is cold pressing or pre-pressing conducted to reduce the mat thickness and flatten the mat surface before going to the hot pressing process. The particles were put on a heated platen and the top of particles is also covered with heated platen. Next, the particles were transferred to the Hot Pressing Machine. The particles were press at 1800 psi for 6 minutes at 165°C. This is to cure the PF resin and to achieve the final thickness of particleboard.

2.6 Conditioning

After hot press, the boards were transferred to a conditioning room at 20°C and 65% of relative humidity to e n sure the boards reach the equilibrium moisture content (EMC).

2.7 Cutting and Trimming

After the boards reach the EMC, the boards were trimmed and cut. The boards were trimmed and cut into specific specimen according to the European Standard (EN) done using a table saw machine.

3. TESTING METHOD

Boards testing include mechanical properties which are bending strenght that involve Modulus of Rupture (MOR) and Modulus of Elastic (MOE) and Internal Bonding (IB). This test was performed according to EN312:2003. The purposes of mechanical testing are to determine the strength, stiffness and the performance of boards bonding. The bending testing is based on EN310 standard where MOR and MOE target is greater than 18N/mm^2 and 2550N/mm^2 respectively. Testing for IB is according to EN319 with target greater than 0.45 N/mm^2.

Physical testing involved thickness swelling (TS) and water absorption (WA) test. These tests were conducted to determine the ability of the boards to absorb water. The tests were determined based on EN317.

3.1 Bending test

The objective of bending testing is to measure the strength of the particle. MOR is the measurements of the rate rupture pieces of the particleboards sample and MOE is to measure the resistance to bending from stiffness of a beam. Using the Universal Instron Machine with the marked number in sample, the boards were tested until it broke and the result are measured in MPa.

$$MOR = \frac{3}{2} \times \frac{Fmax \times L}{b \times d^2}$$

Where:

L = Length (mm)
F max = Maximum load (N)
b = Width mm
d = Depth (mm)

$$MOE = \frac{1}{4} \times \frac{Fpl \times L^3}{bd^3 \times \Delta}$$

Where:

L = Length (mm)
Fpl = Maximum force at proportional limit (N)
b = Width (mm)
d = Depth (mm)
Δ = Deformation (mm)

3.2 Internal bond test

Internal bonding test (using Instron Universal Machine) was to determine the strength of the board based on bonding between particles. The specific test size specimen is 50 mm x 50 mm. The formula to calculate the IB is shown below:

$$IB = \frac{Fmax}{L \times W}$$

Where;

L = Length (mm)
$Fmax$ = Maximum load (N)
W = Width (mm)

3.3 Thickness swelling test

Before the test conducted, the thickness of samples was measured by using Electronic Micrometer. Then, the samples were immersed into water in 24 hours. All the sample was ensure that the overall board surface was properly immersed. The objective of testing is to indicate the durable of the board to water. The thicknesses after boards completed immersion were measured. The percentage of thickness swelling was calculated by used the formula shown:

$$TS (\%) = \frac{\text{Thickness after} - \text{thickness before}}{\text{Thickness before}} \times 100$$

3.4 Water absorption test

The samples were soaked into water to allow the board samples to absorb water. The purpose of this testing is to identify how much boards absorb the water and to indicate the durability of boards towards water. The weights after boards completely soaked in water were taken. The percentages of water absorption were calculated by using the formula shown:

$$WA (\%) = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100$$

4. RESULTS AND DISCUSSIONS

4.1 Effect of resin content on mechanical properties

Figure 2 shows the effect of resin content on the MOR and MOE. While, Figure 3 show the effect of resin content toward IB. The resin contents of 8 %, 10 % and 12 % have significant different for each mechanical testing types. The increase of resin content showed increasing values of MOR and MOE of particleboard. The values of IB increased when the content of the resin increased from 8% to 10% in the board (Ayrilmis et al., 2012).

According to Zheng et al., (2006) higher resin content values resulted in higher values of MOR, MOE and IB. This indicates that the values of MOR, MOE and IB are strongly influenced by the percentage of adhesives and densities (Ayele & Reinhardt, 2010). Higher resin content would cover more surfaces providing better bonding between particles (Gamage, et al., 2008). Another evaluated by Nemli et al., (2003) showed that increasing of adhesive usage caused an increasing improvement on all mechanical properties.

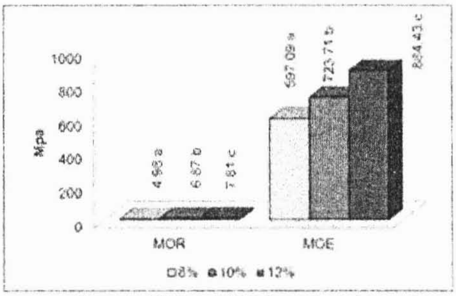

Figure 2: MOR and MOE for each resin content

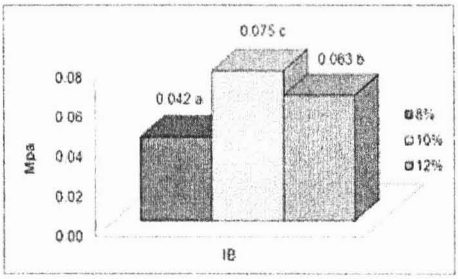

Figure 3: IB for each resin content

4.2 Effect of resin content on physical properties

Figure 4 summarizes the averages results for TS and WA of boards. The TS values decreased from 43.5 % to 32.6 %, and then to 22.3 % when the amount of resin content increased from 8 % to 10 % to 12 % respectively. The same changes occur with values of WA on the boards when the resin content increased. Increment of resin content in the boards significantly decreased the TS and WA values.

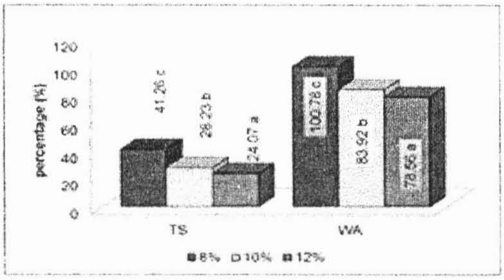

Figure 4: TS and WA for each resin

Meanwhile, the amount of water absorbed by board depends on the amount of the resin added. The ability of water to absorb into the board was decreased when the higher amount of resin is available. Study done by Juliana et al., (2012) stated that the physical properties improved upon increasing the resin content. As noted by Arylmis et al., (2012) the WA values of the boards decreased when the content of PF resin increased from 8 % to 12 %, and similar results were also observed for the TS values. The previous study by Suleiman et al., (2013) also agreed that the quantity of resin added, increases the water absorption.

4.3 Effect of board density on mechanical properties

Three different densities (600 kg/m3, 700 kg/m3 and 800 kg/m3) were used in this study to determine mechanical properties of particleboard made from rice husk and coconut husk. Figure 5 obviously shows that the higher density had higher values than lower density for both MOR and MOE. The values of MOR and MOE have significant difference for each types of density as density increase from 600 kg/m3. The results is supported by Halvarsson et al., (2008) who stated that increased in average density resulted in significant improvement of bending properties.

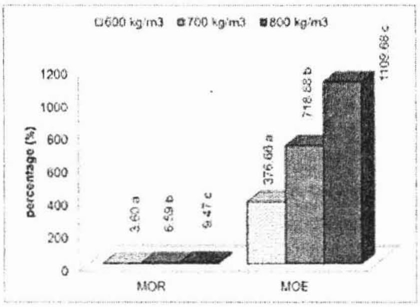

Figure 5: Effect of board density on MOR and MOE

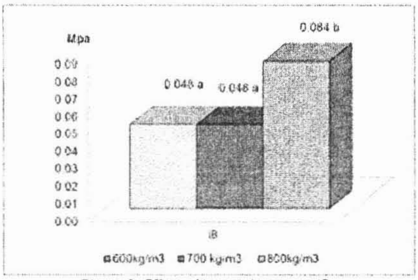

Figure 6: Effect of board density on IB

Figure 6 show values of IB test, with no significant difference between density 600 kg/m3 and 700 kg/m3. However, value of IB was increases when density increases to 800kg/m3. As reported by Gerardi et al., (1998) the IB strength increases with higher density of boards. Previous study by Khedari et al., (2004) noted that a higher internal bond value was accommodated by an increase of particleboard density. Nemli et al., (2003) added that board density increase is followed by with increase in all mechanical properties. It was well known that board density is one of the important factors that affect mechanical properties of particleboard (Li, Cai, Winandy, & Basta, 2010).

4.4 Effect of density on physical properties of particleboard

Figure 7 shows the result of density on the TS and WA of the boards. All the board density has significant different for WA results. Almeida et al., (2002), are convinced that lower density lead to higher WA because of higher voids that can be filled by water. It is similar for

TS that has significant difference for all densities tested. In previous study conducted by Shi & Gardner (2006) it was reported that the TS and WA increases with decrease in the particleboard density.

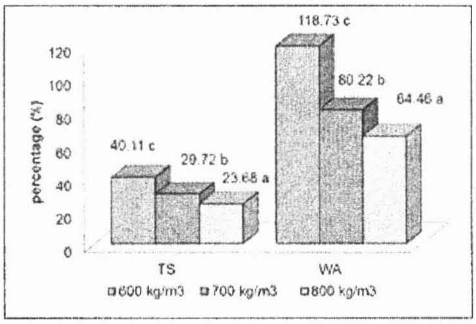

Figure 7: Effect of density on physical properties of particleboard

5. CONCLUSIONS

In this study, the results shows the mechanical and physical performance of rice husk and coconut husk particleboards are highly dependent upon resin content and board density. The bending and internal bonding strength, WA and TS were positively affected by increasing resin contents and board density. Variables, resin content and board density had the significant impact towards mechanical and physical properties of particleboards. The study found that the board density of 800 kg/m3 with 12 % content of PF resin gave the best properties of MOR, MOE, and IB. While the best results for TS and WA was from 800 kg/m3 with 10% of resin content.

In this study, it concluded that the properties of particleboard were improved upon increasing resin content and board density. Unfortunately, all of the boards have not met the minimum EN standard requirements making the rice husk and coconut husk are still not suitable raw material for particleboard for general uses and furniture manufacture.

6. RECOMMENDATIONS

As stated before, rice husk contains high silica and wax, but have lower cellulose and lignin content. While, coconut husk is able to absorb and hold large quantities of water that can reduce the interaction with resin. These characteristics provide negative effect on particleboard properties and will give poor result in the internal bonding. For recommendation, rice husks and coconut husks can be treated using several chemical to improve their performance. Besides that, rice husk and coconut husks could be tested as raw material combined with wood particles.

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