Properties of Hybrid Particleboard from *Acacia mangium* And Oil Palm Trunk

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Abstract

The purpose of this study is to evaluate the effects resin content and wood ratio on the properties of hybrid particleboard made from Acacia and Oil Palm Trunk (OPT). This study used Acacia (100%), Acacia + OPT (50%:50%) and OPT (100%). The middle part from both species was used and the target density was fixed at 650kg/m^3. Twenty seven boards were produced and tested for physical and mechanical properties based on the European Standard (EN). The resin contents of board were 7%, 9% and 11% and phenol formaldehyde resin (PF) was used. On the mechanical properties, from of the three wood ratio, 100% Acacia showed the highest value for modulus of rupture for 11% resin content with 15.19 MPa and the lowest value is from wood ratio 100% OPT, 7% resin content with 3.7 MPa. Meanwhile, the best value for modulus of elasticity test results was from wood ratio 100% Acacia with 11% resin content at value of 2426.96 MPa. Then, internal bond result showed that the highest value is from wood ratio 100% Acacia (11% resin content) with value 0.49 MPa and the lowest value wood ratio 100% OPT (both 7% and 9% resin content) with value 0.05 MPa. On the physical properties, the best value of thickness swelling comes from wood ratio 100% OPT (11% resin content) with value 7.98% and the least value from wood ratio 100% Acacia (7% resin content) with value 13.89%. For water absorption 100% Acacia (9% resin content) with 62.24% gave the best performance while the least value is from 100% OPT (7% resin content) with 81.38%. The entire sample from mechanical properties did not achieve the standard requirements.

Keywords: *acacia, oil palm trunk, resin content, water absorption and thickness swelling*

1. INTRODUCTION

Wood is a valuable natural renewable material that has helped countries lead a sustainable development over centuries. Fast-growing species provide an opportunity to satisfy the increasing need for wood and wood products; however, they are usually harvested young and therefore the stem diameter is small. Therefore, they are usually used in composite and paper manufacturing industries. Composite boards have the advantage of offering a homogenous structure which may be important for many design purposes (Ratnasingam, 2002). Wood-composite-manufacturing factories are in constant search for new sources of fibers as raw materials to be used in their production programs; therefore, potential natural or synthetic fibers should be taken into account to satisfy the raw materials needed for uninterrupted production. Examples of composite are particleboard, medium-density fiberboard, plywood, wafer board and sandwich board.

Particle board are manufactured by mixing waste-wood products, such as sawdust, wood chips or sawmill shavings, with synthetic resin or another type of binder. Particleboard performance is mostly related to the properties of adhesives and their compatibility with particles or fibers (Wang and Sun, 2002). The most commonly used petroleum-based adhesives are urea formaldehyde (UF), phenol formaldehyde (PF), and methylene diphenyl diisocyanate (MDI). Particleboard is defined as panel material produced under pressure and heat from wood particle and other lignocellulosic material in the wood particle with addition of an adhesive (Greg, 2009). Particleboard is produced from small sized wood particles which are primarily manufactured by flat platen pressing method. There are many types of particleboards in the market with various sizes and geometry of particles, amount of adhesive used and the density by which the panels are pressed (Linhares, 2007).It is very beneficial for mankind with the creation of wood and wood composites. With increased of world population, wood composite products usage have increased tremendously. Due to the lack of forest resources, the production costs of composites are greatly affected. However, the advancement of technology has extended possibilities of used of more low quality materials to be produced into composites. Particleboard is one of the oldest composite produced and still remains dominant for furniture panel and also for structural application (Jamaludin, Ahmad and Harun, 2000).

Acacia (A.) *mangium* species was first introduced into Sabah, Malaysia in 1966 (Sahri, Ibrahim & Sukor, 1993). It is a fast growing species and very adaptable to different soil types on degraded sides and hills. A. *mangium* wood is diffuse-porous with mostly solitary vessels and tolerance of very poor soils. It is playing an increasingly important role on sustainable commercial supply of wood products. Due to its good physical properties, *A. mangium* is a potential and suitable source as a raw material for the production of particleboard with excellent dimensional stability (Korai & Nigel, 2000).

Palm oil (*Elais guineensis)* is one of the most important commodities in Malaysia. The total oil palm plantation has been increasing recently along with palm oil production. The shortage of wood from natural forest is becoming a major problem for the last several decades. It is expected that waste from oil palm plantations could serve as an excellent raw material for value-added panel products. These panels would include insulation board, plywood, strandboard, particleboard, medium density fiberboard, hardboard and laminated veneer lumber. Previous studies showed that boards made from oil palm tree had reasonable strength properties (Nur Rohana et al., 2008, Awang and Taylor (nd), Harmaen et al., 2008)

2. BOARD MANUFACTURE

Particleboard or chipboard is manufactured by mixing wood particles or flakes together with a resin and forming the mixture into a sheet. Most particleboard is formed into panels. However, molded particleboard products such as furniture parts, door skins, or molded pallets are also produced. Although some single-layer particleboard is produced, particleboard generally is manufactured in three or five layers. The outer layers are referred to as the surface or face layers, and the inner layers are termed the core layers. Face material generally is finer than core material. By altering the relative properties of the face and core layers, the bending strength and stiffness of the board can be increased. The general steps used to produce particleboard include raw material procurement or generation, classifying by size, drying, blending with resin and sometimes wax, forming the resonated material into a mat, hot pressing, and finishing. See Figure 1.

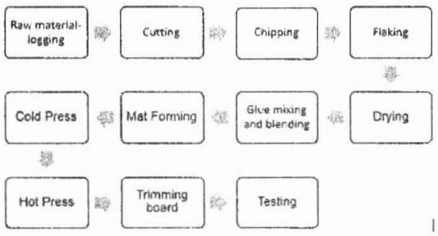

Figure 1: Schematic of particleboard manufacture

2.1 Sample Cutting

After board completion, the boards are cut into small size as samples for the testing. The samples are cut according to the EN Standard. For cutting the testing samples the Table Saw machine was used following cutting pattern in Figure 2.

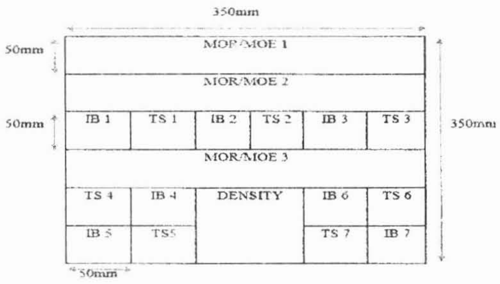

Figure 2: Cutting sample

3. TESTING METHODS

3.1 Bending Strength (EN310:1993)

Bending test is important to know Modulus of Elasticity (MOE) value and Modulus of Rapture (MOR). For bending test, were marked to ensure proper numbering. The sizes dimension of board such as length, width and weight are taken and recorded. By using the Bending machine (Instron machine), the board was supported at 240 mm of span and the load applied. The board was tested until it broken and the results are determined in MPa. The calculation for the bending test can be done using the formula below:

$$\textbf{MOE (N, mm}^{-2}) = PL^3/48ID$$

Where: P: load deflection at midspan in inches/mm

L: span in inches

I: moment or inertia, a function of beam size

D: (width x depth^3)/12 for beams with rectangular cross section

$$\textbf{MOR (N, mm}^{-2}) = 1.5PL/bd^2$$

Where: P: breaking (maximum) load

L: distance between support or span (mm)

d: depth of the beam (mm)

b: width of the beam (mm)

3.2 Internal Bonding (EN319:1993)

Internal bonding (IB) is to determine the tensile strength of the board. The sample size is 50mm x 50mm. After that, the sample bonded together to two steel blocks by using epoxy resin and the samples were left for 24 hours to allow proper glue cure. European Standard specified the method for determining the resistance to tension perpendicular to the plane of the board (IB) of hybrid particleboard, fibreboard and wood cement board (EN319:1993). Calculation of IB follows:

Internal bond (N, mm^{-2}) =P/2Bl

Where P = Maximum load (N) at the time of failing force

b = Width (mm) of sample

L = Length (mm) of sample

3.3 Thickness Swelling (EN317:1993)

To testing the thickness swelling (TS), all of the samples must be precisely soaked into the water to make sure that the overall of the samples were properly soaked. The sample size is 50 mm X 50 mm. Marked samples will be soaked in the water until all part of the board sink for 24 hours. The formula that is used in calculation to know the TS is given below:

$$\text{Formula thickness swelling (TS)} = \frac{\text{final thickness-initial thickness}}{\text{Initial thickness}} \times 100$$

3.4 Water Absorption

The purpose of water absorption (WA) testing is basically to determine amount of water absorbed by the particles. This WA testing also indicates how durable the particleboard to the water resistance .The formula that is used in calculation for percentage of WA is as below:

$$\text{Formula water absorption (WA)} = \frac{\text{final weight-initial weight}}{\text{Initial weight}} \times 100$$

3.5 Experimental design

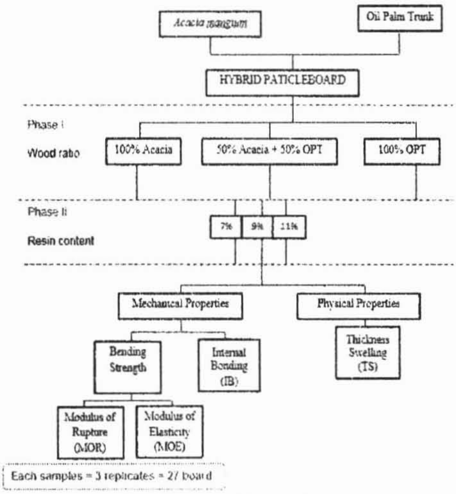

Figure3.3: experimental design samples

Figure 3: Experimental Design

Figure 3 shows the experimental design to produce hybrid particleboard by using Acacia and oil palm trunk (OPT). Phase 1 show the wood ratio 100% Acacia followed 50% Acacia + 50% OPT and lastly 100% OPT. For resin content dosages of 7%, 9% and 11% were used. This parameter will be tested for physical (TS and WA) and mechanical properties (MOR, MOE and IB) based on the European Standard (EN).Target density has been set at 650 kg/m3.

4. RESULTS AND DISCUSSIONS

4.1 Bulk density

Bulk density is defined as the weight per unit volume of material. Apparent density value is recorded as g/l. The result is shown in Figure 4.1 where weight of particle of Acacia is 124.3g/l while particle of Oil Palm Trunk is 85.6g/l. The highest bulk density need the small quantity of particles to fill the space, the low bulk density is good to produce particleboard. If the space is reduce can make board more compact and stable (Ismail, 1995)

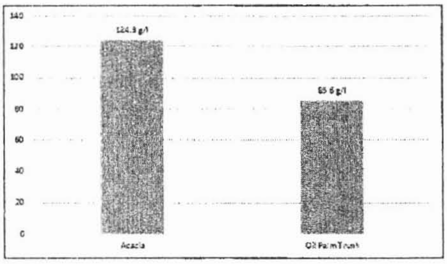

Figure 4.1: Bulk density

4.2 Mechanical and physical properties

Table 4.1: mechanical and physical properties of the particleboard from Acacia and Oil Palm Trunk

Wood Ratio (%)	Resin content (%)	TARGET DENSITY (kg/m³)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)	WA (%)
100 Acacia	7		12.22	1876	0.41	13.89	75.46
	9		15.00	2269	0.47	10.07	62.24
	11		15.19	2426.96	0.49	10.41	65.45
50 Acacia + 50 OPT	7		10.59	1646.05	0.17	11.71	71.57
	9	650	13.21	1765.67	0.19	10.08	69.34
	11		14.26	2293.18	0.23	8.91	68.56
100 OPT	7		3.70	719.22	0.05	12.46	81.38
	9		5.05	1172.84	0.05	11.11	80.47
	11		5.68	1252.62	0.08	7.98	76.37
EN			≥ 16	≥ 2300	≥ 0.4	16	

From Table 4.1 the summarized physical and mechanical properties of hybrid particleboard based on European

Standard EN 312:2003 is shown. On the mechanical properties of MOR, 100% Acacia showed the highest value for 11% resin content (15.19 MPa) and the lowest value from for 100% OPT of 7% resin content with 3.7 MPa. Meanwhile, the best value for MOE value from wood ratio 100% Acacia with 11% resin content (2426MPa). Then, for IB result show that the highest value from 100% Acacia (11% resin content) with value 0.49 MPa and the lowest value for 100% OPT with 7% resin content (0.05 MPa).

On the physical properties, the best value of TS from wood ratio 100% OPT (11% resin content) with value 7.98% and the worst value from wood ratio 100% Acacia (7% resin content) with value 13.89%. Then, the best value of WA from wood ratio 100% Acacia (9% resin content) with 62.24% and the least value from wood ratio 100% OPT (7% resin content) with 81.38%. In conclusions, all boards do not achieved of the EN standard.

4.3 Statistical significance

Table 4.2 shows the analysis of variance (ANOVA) of the effects of wood ratio and resin content on the hybrid particleboard. Wood ratio showed significant effect on all board properties. Resin content shows significant effects on MOR, MOE, TS and WA values but not for IB. The relationship between wood ratio and resin content showed all sample are significantly different.

Table 4.2: shows the statistical significance of the effects of the wood ratio and resin content on the hybrid particleboard

SOV	DF	MOR	MOE	IB	TS	WA
Wood Ratio	2	156.477*	40.741*	93.811*	9.636*	27.376*
Resin content	2	5.189*	7.817*	1.854**	77.673*	7.778*
Wood Ratio + Resin content	4	1.036**	0.102**	0.348**	7.293*	2.825*

*value are significant at $p < 0.05$ **value are not significant at $p > 0.05$

4.4 Effect of resin content on hybrid particleboard

4.4.1 Mechanical properties

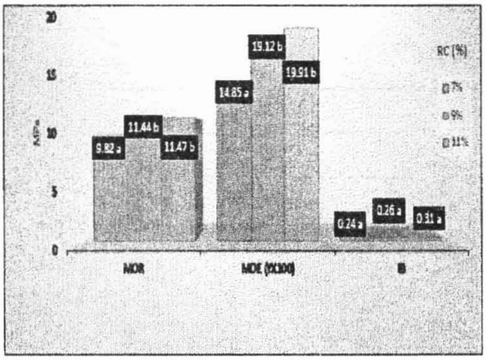

Figure 4.2: effect of resin content on the mechanical properties on hybrid particleboard

From Figure 4.2, it shows that increasing in resin content increase the MOR, MOE and IB values for Acacia *(Acacia mangium)* and OPT *(Elais guineensis)* hybrid particleboard. It was observed that, presence of resin has significantly affected the bending strength positively. For MOR and MOE values from all resin dosage were recorded. For IB all dosage of resin is shown to be not significant. So using a lower resin is better for cost-effective production of the resin for example 7% compared with 9% and 11%. According to Loh et. al., (2010) lighter density particles have tendency to flow on top of the mixing tank and absorb more resin compared to high density which can attribute to poor adhesion between particles.

4.4.2 Physical properties

Figure 4.3 shows the effects of resin content on thickness swelling and water absorption. From the result, the TS and WA value improved when resin content increase from 7% to 11%. Higher amount of resin available increase bonding between the particles and decreases the ability of water to absorb into the particle of Acacia (*Acacia mangium)* and OPT (*Elais guineensis)*. According to (Nadir, 2008), when resin content increase; it will improve the percentage of thickness swelling.

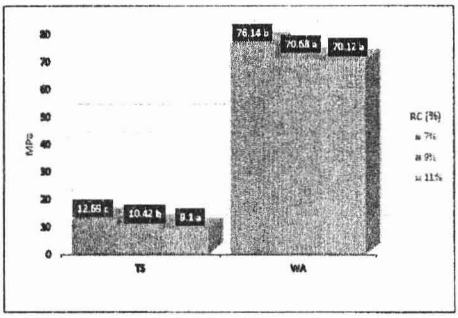

Figure 4.3: The effect of resin content on physical properties on hybnd particleboard

4.5 Effect of wood ratio on hybrid particleboard

4.5.1 Mechanical properties

From figure 4.4, shows that wood ratio to produced hybrid particleboard by using 100% Acacia, 50% Acacia + 50% OPT and 100% OPT for MOE, MOR and IB test. For all test, graph shows that wood ratio from 100% Acacia increase significantly compared with the other wood ratio. This is because density of acacia is about 0.6-0.65g/ cm^{-3} and the OPT 0.3-0.5 g/cm $^{-3}$ according to (Md Qumruzzaman, 2004). Higher value for Acacia because 100% wood particle with higher density compared to OPT particle. According to Xu and Suchlan (1999), mixing of wood species in particleboard manufacturing may relate to the variation of density that affects the resin uptake by difference species. Strength properties of particleboard increased when raw material density decreased with an average particleboard density and this is related to the volume of compacted wood used to form a board.

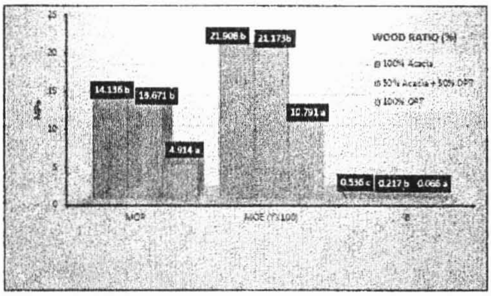

Figure 4.4: The effect of wood ratio on mechanical properties on hybrid particleboard

4.5.2 Physical properties

Figure 4.5, shows the thickness swelling (TS) for both of Acacia and OPT and their admixture. Significant effect was shown by 100% Acacia OPT and their admixture. So, wood ratio from OPT absorb more water compared the others ratio. According to (Rokiah et al., 2011), the specimens formed with high mechanical strength also showed high stability against moisture.

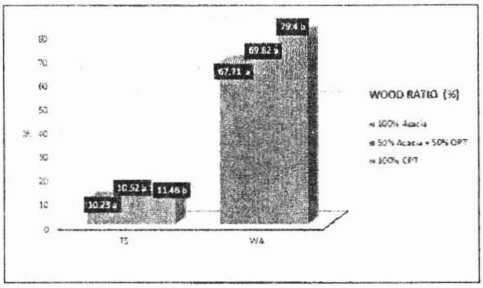

Figure 4.5 The effect of wood ratio on physical properties on hybrid particleboard

5. CONCLUSIONS

When resin content (PF) increases from 7% to 11%, value of MOR, MOE, and IB were increased significantly and for physical properties the TS and WA value were improved significantly. Higher amount of resin available increase bonding between the particles and decreases the ability of water to absorb into the particle.

For the effect of wood ratio on boards, the result of mechanical properties shows that 100% Acacia was better properties compared the 50%+50% mixing and 100% OPT respectively. When the density of wood particle increased, the strength of mechanical properties of board increased. Based on this finding, it can be concluded that the wood ratio of 100% acacia with 11% resin content are the best choice to produced particleboard.

Effect of wood ratio and resin content showed for MOR, TS and WA do not achieved the EN standard. Sample of MOE and IB test achieved the EN standard.

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