Influence of the Oil Palm Trunk and *Acacia mangium* on the Particleboard Properties

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Abstract

The objective of this study was to evaluate both physical and mechanical properties of particleboard from oil palm trunk (*Elais guineensis*) and *Acacia mangium* when using phenol formaldehyde adhesive. For this study the bottom part from both species had been used and the target board density was fixed at 650kg/m³. Experimental boards were from 100% OPT, 100% Acacia and 50:50 mixture of OPT and Acacia. Resin content variations of 7%, 9% and 11% were applied on each combination. Modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding strength (IB), density (ρ) thickness swelling (TS) and water absorption (WA) of the samples were tested based on European Standard (EN). Panels made with 100% Acacia particles had the highest average for both modulus of rupture (MOR) strength and internal bonding at 11.94 MPa and 0.37 MPa respectively. Mixture of Acacia and OPT in the boards influenced their physical properties in both TS and WA. Based on this research it is shown that both species have potential to be used as raw materials for particleboard.

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

1. INTRODUCTION

Applications of wood composite panel are widely found in many industry including packaging and furniture. The global demand for wood composite panels is still increasing. Particleboard is a wood-based composite made up of variant sizes and shapes of particles of lignocellulosic materials mixed together with an adhesive formed under heat and pressure. It is known that the global demand for particleboard has been increasing over the last 20 years. The worldwide trend shows that the market place is moving towards using particleboard with less or no formaldehyde. The industrial use of wood as a raw material for particleboard has been established. However, with the increasing price of wood nowadays, there is a need to find new raw material for particleboard manufacture (Rokiah et al., 2010).

Wood-based composites are normally used for a number of structural and non-structural applications. Product types include panels for both exterior and interior uses, furniture components and support structures in buildings. Study of the mechanical properties of these products is of critical importance to ensure their proper use. Wood-based composites provide uniform and predictable in-service performance, largely due to standards used to monitor and control their manufacture. The mechanical properties of wood composites is influenced by varieties of wood species, forest management regimes (naturally regenerated, intensively managed), types of adhesive used to bind the wood element together, geometry of the wood elements (flakes, strands, particles, fibers, veneer, lumber), and density of the final product (Zhiyong & Ross, 2006).

Rubberwood is very popular as raw material for manufacturing wood composites such as particleboard and medium density fiberboard. Rubberwood composites are available in many sizes and are frequently used as furniture and partitioning inputs (Izran et al., 2011). To-date there are many new fast growing plants introduced as potential substitutes for timbers from the forest, despite that the demand for rubberwood is still on the increased.

The pioneer species Acacia (*Acacia mangium*) was first introduced into Sabah, Malaysia in 1966 (Wan Noor et al., 2014). This species is fast growing, intense and adaptable to different type of soils. The wood properties are diffuse-porous with mostly solitary vessels and tolerance towards lack of soils. It holds significant and effective role on commercial supply of wood products. Based on its good physical properties, *Acacia mangium* has potential and is an appropriate source as raw material for the production of particleboard (Wan Noor et al., 2014).

The second species, oil palm (Elaeis guineensis Jacq.) which originated from West Africa, is a very crucial cash crop in Malaysia and is undergoing rapid plantation expansion. The oil palm trunk (OPT) is considered as a renewable and sustainable natural resource biomass. OPT has been utilized as a cellulosic raw material in the production of panel products which includes particleboard, medium density fibreboard, cement bonded particleboard, block board, plywood and recently in the development of binderless board (Junaidah et al., 2013).

2. MATERIALS AND METHODS

2.1 Field Procedure

The process of particle preparation starts will OPT and tree felling. These were cut into logs by chain saw moved to sawmill and further cut into blocks. The blocks were debarked using cleaver, to remove the unwanted barks. The next step is cutting to smaller sizes (chip) using wood chipper. Finally flaking (important) was done, to obtain the desirable thickness and length.

After flaking, the particle must be dried. Once particle are dried they were screened to remove fines and dust like particle. These unwanted fines tend to absorb more glue thus reducing the strength of the board.

After the screening process, the particles were oven dried to ensure moisture content of below 5%. If not, the boards will blow in the hot press section caused by presence of excess water in the particles. The temperature of the oven is 80°C and the particles were kept for 24 hr until moisture content below 5% are reached.

2.2 Board Manufacture

The amount of resin in a product and how effectively it is mixed determines the strength of the board. For this project, phenol formaldehyde (PF) was use as binder. Blending was done, where this is the process of mixing resin adhesive with particles using glue mixer.

After blending, mat forming was done. A mat former with steel slots or slits was used to form the board manually. Before forming, silicon release agent is sprayed onto the tray, so that the particles do not stick on the tray and mould. The size of mould is 350 mm x 350 mm. The objectives of forming are to lay a mat which is even in weight along its length and across its width. The production of homogenous boards requires only one forming stations.

The particle from the forming process will be sent to cold press to reduce the mat thickness and enabling the mat to be easily handled before hot pressing process. The hot press temperature was 165°C and time 6 min. Three levels of pressure were used. The board final target thickness is 12 mm.

Lastly the samples were left in a conditioning room with a relative humidity of 60 ± 5 % and the temperature Of 20 ± 2 %. Table 2 below shown the pressure time and pressure cycle used in making the board.

Steps	Times(minutes)	Pressure(psi)
1	3	1800
2	2	1200
3	1	800

Table 1: Hot press time and pressure

2.3 Sample Cutting

For sample testing, the panel boards were check for bonding conformance and thickness tolerance before side trimming and cutting for accurate dimension. The board will be cut into the required sizes for testing process using the table saw machine. The line must be drawn on the board according to the standard size of each test. Figure 1 below show the particle board sampling.

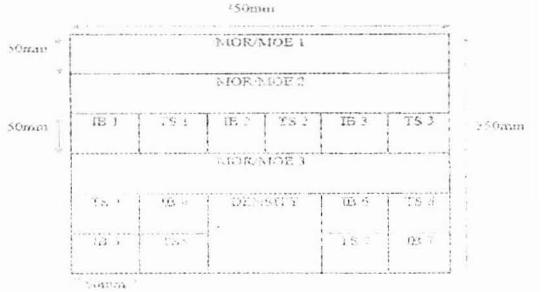

Figure 1: Cutting sample

3. TESTING METHODS

3.1 Bending Strength

Bending test gives modulus of elasticity (MOE) value and modulus of rupture (MOR). Tests samples were clearly labelled, and all required parameters measured and recorded. By using the Bending test was done on (Instron), and the results are determined in MPa and calculated according to the following formula:

MOE (N/mm^2) = $PL^3/48ID$

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

L: span in inches

I: moment of inertia, a function of beam size

D: (width x depth³)/12 for beams with rectangular cross section

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

A sample of size 50mm x 50mm was prepared. It was then glued to a wood block. The test was done using Instron Universal Testing machine, with two forces going to opposing direction until the sample break at middle point. Internal bond is calculated using the formula below:

$$\text{Internal bond } (N.mm^{2}) = \frac{P'}{2bL}$$

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

All the thickness swelling (TS) test samples was sized to ~50 mm X 50 mm and marked. Actual size measured and all the data recorded. Then the samples were precisely soaked in the water, making sure that the overall samples were properly soaked for 24 hours. The formula that use in thickness swelling is as follows:

$$\text{Thickness swelling: } \frac{\text{Final dimension - Initial dimension}}{\text{Initial dimension}} \times 100$$

3.4 Water Absorption

The purpose of water absorption testing is basically to determine how much the particles absorbs the water. This thickness swelling testing also indicates how durable the particleboard is to the water and fire resistance .The formula that is used in calculation to know the percentage of water absorption given below:

$$\text{Water absorption: } \frac{\text{Final weight} - \text{Initial}}{\text{Initial weight}}$$

4. RESULTS AND DISCUSSIONS

4.1 Mechanical and physical properties of particleboard from *Acacia mangium* and oil palm trunk

Table 4.1: Mechanical and physical properties of particleboard from Acacia mangium and oil palm trunk

Wood ratio (%)	RC (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)	WA (%)
100 acacia	7	9.31	844	0.20	19.02	92.24
	9	10.47	1296	0.23	10.88	8.37
	11	12.51	1738	0.37	7.75	64.42
50 acacia + 50 OPT	7	6.71	700	0.15	15.96	93.61
	9	7.73	855	0.16	13.03	89.21
	11	8.70	1389	0.18	11.03	87.80
100 OPT	7	5.35	655	0.04	20.14	103.87
	9	6.18	750	0.06	15.71	97.69
	11	6.44	896	0.07	6.58	95.94
EN standard		≥16	≥2300	≥0.40	≤16	

Note: Board density at 650kg/m^3

The summarized data of physical and mechanical properties of particleboard based on European Standard EN 312:2003 can be seen in Table 4.1. All the final values of this test were compared with European Standard, EN 310 for MOR and MOE strength, EN 319 for IB strength, EN 317 for TS and WA.

The objectives of this study were to determine physical and mechanical properties of OPT and *Acacia* particleboards based on the effects resin content (7%, 9% and 11%) and wood ratio of (100% Acacia, 50% Acacia + 50% OPT and 100% OPT). For mechanical properties, from the three wood ratios, 100% Acacia showed the highest value of MOR from 11% resin content with 12.51 MPa and the lowest value from 100% OPT with 7% resin content (5.35 MPa). Furthermore, the best value for MOE is also 100% Acacia with 11% resin content at 1738 MPa. IB result showed the highest value also from 100% Acacia of 11% resin content with value 0.37 MPa and the lowest value, 0.04 MPa, from 100% OPT with 7% resin content). This is because acacia is a medium hardwood having density between 0.6-0.65g/cm^3, whereas OPT is non wood and the density is between 0.3-0.5g/cm^3 (Md Qumruzzaman, et al. 2004). None of the samples achieved the EN standard of MOR, MOE and IB.

On the physical properties, the highest and lowest value of TS was obtained from 100% OPT (7% resin content) with value 20.14% and 100% OPT (11% resin content) with value 6.58% respectively. According to Norhafizah et al., (2013), when resin content increases; it improved the properties of board by reducing the board TS. For TS test only two samples failed to achieved of the EN standard. The highest value of WA was obtained from 100% OPT (7% resin content) with value of 103.87% and the lowest value from 100% Acacia (11% resin content) with 64.42%. Norhafizah et al., (2013) stated that when resin content decrease; it will increase the percentage of WA.

4.2 Statistical significant for Particleboard

Table 4.2 shows the analysis of variance (ANOVA) of the effects of wood ratio and resin content on the particleboard. Both wood ratios and resin contents shows high significant effect on all MOR, MOE, IB, TS and WA values. All samples are significant at $p < 0.01$. When correlated, the relationship between wood ratio and resin content shows highly significant effects on MOE, IB, TS and WA values. MOR is an acceptation and is not significant.

Table 4.2: Shows the statistical significance of the effect of wood ratio and the resin content on the particleboard.

SOV	DF	MOR	MOE	IB	TS	WA
Wood Ratio	2	71.05**	70.79**	347.37**	22.53**	115.68**
Resin Content	2	13.36**	94.90**	51.81**	874.40**	62.89**
Wood Ratio * Resin Content	4	1.31ns	10.65**	21.89**	82.71**	19.05**

Note: $p > 0.05$, not significant (ns), $p < 0.05$ significant (*), $p < 0.01$ highly significant (**)

4.3 Effect of wood ratio on mechanical and physical properties

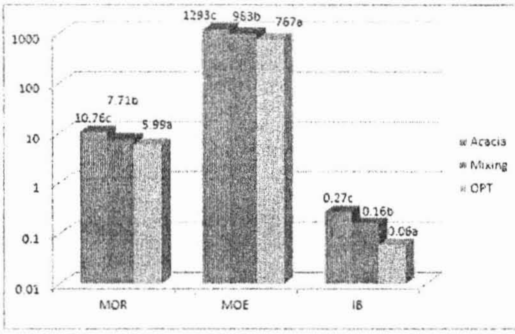

Figure 4.1: Effect of wood ratio on the mechanical properties of particleboard.

Figure 4.1 shows the effects of wood ratio on MOR and MOE values for Acacia, mixing and OPT. All of the mechanical properties values shows significant different. The higher value of is probably due to higher ratio of the acacia. This is because density of acacia is about 0.6-0.65g/ cm³ and the OPT 0.3-0.5 g/cm³ according to Md Qumruzzaman et al., (2004). For IB, the influence of resin quantity and strength of fibre caused the higher value for acacia according to Mohana et al., (2013).

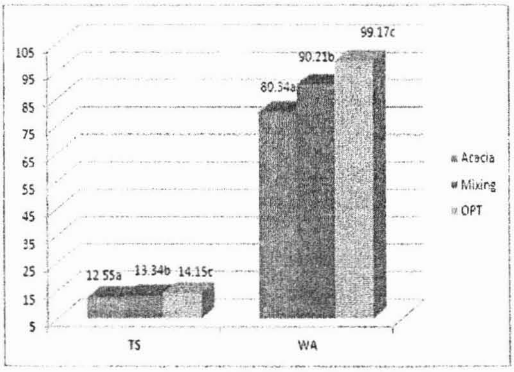

Figure 4.2: Effect of wood ratio on physical properties

Based on the result shown in Figure 4.2, it shows both TS and WA for Acacia, mixing and OPT have significant different. For the TS, species of acacia, mixed of 50% OPT + 50% acacia and OPT, and the graph show the increasing trend as OPT ratio increase. According to previous study (Rokiah et al., 2010), the specimens formed with high mechanical strength also showed high stability against moisture. WA also increased from acacia 100% to 50:50 mix to OPT 100% because of good contact between particles could help to reduce moisture content penetration into panel based on study by Jia et al., 2012.

4.4 Effect of resin content on mechanical and physical properties

According to (Nourbakhsh et al., 2008) from figure 4.3, it shows that increased in resin content would increase the MOR, MOE and IB. It showed that there were significant different between resin content of 7%, 9% and 11% respectively. The highest value of three test for MOR, MOE and IB was obtained from 11% resin content with 9.22MPa (MOR), 1341 MPa (MOE) and 0.21 MPa (IB). All of the sample does not achieved the EN standard

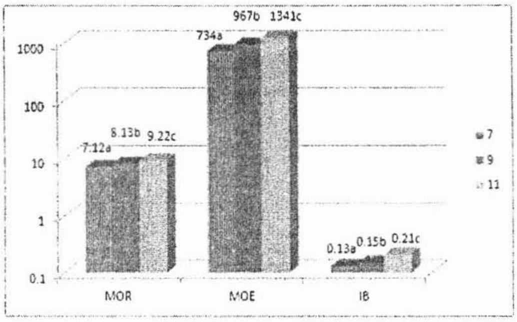

Figure 4.3: Effect of resin content on the mechanical properties of particleboard.

Figure 4.4 shows the effects of resin content on TS and WA. Based on EN Standards, particleboard should have a maximum TS value of 16% for 24 h requirement EN 312-4 (1996). Based on the result, Izran, (2012) were established by a previous study that both of the TS and

WA were significantly different and the graph showed decreasing trend when resin content increase from 7% until 11%. It because the highest amount of resin available increase bonding between the particle and decreases the ability of water to absorb into the particle of Acacia *and* OPT (Izran, 2012).

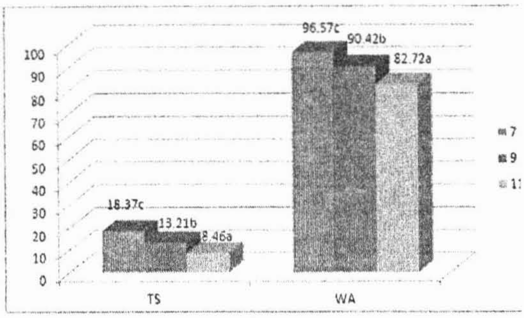

Figure 4.4: Effect of resin content on physical properties of particleboard.

5. CONCLUSIONS

In this study, mechanical and physical performance characteristics of 100% Acacia, mixing 50% Acacia + 50% OPT and 100% OPT particleboards were evaluated. The mechanical properties for 100% Acacia gave the best values compared to those of mixed and 100% OPT. When the density of wood particles increased, the strength of mechanical properties of board increased. Based on this finding, it can conclude that the 100% of Acacia with 11% PF of adhesive gave the best particleboard in this study.

For the effect of resin contents on boards, the result of mechanical properties (MOR, MOE and IB) on board increased significantly with the increase of resin content. For the thickness swelling result, it was decreased when the resin contents were increased from 7% until 11%. Overall, effect of wood ratio and resin content showed that MOR, MOE and IB values did not pass the EN standard.

Acknowledgements

Alhamdulillah, praise to Almighty Allah S.W.T for the strength and opportunity to finish the final year project entitled "Influence of oil palm trunk and acacia on the particleboard properties". Firstly, I wish to express my sincere to my dearest supervisor, Madam Zaimatul Aqmar Abdullah for the continuous encouragement and patience and willingness to contribute her knowledge, time and effort to make it possible for completion of this final project.

Thanks for all wood industry lecturer and staffs for their helps, support and encouragement from semester one until completion. All their contribution is highly appreciated. Thanks also to my beloved parents respectively for their moral and financial support throughout the year study. Also thanks to members and others who are involved directly or indirectly during finishing of this project.

REFERENCES

BS EN 312. (2003). Particleboard Specifications. *British Standard BS EN 312:2003* 12/24

EN310, BS EN312:2003, (2003). Wood Based Panels-Determination of Modulus of Elasticity in Bending and of Bending Strength

EN317, BS EN312:2003, (2003). Particleboards and Fiberboards: Determination of Swelling in Thickness after Immersion in Water

EN319, BS EN 312:2003, (2003). Particleboards and Fiberboards-Determination of Tensile Strength Perpendicular to the Plane of the Board

Izran K. Abood, F.,Yap, K.C., Abdul Rashid,A.M.& Zaidon, A. (2011). Properties and Performance of Rubberwood Particleboard Treated With Bp Fire Retardant. *Journal of Science and Technology* 3(2):Pp1-2

Izran K. (2012). Fire Resistance and Reaction-To-Fire of Shorea macrophylla and Acacia mangium Particleboards Treated with Boron and Phosphorous-based Fire Retardants. *Pertanika J. Trop. Agric. Sci. 35 (4):* Pp755 - 766

Jia G. B. R. H. (2013). Influence of Processing Parameters on Some Properties of Oil Palm Trunk Binderless Particleboard. *ORIGINALS ORIGINALARBEITEN* , Pp4-7

Junidah, L., Rokiah, H.,Othman, S.,Tomoko, S.,Masatoshi, S.& Salim, H. (2013). Measurement of Some Properties of Binderless Particleboards made from Young and Old Oil Palm Trunks. *Measurement 47;* Pp813–819

Md Qumruzzaman Chowdhury, M. I. (2004). Effects of Age and Height Variation on Physical Properties of Mangium (Acacia mangium Willd.) Wood. *Forestry and Wood Technology Discipline* , p18

Mohana B., R. H. (2013). Influence of Steam Treatment on the Properties of Particleboard made from Oil Palm Trunk with Additional of Polyhydroxyalkanoates. *Industrial Crops and Products* , Pp6-8

Norhafizah S. R. H. (2013). Properties of Steam Treated Binderless Particleboard made from Oil Palm. *Composites* ,Pp 2-6

Nourbakhsh A. A. (2008). Effect of Press Cycle Time and Resin Content on Physical and Mechanical Properties of Particleboard Panels made rrom the Underutilized Low-

Quality Raw Materials. *Industrial Crops and Products* , Pp228-229

Rokiah,H., Norhafizah, S., Othman, S., Tomoko, S., Salim, H., Masatoshi, S. & Ryohei, T. (2010). Effect of Particle Geometry on the Properties of Binderless Particleboard Manufactured from Oil Palm Trunk. *Materials and Design 31 (2010)* Pp4251–4257

Wan Noor, A.W.N., Rokiah,H.,Salim ,H., Othman, S., Jia, G.B., Kushairi, M.S., Mohd, Fahmi, A.,Masatoshi, S. & Tomoko, S. (2014). Measurement of Some Properties of Binderless Composites Manufactured from Oil Palm Trunks and *Acacia mangium measurement 50 (2014)*: Pp250–254

Zhiyong,C. & Ross (2006). Mechanical Properties of Wood-Based Composite Materials. *General Technical Report FPL–GTR–190*: Pp12-10.