Properties of Hybrid Particleboard from *Acacia mangium* and Petai belalang Using Phenol Formaldehyde Resins

Wan Hazwani Wan Hassan [1]*, Jamaludin Kasim [2], Said Ahmad [3]

Faculty of Applied Sciences, Universiti Teknologi MARA (Pahang) Malaysia[1, 2, 3]
*deqwanhazwani@yahoo.com.my**

Abstract

This study was carried out to investigate the properties of hybrid particleboard from *Acacia mangium* and Petai belalang using Phenol formaldehyde resins. The particleboard was produce from two types of species which are *Acacia mangium* and Petai belalang (*Leucaena leucocephala*) with different resin content (7%, 9%, and 11%) and the ratio of the percent wood species (100, 60:40, 50:50, and 40:60 %). The experimental particleboards were tested under two different testing conditions which are mechanical testing (modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB)) and physical testing (thickness swelling (TS) and water absorption (WA)) in accordance Japanese Industrial Standard (JIS A 5908:2003). In this study, the results showed, for the ratio of the percent wood species, there were significant interactions which had impact on all board properties and for different resin percentage only had significant effect on thickness swelling. Particleboard from 100% Acacia shows the highest value of MOR, MOE and IB compared with other boards. The physical properties of 100% Acacia had the best TS and WA. In conclusion, the properties from the particleboard made of 100% Acacia passed all the requirement of JIS A 5908:2003.

Keywords: *Petai belalang, Acacia mangium, particleboard, phenol formaldehyde*

1. INTRODUCTION

Particleboard is one of the oldest composite produced and stills remains dominantly for furniture panel and also for structural application (Jamaludin et al., 2000). Particle board is defined as engineered wood composite manufactured from wood particles such as saw mill shavings, chips or even sawdust that are bonded together with synthetic resin or other suitable binders which is pressed under the controlled heat and pressure (Nemli and Aydin, 2007). Bowyer et al., (2007) stated that there are many types of particleboards in the market with various sizes and geometry of particles, amount of adhesive used and the density in which panels are pressed. In today's world, particleboard has been widely used in the applications of furniture manufacturing, wall, stairs treads, interior signs, bulletin board and other industrial product (Wang, 2008).

Hybrid particleboard is an advanced wood composite that have two or more element in the combination of high-performance reinforcements. Advantages of hybrid wood composite are improved physical and mechanical properties of wood composite. The combination of two materials or element could cover the lack of properties and by synergistically improving the overall properties of the final board made (Wan Noor Aidawati et. al. 2014). In addition, lack of the raw materials as solid wood is one of the causes that introduced the hybrid composite.

To ensure the continuity of raw materials, *Acacia mangium* (Acacia) and Petai belalang will be used as alternative raw materials to produce hybrid composite. Acacia species was first introduced into Sabah, Malaysia in 1966. It is a fast growing species and is very adaptable to different soil types on degraded side and hills. Acacia wood is diffuse-porous with mostly solitary vessels and is tolerance of every poor soil (Wan Noor Aidawati et al., 2014). Petai belalang or Leucaena leucocephala is another alternative choice. Petai Belalang is a thornless, evergreen, branched shrub or small tree growing up to 8m high with deep roots (Imededdine et al. 2014).

Resin used in board manufacture can be classified into two types which are natural and synthetic. Typical natural resins are either carbohydrate or protein based. They are mainly derived from animal and vegetable sources or from inorganic materials. While, synthetic resins are produced by the controlled polymerization of various monomeric organic substances. These resins can be further divided into thermosetting and thermoplastic categories (Pizzi, 1994)

Phenol formaldehyde (PF) resins are extensively used as adhesives and binders for lignocellulosic materials. Lignocellulosic materials, conversely, are often used as fillers for PF resins in many of applications. Adhesion between an adhesive and an adherend can be described as a physicochemical phenomenon, and interaction between PF resins and cellulose is no exception. PF resins are currently produced in large quantities for many used for instance, the manufacture of exterior grade wood adhesives (Pizzi, 1983). PF resins make excellent wood adhesives for plywood and particleboard because they form chemical bonds with the phenol-like lignin component of wood. They are especially desirable for exterior plywood, owing to their good moisture resistance. Phenolic resins, invariably reinforced with fibers or flakes, are also molded into insulating and heat-resistant objects such as appliance handles, distributor caps, and brake linings.

The main objectives of this study are, firstly, to determine the properties of hybrid particleboard from Acacia and Petai belalang by using PF resin and secondly to evaluate the effect of wood ratio and resin content on particleboard properties.

2. MATERIALS AND METHODS

Three Acacia mangium (3 years old) was harvested from UiTM Jengka Plantation and five Petai belalang (3 years old) was harvested using chain saw from UiTM Jengka Leaucaena Plantation located in Temerloh. The tree diameter was measured at breast height (DBH) level. DBH is a standard method of expressing the diameter of the trunk or bole of a standing tree. The felled trees was measured and cut into logs length. The leaflets and trunks were removed from the logs and the logs were then transported back to the UiTM wood industry workshop.

The Acacia's logs were debarked before being chipped but not for Petai belalang. After debarking, the logs were cut into planks by using band saw. The plank size is, 25-50mm thick, 70-100mm width and 500 mm in length. Next, the planks were then transformed into chips by using the wood chipper machine and then chips were put into knife ring flakers for the production of particles. After being air-dried, the particles were left unscreened. The Acacia and Petai belalang particles were then oven dried at 80oC until the desire moisture content of below 5% had been reached. The bulk density of the particles was determined by using measuring cylinder. The empty measuring cylinder was weighted and then the particles are slowly dropped into the measuring cylinder. The hand and the cylinder must be at least 10mm distance because to avoid the empty space existence in the measuring cylinder.

PF was used as a binder. A total of 27 single layer panels, three for each combination from Acacia and Petai belalang particles at ratio of 100:0, 60:40, 50:50, 40:60 and 0:100 were manufactured with three different resin content (7, 9, 11 %). Board thickness was 12mm. The target density of the board is 700 kg/m3. The dried particles were put into a mixer, and before they were mixed, the amount of resin required for each board was calculated. Hand formed mats in a mold having dimensions 340mm X 340mm were pre-pressed for 1min.The mats were then placed in hot press using a temperature 165oC for 6 min. The panels were then exposed to room temperature before being placed in the conditioning room.

The samples were cut into specimens for mechanical and physical test including internal bond (IB), modulus of rupture (MOR), modulus of elasticity (MOE), thickness swelling (TS), and water absorption (WA). Properties of the samples were evaluated according to the Japanese Industrial Standard (JIS A 5908:2003).

3. RESULTS AND DISCUSSIONS

Figure 1 shows the bulk density for Petai belalang and Acacia. Bulk density of Petai belalang is higher at 99.79 g/l, while bulk density for Acacia is at 89.42 g/l. If the bulk density is high, the mass of the particles used is also high in order to achieve the same desired volume of the particles. The lower bulk density particles result in a higher compaction ratio, which will subsequently produce higher strength panel than will higher bulk density particles (Suchsland & Woodson, 1990).

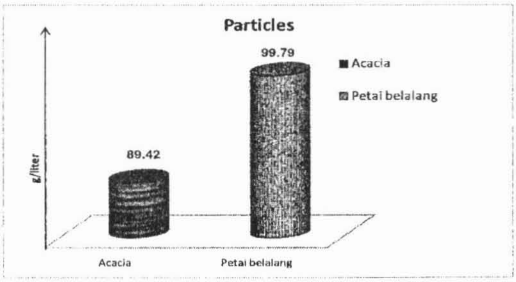

Figure 1: Bulk densities of the particles

Table 1 shows the mechanical and physical properties of hybrid particleboard from Acacia and Petai belalang using PF resin. From the table, the highest MOR (17.31 MPa) is from board made of 100% Acacia-11% resin content and the board with the lowest MOR (7.87) MPa value is board made from 60:40 wood ratios at 7% resin content. The highest MOE (2540 MPa) particleboard is made of 100% Acacia at highest resin content 11%. The lowest MOE (1129 MPa) particleboard is made of 100% Petai belalang with 11% resin content.

Table 1: Mechanical and physical properties of hybrid particleboards

Wood ratio	Resin (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	WA (%)	TS (%)
100A	7	16.01	2004.08	0.53	74.46	13.90
	9	16.94	2222.05	0.55	57.69	12.64
	11	17.31	2540.39	0.63	45.47	9.70
100PB	7	7.94	1128.92	0.35	68.15	14.96
	9	8.46	1164.87	0.48	86.08	14.35
	11	12.56	1578.07	0.44	81.72	11.80
60A:40PB	7	7.87	1625.93	0.36	85.30	26.24
	9	12.06	1175.63	0.39	88.77	18.41
	11	13.75	1828.19	0.61	68.58	16.31
50A:50PB	7	9.12	1309.90	0.46	88.79	26.62
	9	12.94	1520.95	0.52	85.29	17.37
	11	19.35	1161.70	0.30	96.70	16.04
40A:60PB	7	11.17	1651.36	0.53	84.50	16.86
	9	12.55	1604.54	0.55	73.25	15.77
	11	17.35	2042.32	0.52	73.53	14.64
JIS A 5908:2003		MOR >13.00	MOE >2500	IB >0.2	WA <12.00	TS <12.00

The table also shows the values of WA and TS. The lowest value of WA and TS is the best properties for the particleboard. Particleboard made from 100% Acacia with 11% resin content shows the lowest WA and TS of 45.47% and 9.70% respectively. The highest water absorption of 88.79% is from the board made of 50:50 wood ratios at 7% resin content. This board also has highest TS indicate as 26.62%. According to the results from the Table 1, the particleboards made of 100% Acacia at 11% resin content passed all the requirement of JIS A 5908:2003.

Table 2: Summaries of ANOVA for the effect of Resin and Ratio on the particleboard properties

SOV	df	MOR	MOE	IB	TS	WA
Ratio	4	11.45**	17.09**	8.23**	64.58**	30.87**
Resin	2	0.32^{NS}	1.32^{NS}	2.41^{NS}	180.98**	6.06**
Ratio*Resin	8	1.83^{NS}	2.11^{NS}	2.92*	18.40**	10.91**

The summary of analysis of variance (ANOVA) on the effect of wood ratio and resin content on particleboard properties are shown in Table 2. The results indicated that there were significant interactions between wood ratio and resin content. For the wood ratio, there was significant effect on all the properties of the particleboard. For the resin content, it had only significant effect on the thickness swelling and water absorption.

3.1 Effects of Wood Ratio on Particleboard Properties

3.1.1 Effects of Wood Ratio on Mechanical Properties

The mechanical properties of the particleboards in Figure 2 showed that there are significant effects on all the board properties. Particleboard made of 100% Acacia perform better compared with other boards. Acacia has higher wood density compared to Petai belalang. Properties were directly related to species density whether of single specie or of a mixture of species. High density of wood will improved the values for MOR, MOE, and IB (Stewart, 1973). Petai belalang bark was not removed before the chipping process. The bark will reduce the strength of the particleboard. According to Sabrina et al., (2013), for Petai belalang the inclusion of the bark in the composite gave reduction in mechanical properties. It is because inherently weaker characteristic of bark compared to wood.

As seen for 40:60 wood ratios, it performs better in MOR, MOE and IB compared to 100% Petai belalang. Wan Noor Aidawati et al., (2014) stated that the combination of two materials could cover the lack of each other properties and could improve the overall properties of the final board made.

3.1.2 Effect of Wood Ratio on Physical Properties

Figure 3 shows the effect of wood ratio on physical properties of the particleboard. The results revealed a significant effect in the dimension change with excessive water content in board. It is closely related to the different wood species influence towards change in the dimension stability of the specimens. According to Moslemi, (1974), less swelling is expected when wood species with high density are used due to the lower degree of mat compaction. Benedito (1974), also state that high density of the wood species results in less swelled on the board. Wood density influences binder consumption and therefore, will influence the strength properties of the board and the dimensional stability.

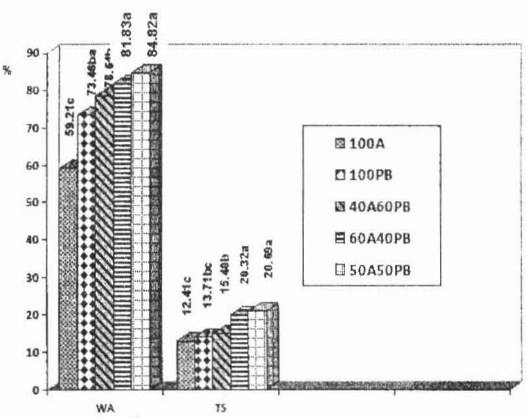

Figure 3: Effect of wood ratio on mechanical properties of particleboard

3.2 Effect of Resin Content on Particleboard properties

3.2.1 Effect of Resin Content on Mechanical Properties

Figure 4 shows the effect of resin content on mechanical properties of the particleboards. It was shown that there is an increment in both the MOR and MOE but they are not significant. However IB showed significant effect, showing that with more resin content, more bonding site are made available, thus improving the strength properties. In previous study Sarmin et al., (2013) found that the resin content affected the performance properties of the panels. When the resin content was increased, the performance of the panels improved. This might have been due to resin itself, which filled the void among the particles and thereby reduced the moisture uptake from the environment.

3.2.2 Effect of resin Content on Physical properties

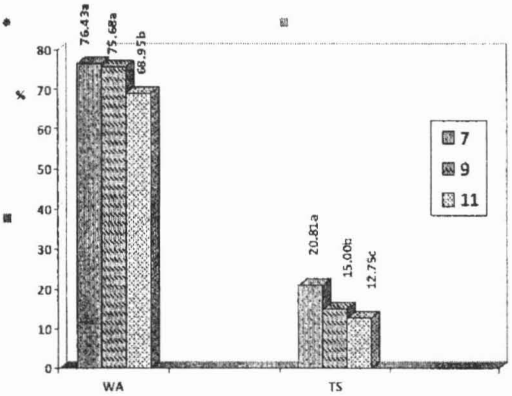

Figure 5: Effect of Resin content on Physical properties of particleboard

Figure 5, shows increasing the amount of resin content improved significantly the physical properties of the particleboard. This expected finding is due to the increasing of bond between particles. According to Ayrilmis, Kwon & Han, (2012), the dimensional stability will improve by increasing the resin content. The more resin added to the particle means that greater area of the particles covered with resin and the particles can be bonded together, hence less water can penetrate between particles and also lead to less regaining of the particle original shape (Medved, 2013).

4. CONCLUSIONS AND RECOMMENDATIONS

From this study, the results indicate that there were significant interactions between ratio and resin content. For the wood ratio, there was significant effect on all the properties of the particleboard. For the resin content, it had only significant effect on the thickness swelling and water absorption. The particleboards made of 100% Acacia at 11% resin content passed all the requirement of JIS A 5908:2003. Further study properties of admixture particleboard should be continued in order to develop alternative materials in the wood based industry.

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