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Research paper



Influence of Resin Content and Particle Size on Particleboard from Leucaena Leucocephala

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Abstract

Overcoming shortage of raw material for particleboard manufacturing in Malaysia is crucial. Using fast growing forest plantation species such as *Leucaena leucocephala* provide a possibility. The study investigates the physical and mechanical properties of particleboard (density 700 kgm^3) from *Leucaena leucocephala* with variables of resin content (10, 12 & 14 %). and particle size (1.0 mm, 2.0 mm & Unscreen). Resin used was melamine urea formaldehyde, for high moisture resistance particleboard. It is aimed for use at flooring and wet kitchen cabinet. Resin content influence physical and mechanical properties of particleboard with increase of resin content. Bigger particle size contributes to better mechanical properties, but higher in absorption of water. The result shows treatments passing minimum requirements of BS EN standard.

Keywords: *Particleboard, Leucaena leucocephala, Melamine Urea Formaldehyde*

1. Introduction

A composite is broadly defines as two or more different type of materials combined to create a superior and unique material [2], [9]. Composite history in the ancient times, showed straw mixed with mud to form bricks or board for building material. In wood industry, composite refers to combination of material from reconstructed wood bonded together with adhesives. The common wood adhesives are urea formaldehyde (UF), melamine formaldehyde (MF), melamine urea formaldehyde (MUF) and phenol formaldehyde (PF). These composites require specific temperature to bond. According to Brent [3], engineered products are commonly made up of wood from plants with lower quality, smaller log diameter, fast growing and environmentally appealing. Particleboard or chipboard is a product known for its durability, suitability and better consistency of quality suitable for making furniture, wall, cabinets, kitchen and flooring [13].

Particleboard process needs large amount of material, in form of wood material. The most common material used in Malaysia for particleboard manufacturing is rubberwood [4]. Continuous usage of rubberwood by industry has depleted the resources and current supply is estimate not to last past the next 2 decades. Trees take years to grow and remains juvenile in the first 3 to 5 years. According to Oggiano et al. [11], fast growing species wood composite production has an advantage in terms of shorter time for wood supply cycle. *Leucaena leucocephala* (Petai Belalang) have high potential as raw material due to its fast growth [16]. This study, investigate the suitability of producing particleboard from *Leucaena leucocephala* by evaluating the effect of resin content and particle size on particleboard properties.

2. Materials and Methods

The study used *Leucaena leucocephala* wood with MUF resin as the binder. The 4 years old trees was harvested from trial plot area in Forest Reserved of UiTM Pahang, Malaysia. At this point *Leucaena leucocephala* diameter ranged between 14 cm to 18 cm with an average height of 6 meter. The MUF specification was pH 8.34, viscosity 200 cps at 30°C, solid content 65.4%, specific gravity 1.275 and gelation time 73 sec. The resin was obtained from local particleboard company. Target board with density of 700 kgm^{-3} and dimension of 340 mm x 340 mm with thickness 12 mm was made. Resin content of 10%, 12% and 14% (MUF) was used together with three particle combination; sizes range of 1.0 mm, 2.0 mm and unscreen. The resin was blended with wood particle followed by pressing under heat (165°C) for 6 minutes forming the boards.

Boards were evaluated for mechanical properties namely, bending and internal bonding (IB). Meanwhile, physical properties were measured by thickness swelling (TS) test and water absorption (WA). Test preparation and evaluation of board was carried out according to BS EN standard (1993). Table 1 summarized the results of mechanical and physical testing.

3. Results and Discussion

The mechanical and physical properties of particleboard of this study are presented and discussed according to particle size and resin content (Table 1).

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Table 1: Mechanical and Physical Properties of *Leucaena Leucocephala* Particleboard

PS (mm)	RC (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	CT.IB (MPa)	T.S (%)	W.A (%)
1.0	10	11.29	2284	0.45	0.03	18.7	101.8
1.0	12	11.95	1973	0.53	0.23	15.0	90.2
1.0	14	14.44	2353	0.66	0.08	13.5	87.3
2.0	10	12.13	2470	0.52	0.32	19.9	91.8
2.0	12	17.93	3320	0.89	0.14	20.9	73.9
2.0	14	19.40	3437	0.91	0.40	18.8	78.4
US	10	16.39	2993	1.15	0.14	14.9	66.9
US	12	16.04	2901	0.94	0.47	14.6	72.2
US	14	12.11	2748	0.85	0.48	12.9	72.7
BS,EN Standard		17 MPa	2300 MPa	0.40 MPa	0.15 MPa	≤ 16 %	

Note: PS = Particle Size, RC = Resin Content, US = Un-screen, MOR = modulus of rupture, MOE = modulus of elasticity, IB = internal bond, CT.IB = internal bond after cyclic test, TS = thickness swelling, WA = water absorption

The analysis of variance (ANOVA) on particleboard properties is shown in Table 2. The result shows highly significant difference for all of the testing based on density. The F-value of modulus of rupture (MOR) is 140.83, modulus of elasticity (MOE) 197.60, IB 10.34, TS 32.28, WA 82.32 and cyclic test in IB (CT.IB) 33.55.

Table 2: Analysis of Variance on Particleboard Properties

SOV	Df	MOE	MOR	IB	TS	WA	CT.IB
RC	2	2.56ns	2.57ns	8.92**	55.38**	10.19**	24.97**
PS	2	18.28**	10.57**	6.09**	114.69**	20.30**	35.82**
RC*PS	4	5.43**	5.65**	1.04ns	7.44**	6.75**	6.60**

Note: RC = Resin Content, PS = Particle Size, SOV= Source of Variance, Df = Degree of Freedom, MOE = Modulus of Elasticity, MOR = Modulus of Rupture,
IB = Internal Bonding, TS = Thickness Swelling, WA = Water Absorption, CT.IB = Cyclic Test, ** = highly significance

Resin content results showed no significant difference for MOR and MOE. The IB, TS, WA, and CT.IB showed highly significant difference when resin content is varied. Particle size showed highly significant impact for all tested particleboard properties parameters. The F-value for TS at 114.69 indicated the large effect of size on *Leucaena leucocephala* particleboard stability behavior. Combination of resin content and particle size effect registered highly significant difference in MOE, MOR, TS, WA and CT.IB with IB as an acceptation.

The Duncan's Multiple Range Test (DMRT) based on the effect of resin content on properties showed no significant difference in MOE for resin content 12 and 14 % despite higher MOE values of 2832 MPa for 14% resin content. The MOR DMRT showed no differences between 10 and 12 % content of resin content. However these two values showed significant difference from 14 % resin content, which attaints the highest result. For IB, no significant difference between 12 and 14 % of resin content followed MOE and 10% resin is of significant difference to 12 and 14 %. The strength of IB is dependent on the amount of resin applied to the board [15]. All resin contents results for CT.IB are significantly different. On TS, there are significant difference between 10, 12 and 14% resin content. Highest value is seen on 10 % (20.95 %) and lowest value is 14.98 % for 14% resin. Again, WA testing on resin content impact put 12 and 14% resin content at par and is significantly different from 10% resin content. The highest value WA for 10% resin content measured at 93.9 %.

3.1. Effect of Resin Content

The MOE and MOR comparison for resin content is shown in Fig. 1. Higher resin content contributes to higher board strength. Stronger board contributes to higher durability of the particleboard. All board made had MOE value exceeding BS EN standard requirement, but for MOR only on 14% resin content surpassed the standard. Thus, 14% resin content the particleboards is suitable for interior fixtures including furniture manufacture application.

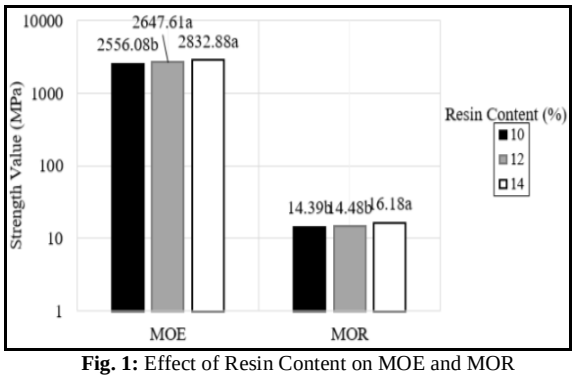

Fig. 1: Effect of Resin Content on MOE and MOR

Internal bonding data ranged from 0.51 MPa to 0.86 MPa and CT.IB data range from 0.15 MPa to 0.39 MPa. The minimal requirements of EN 319: 1993 Standard for general purpose IB is 0.40 MPa and CT.IB is 0.15 MPa. Fig. 2 showed that all particleboard test results are higher than EN requirements. Strength of IB value of specimen increased with increasing resin content [1]. For use in high purpose particleboard, the result shows 14% resin gave more strength in IB and CT.IB.

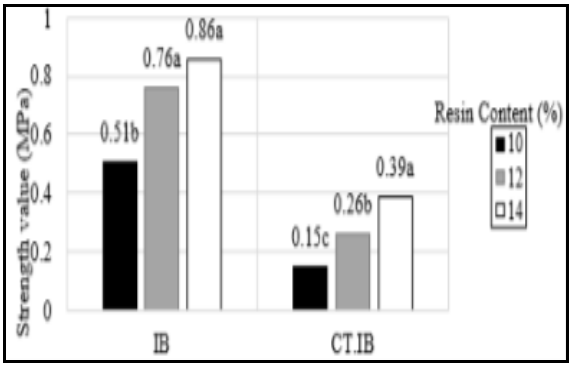

Fig. 2: Effect of Resin Content on IB and Cyclic Test

Fig. 3 range on TS is 14.98 % to 20.95 % and WA is 79.5 % to 93.9 %. Value ≤ 16% for TS is needed to pass BS EN 317: 1993. For WA, there is no standard indicated. With boards made with 14% resin content the TS and WA are better and the results of CT.IB showed that this board could be used for high moisture resistance board. According to Kalaycioglu et al. [8], springback of panel when soaked in the water translate to lower dimensional stability, a common behavior of any wood composite. Treatment such coating at board surface with laminates makes the board become a more stable product [10].

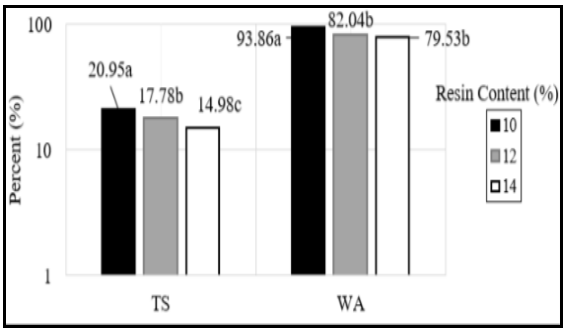

Fig. 3: Effect of Resin Content on TS and WA

Correlation analysis (Table 3) between board properties with resin content showed positive correlation on MOE (r = 0.21*). For MOR (r = 0.22**), IB (r = 0.38**) and CT.IB (r = 0.40**) highly positive correlation was observed. Highly negative correlation was

seen for TS (r = -0.43**) and WA (r = -0.30**) as resin content increase. Overall particleboards showed relatively better dimensional stability and mechanical properties with increasing resin concentration [7].

Table 3: Correlation Coefficient of Resin Content on Board Properties

MOE	MOR	IB	TS	WA	CT.IB
0.21*	0.22**	0.38**	-0.43**	-0.30**	0.40**

Note: * = significant at $p < 0.05$, ** = highly significant at $p < 0.01$, MOE = Modulus of Elasticity, MOR = Modulus of Rupture, IB = Internal Bonding, TS = Thickness Swelling, WA = Water Absorption, CT.IB = Cyclic Test using Internal Bonding.

3.2. Effect of Particle Size

Fig. 4 shows the effect of particle size on strength properties of *Leucaena leucocephala* particleboard. The particle size 2.0 mm showed better performance for both MOE and MOR. The MOE are significantly different for particle sizes 1.0 mm, 2.0 mm and unscreen. The highest result was for 2.0 mm at 2971 MPa. The results follow [5], which state particles with bigger surface area give better stress distribution than smaller size. Based from research done by Rokiah et al. [12], strength properties in glueline are increased by the large surface area. In MOR and MOE, 2.0 mm is better than 1.0 mm and unscreen. The MOR of 1.0 mm and unscreen have no significant difference. However both are of significant difference compared to 2.0 mm with highest result of 17.15 MPa. Particleboard made from larger particle showed better mechanical properties [15].

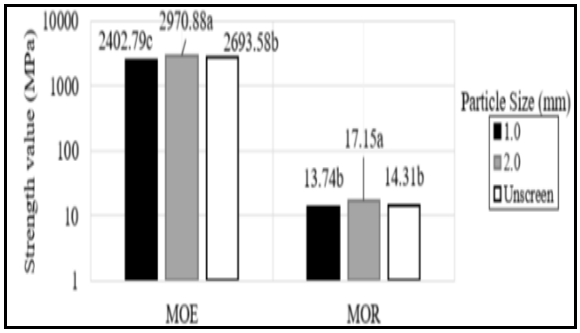

Fig. 4: Effect of Particle Size on MOE and MOR

The IB exhibited the same trend to MOR. Highest result gained by 2.0 mm due to easier resin spread into particle. From data comparison IB in Fig. 5, 2.0 mm has highest IB with 0.85 MPa. However, this is different from CT.IB which shows unscreened retaining higher CT.IB than 1.0 and 2.0 mm. For CT.IB, the value show significant different between 1.0 mm, 2.0 mm and unscreen. Highest value obtained from unscreen particle.

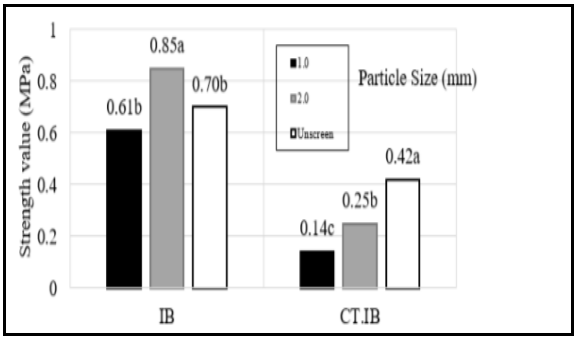

Fig. 5: Effect of Particle Size on IB and Cyclic Test

The effect of particle size on TS and WA of *Leucaena leucocephala* particleboard shown in Fig. 6. Reaction of board to WA and TS are important part to determine acceptable particle size. From the data, TS 2.0 mm highest showing worst performance for particle size (22.38 %). Result of TS show significant difference between 1.0 mm, 2.0 mm and unscreen. Since all sizes are significantly different, better board could be produce with unscreened particle followed by 1.0 mm size. The 2.0 mm particle fail TS requirement of BS EN standard.

WA gave equivalent result for 2.0 mm and unscreened particle. The 1.0 mm particle is significantly different from the two mentioned sizes. With increased of densification of the wood, swelling pressure also increase [14]. For 2.0 mm, TS is higher likely, due to compactions, which occur when pressing the board in hot press. Unscreen is better in TS despite having higher WA. Increasing of particle size could produce large surface area, which makes it easier for water to soak into board compared to smaller particle size [6]. Presence of both large and small particles creates a better intertwining of particles thus reducing swelling even when water is absorbed by the board.

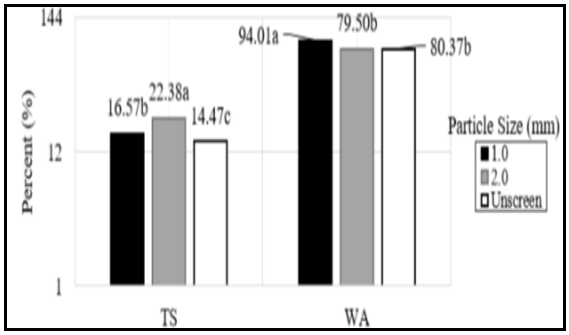

Fig. 6: Effect of Particle Size on TS and WA

Correlation analysis (Table 4) showed positively significant correlation ($p \leq 0.01$) for IB (0.15**) and CT.IB (0.48**) to particle size. The analysis also showed TS (-0.16**) and WA (-0.21**) are negatively affected by particle size. Meanwhile MOE and MOR gave no significant correlation to particle size.

Table 4: Correlation Coefficients of Particle Size on Board Properties

MOE	MOR	IB	TS	WA	CT.IB
0.14ns	0.75ns	0.15**	-0.16**	-0.21**	0.48**

Note: ns = not significant, ** = highly significant at $p < 0.01$, MOE = Modulus of Elasticity, MOR = Modulus of Rupture, IB = Internal Bonding, TS = Thickness Swelling, WA = Water Absorption, CT.IB = Cyclic Test using Internal Bonding.

4. Conclusion

The study of 700 kgm^{-3} *Leucaena leucocephala* particleboard made with MUF had shown impact of resin and particle size on board properties. Resin content at 14% gave an overall better performance for all aspect of mechanical and physical properties. Particle size of 2 mm gave higher performance in MOR and MOE, while size of unscreen particle are able to give good TS stability. When combined, best performing board is with 14% resin content and unscreen particle. The CT.IB result had identified a number of combinations, which show good potential to become high moisture resistant product.

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