Effect of Particle Size and Resin Content on *Leucaena leucocephala* Particleboard Properties

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Abstract: This research was carried out to investigate the effect of particle size and resin content on mechanical and physical properties of particleboard made from *Leucaena leucocephala* species. The *Leucaena* tree was harvested from UiTM Jengka forest. 24 boards were made from different particle sizes which are 1.0mm, 2.0mm, and 1.0mm + 2.0mm (mix). The resin content for three different types of particle size was 8%, 10%, and 12%. Urea formaldehyde (UF) was selected in this research. The press condition for the particleboard was 180°C at duration of 6 minutes. The mechanical properties in static bending for modulus of rupture (MOR), modulus of elasticity (MOE), tensile perpendicular, water absorption and thickness swelling were found to be significantly affected by the varying particle sizes and resin content used in the study. All boards passed the minimum requirements of BS EN Standards except for the dimensional properties. *Leucaceana leucocephala* wood is a potential source of raw material for the wood composite industry.

Keywords: particle size, resin, *Leucaena Leucocephala*

1. Introduction

In 1970 and early 1980s, *Leucaena leucocephala* was known as a 'miracle tree' because of its worldwide success as a long-lived and highly nutritious forage tree and its diversity of other uses such as timber, firewood, human food, green manure and erosion control Brewbaker and Sorensson (1990). *Leucaena* originates in Central America and the Yucatan Peninsula of Mexico where its fodder value was recognized over 400 years ago by the Spanish conquistadores who carried *leucaena* feed and seed on their galleons to the Philippines to feed their stock. From there, *leucaena* was used as a shade plant for plantation crops and it has spread to most tropical countries. *Leucaena* was introduced into Australia in the late 19 century and is naturalized in parts of North Australia by 1920 (White, 1937). *Leucaena* is capable of producing a large volume of a medium-light hardwood for fuel (specific gravity of 0.5-0.75) with high heating value and low moisture, and excellent charcoal, producing little ash and smoke. It is also used for parquet flooring and small furniture as well as for paper pulp. *Leucaena* poles are used for props, posts and frames for many varieties of climbing crops (Brewbaker et al. 1985).

Leucaena is one of the most productive leguminous tree species and is widely cultivated in the subtropical and tropical regions, including Australia, Hawaii, and Southeast Asia (National Research Council, 1984). *Leucaena leucocephala* is vigorous, highly fodable, tolerant drought, protein rich, highly yielding and can grow in a wide range of soils. In short, it is multipurpose tree species (Gupta and Atreja, 1999). This species is also used for cattle forage, a shade in crop field, or as a fuel wood. *Leucaena leucocephala* has a pale yellow sapwood and light reddish-brown heartwood with medium to heavy hard wood (about 800kg/m^3). The wood is known to be of medium density and to dry without checking or splitting. It is medium texture, strong, closed-grain easily workable for widely carpentry purposes. The uses of sawn timber, flooring, mine props and parquet increasing. The uses of *leucaena leucocephala* for sawn timber are greatly limited by its generally small dimensions (usually not greater than 30 diameter), its branches, the length limits of clear bole available and the knotty wood, and its large proportion of juvenile wood (Hughes, 1998).

In Malaysia, *Leucaena leucocephala* is locally known as 'petai belalang' and is a fast growing tree but lesser known species. It was introduced in order to sustain the wood composites as an alternative material. These trees are widely regarded as lead tree after clear landing or logging activities. At present, this species is normally cut, and burned or left to endure the degradable process during land clearing activities. The woods is also consider as agricultural residues but it is very useful in wood composite material in place of the existing raw material (rubberwood) which has become more difficult and expensive to obtain (Marzuki, 2009).

Malaysia has been known as a major player of wood based industries. Therefore, the demands for wood based product have increased. In order to maintain and fulfill the demand for Malaysian wood passed product, rubber wood was utilized as a raw material. However, rubberwood is getting costly and limited in resources. This situation has lead to the increasing demand for rubberwood timber as a raw material for the local wooden furniture making industry. Thus, the new wood alternatives to back up tropical hardwood and rubberwood as a timber resource in order to support the wood industries must be explored. The main objectives of this study were to determine the properties of *Leucaena leucocephala* on particleboard and to study the effect of particle sizes and resin content on the particleboard properties.

2. Material And Method

Field Procedure and Material Preparation

Leucaena leucocephala from UiTM Pahang Plantation Plot was harvested for the study. Selected trees diameter was measured at the DBH level. The bole were cut using chain saw into 8ft length and delivered to the Wood Technology Workshop. Barks were removed from logs by using a cleaver. Then, the logs were chipped into wood chips. Flaking process was then employed to reduce the size of particle into smaller sizes. After flaking, the particles were air dried for a week to reduce the moisture content and then screened. The particles were screened into 1.0 mm and 2.0mm sizes. The particles were then dried in the oven at 80 °C until the moisture content was less than 5%. Dried particles were then kept in plastic bags until needed.

Board Manufacture

A weighted amount of particles (1.0, 2.0mm and mixture) were placed in the particle mixer and sprayed with urea formaldehyde resin between 8 to 12%. After mixing the sprayed particles were formed into a mat manually in a wooden mould with dimensions of 35 cm X 35 cm. After mat forming the boards were then cold press to consolidate its thickness. Prepress was conducted at 300 – 500 psi pressure for about 30 seconds. The consolidated mat was then hot pressed in a thermal-oil heated hydraulic hot press at an elevated temperature of 165°C with a three stage of pressure which were 1800 psi for 180 second follow by 1200 psi for 160 second and 800 psi for 60 second. After hot pressing the finished boards were then cooled at room temperature. The boards were cut into the required sizes for testing as shown in Table 1.

Table 1. The number and size of sample according to testing.

Property	Sample size (mm)	No. test sample/board
Bending Strength	240 x 50	3
Internal Bonding	50 x 50	7
Thickness Swelling	50 x 50	7
Water Absorption	50 x 50	7
Density	100 x 100	1

Particleboard Evaluation

The physical and mechanical properties of the board was tested according to the Static Bending Test (MOR and MOE), Internal Bond Strength (IB), Thickness swelling (TS) and Water absorption (WA). The physical and mechanical data were analyzed for Analysis of Variance (ANOVA) to determine the significant effects and Multiple Range t_tests were were further analyzed to determine the significant level of the variables used in this study. Testing of smples followed the BS EN Standard Methods (BS EN 312:2004). Figure 1 shows the experimental design of *leucaena leucocephala* used in the study.

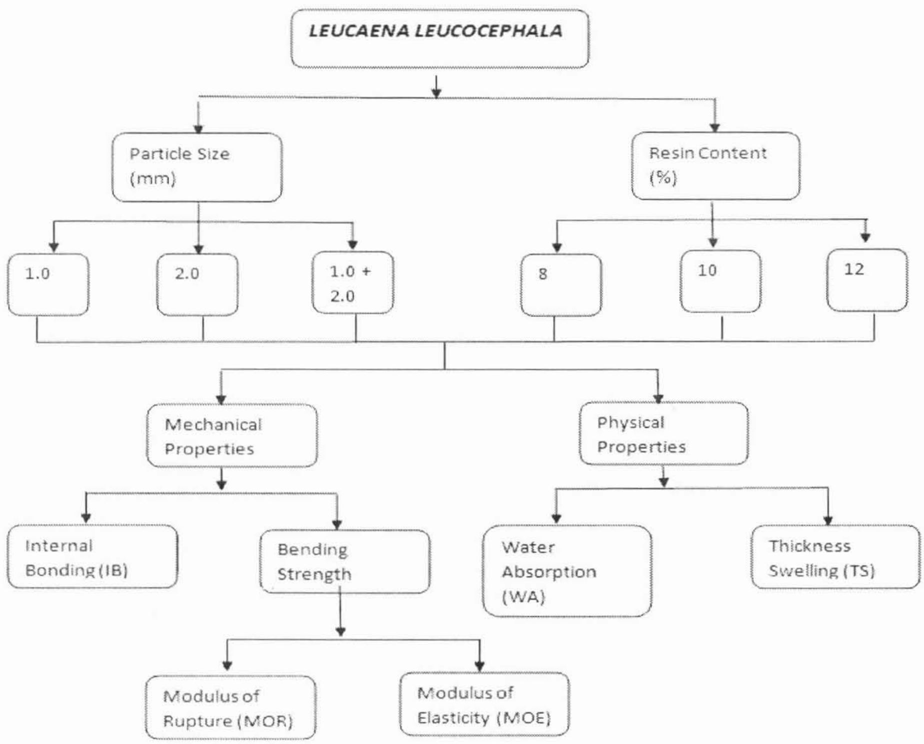

Fig. 1 Experimental Design used in the study

3. Results And Discussions

Mechanical and Physical Properties

Table 2 shows the mechanical and physical properties of the particle boards made from *Leuceana leucocephala*. According to the EN standard (1996), the requirement for specific mechanical and swelling strength properties were 17MPa, 2300MPa, 0.4MPa, and 16% for modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), and thickness swelling (TS) respectively. Results showed that all boards passed the BS EN standard for MOR, MOE, IB and TS. Particle board produced from particle size of 2.0mm and 12% of resin content gave the highest mechanical properties in MOR, MOE and IB. While the particle board produced from particle size of 1.0mm and 8% resin content gave the lowest value for mechanical test in MOR, MOE, and IB. All boards failed in the TS values of 16 %.

Table 2. Mechanical and Physical Properties of Particle Board from *Leucaena leucocephala*

Particle Size (mm)	**Density (Kg/m^3)**	**Resin (%)**	**MOR (MPa)**	**MOE (MPa)**	**IB (MPa)**	**TS (%)**	**WA (%)**
1.0	500	8	17.69	2406.28	0.42	21.00	70.10
1.0	500	10	20.44	3081.30	0.50	19.00	67.58
1.0	500	12	21.26	3332.56	0.63	17.30	65.30
2.0	500	8	18.50	2823.15	0.49	37.20	92.40
2.0	500	10	24.24	3578.57	0.59	36.60	86.0
2.0	500	12	25.58	3788.75	0.82	32.20	82.80
1.0 + 2.0	500	8	18.11	2658.97	0.47	29.40	78.45
1.0 + 2.0	500	10	22.37	3221.84	0.55	26.60	76.35
1.0 + 2.0	500	12	23.43	3508.35	0.69	23.70	72.38
BS EN			**17**	**2300**	**0.4**	**16.00**	-

MOR- Modulus of rupture, MOE- Modulus of elasticity, IB- Internal bond, TS- Thickness swelling, WA- Water absorption

Statistical Significance

The analysis of variance (ANOVA) of the properties of the particle boards was shown in Table 3. From the table, the particle size and resin content were shown to significantly affect all the board properties. Their interaction also showed similar effects.

Table 3. Summary of ANOVA on properties of particle board from *Leucaena leucocephala*

SOV	Df	MOR	MOE	IB	TS	WA
PS	2	212.33*	95.19*	28.08*	900.34*	1094.21*
RC	2	558.42*	374.54*	129.48*	99.41*	125.19*
RC x PS	4	24.02*	1.629*	2.82*	0.48*	7.14*

Note: *significant at $p<0.05$, SOV- Source of variance, Df- degrees of freedom, MOR- Modulus of rupture, MOE- Modulus of elasticity, IB- Internal bond, TS- Thickness swelling, WA- Water absorption

Effect of Particle Sizes on Board Properties

In general, the particle size play an important role for determining the strength properties of particleboard. Based on previous research, a larger particle size gives higher strength properties of particleboard. The properties of particle boards can be significantly affected by particle geometry, which includes the shape and particle size (Frybort et al. 2008). The particle geometry plays a more significant role in the development of board properties than the actual mechanical properties of the fiber type panel (Suchsland and Woodson, 1987). Miyamoto et al., (2002) showed the effect of particle shape on the linear expansion of particle board. The effect of particle size often was observed on internal bond strength of the boards (Ngueho Yemele et al., 2008). Biswas et al. (2010) observed the variation of particle geometry has significant influence on the strength properties of the particle. The smaller particle size improved the properties of the particleboard. Hence, the internal bonding strength of the board mostly increased with decreasing bark particle size (Ngueho Yemel et. al., 2008). Moreover, studie conducted by Steiner and Wei, (1995) and Kruse et al., (2000) showed that particle size strongly influences the density distribution of the panel.

Mechanical Properties

Figure 2 shows that the effect of particle size on modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB). All the strength value of MOR, MOE and IB showed better performance as the size of particle increased. All the mechanical properties were significantly affected by the change in particle size. MOR was shown to increase by about 17%, MOE by 16% and IB by 26% when the particle size of 1.0 mm was changed to 2.0 mm. The better strength properties were due to larger particle as it provides better surface area to distribute the stress compare to small. Jamaludin et al. (2010) stated that the values of MOR are usually high with increase of particle size due to the higher quantity of resin content available in the board. The results indicate that the higher particle size encourage stronger bonding between fibers in the boards, and thus prolonging the ability the boards to withstand the pulling force created though the test (Jani and Izran, 2009).

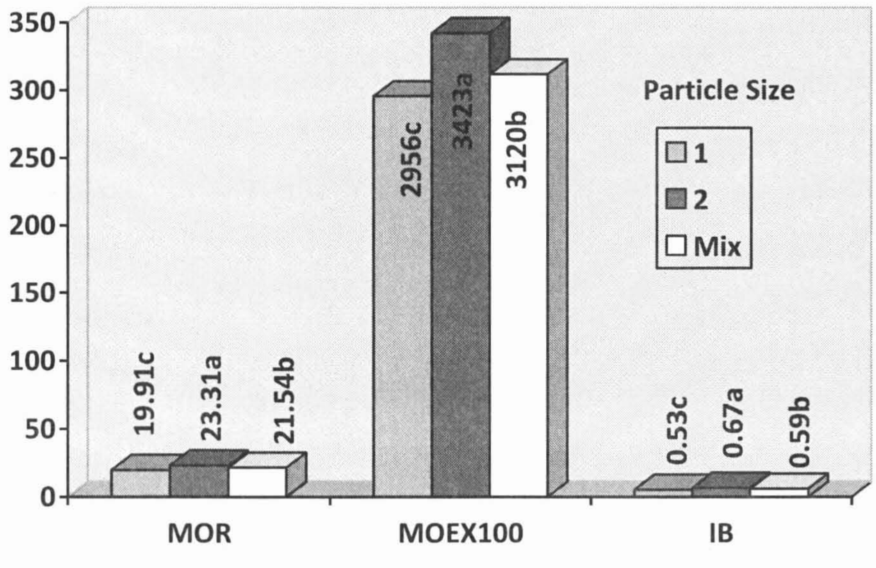

Fig. 2 Effects of Particle Size on Mechanical Properties

Dimensional Properties

Figure 3 shows the effects of particle size on the dimensional properties. The significant improvement of water absorption corresponds to the decrease from 2.0mm size to mix size and 1.0mm, respectively. It was shown that the WA improves by about 23% when the particle size was changed from 2.0mm to 1.0mm while the TS also improve by 45%. Bigger particles of 2.0mm absorb more water compared to mix size and 1.0mm. Particle size 1.0mm absorbs less water since it has higher surface area and provides close bonding of the particles and creates fewer voids among the particles. Smaller particle size cause significant decrease in absorption of water (Biswas and Jamaludin, 2010).

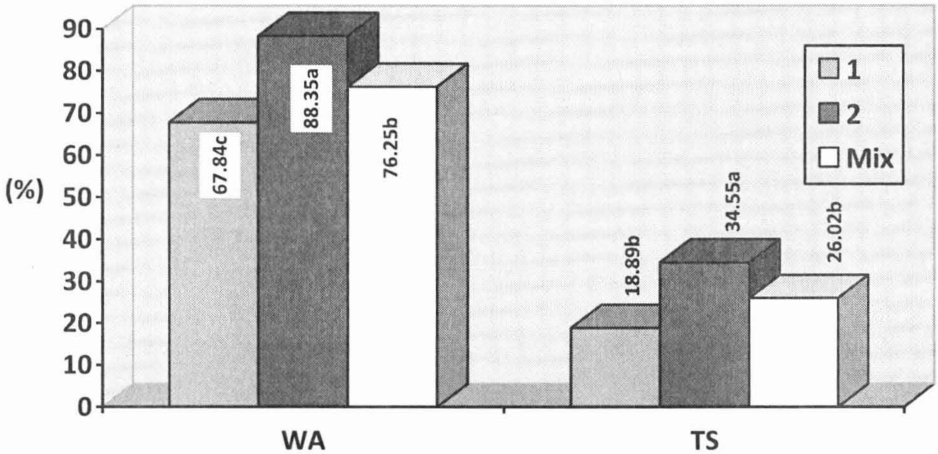

Fig. 3 Effect of Particle Size on Dimensional Properties

Effect of Resin Content on Board Properties

In general, the resin content has a big effect on the strength properties of particleboard. Previous study showed that the higher the resin content, the stronger the particleboard (Jani, 2010). The impact of the resin content on swelling stress (Niemz and Steinmetzler, 1992) has been reported. Swelling increased with increasing thickness swelling, which was more obvious with board with higher particle size. It was also observed that thickness swelling and water absorption decreased with increasing resin content.

Mechanical Properties

Figure 4 shows the effects of resin content on Modulus of Rupture (MOR), modulus of elasticity (MOE) and internal bond (IB). With higher resin content the mechanical properties increases significantly. The increase in MOR was about 28%, MOE by 34% and IB by 43%. These result showed that, the amount of resin content used had affect significantly the mechanical properties value proportionally as the amount of resin content increased, the strength values also increased (Izran and Jani, 2009). Jamaludin (2010) also reported similar findings.

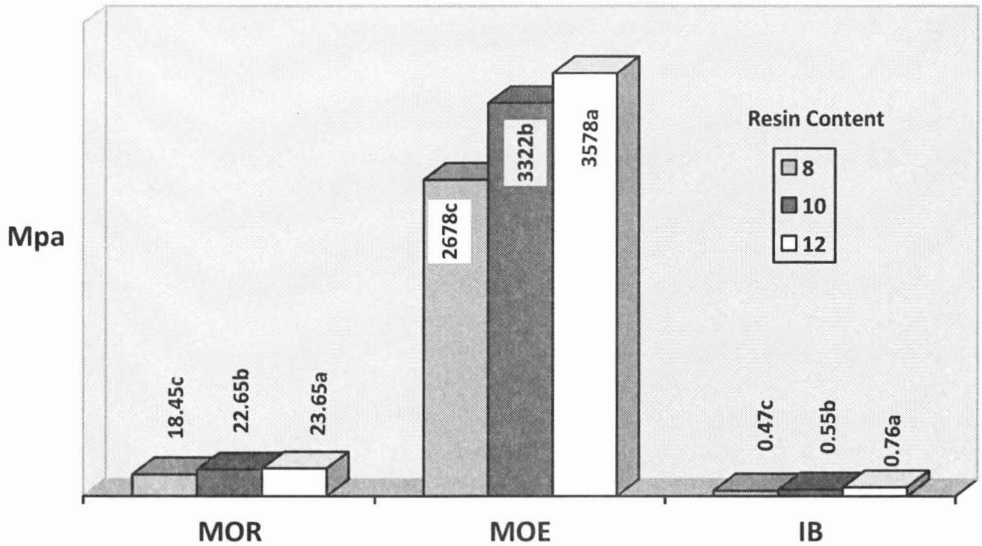

Fig. 4 Effects of Resin Content on Mechanical Properties

Dimensional Properties

Figure 5 shows the effects of resin contents on the dimensional properties. The higher resin content was shown to improve the dimensional properties of WA and TS. Increasing the RC from 8 to 12% improved the WA by about 9% and TS by 18%. Higher resin content provides more resin on the particle surface thus providing more bonding coverage on the particle surface. This creates better bonding thus reduces the particle surface to be in contact with water thus reducing the WA. This may be due to the chemical components in the resin that is capable to cross-link with the hydroxyl group of the particles hence, reducing the hygroscopic of the boards (Jani and Izran, 2009). Although the amount of resin increased, the particleboard can still absorb water or moisture (Jani, 2010).

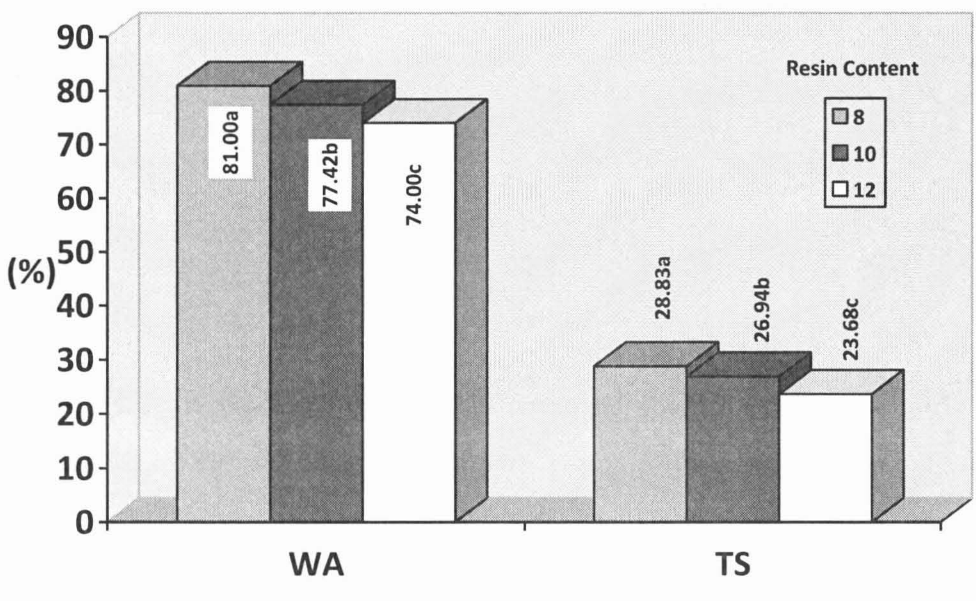

Fig 5. Effect of resin content on Dimensional Properties

4. Conclusions and Recommendations

From the study it was shown that the particle size and resin content were shown to significantly affect all the board properties. All the strength value of MOR, MOE and IB showed better performance as the size of particle increased. It was shown that the WA improves by about 23% when the particle size was changed from 2.0mm to 1.0mm while the TS also improve by about 45%. With higher resin content the mechanical properties increases significantly. The increase in MOR was about 28%, MOE by 34% and IB by 43%. Increasing the RC from 8 to 12% improved the WA by about 9% and TS by 18%. There is great potentials for particleboards made from *Leucaena leucocephala* to be further developed for the particleboard industry. *Leucaena* wood species should be used in particleboard and furniture industry making as it can save production cost. *Luecaena* wood is easy to get in Malaysia as a wild plant species, easily handled with any kind of tools and have a good mechanical properties based on the results from the research done. Particleboard from *leucaena* has surpassed the minimum requirements of BS EN 310:1993 standard on MOR, MOE and IB. However the dimensional stability properties have to be further improved before a final decision can be made.

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