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Research paper

Properties of Fibreboard Made from Cultivated *Leucaena leucocephala* and Rubberwood

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Abstract

Fibreboard made from cultivated *Leucaena leucocephala* (3 and 5 year-old) and rubberwood has been prepared. Three wood ratios of *Leucaena leucocephala*/Rubberwood (20:80, 50:50 and 80:20) and three levels of resin content (15%, 18% and 20%) were the selected variations in this study. The objective of the study is to determine the physical and mechanical properties of fibreboard made from *Leucaena leucocephala* and rubberwood. Results showed that the mechanical properties of modulus of rupture (MOR), modulus of elastic (MOE) and internal bond (IB) exhibit an increasing trend along with the increment of *Leucaena leucocephala* percentage (20% to 80%) in the fibreboard. Mechanical and physical properties of the board made from 3 year-old *Leucaena leucocephala* and rubberwood shows positively enhancement with the increasing of resin content. Whereas, the enhancement of the mechanical properties of fibreboard made from 5 year-old *Leucaena leucocephala* and rubberwood was observed as the percentage ratio of *Leucaena leucocephala* increased. Both of fibreboard made from 3 and 5 year-old *Leucaena leucocephala* passes the minimum mechanical properties requirement of JIS A 5905: 2003 Fibreboard.

Keywords: *Rubberwood, Leucaena leucocephala Age, Wood Ratio, Resin Content*

1. Introduction

Wood composite is a material made from a combination of wood and adhesive [1]. Fibreboard is one of the wood composite products [2]. Factors that influence the properties of fibreboard are wood species, forest management regimes, type of resin, and geometry of wood elements and density of the final products [3]. Fibreboard was first established by the end of 19th century and is heavily used as sheathing and interior panelling. The production of fibreboard has been increased due to the numerous advantages compared to solid wood and other composite products. The surface of fibreboard is suitable for furniture manufacturing [4]. Malaysia has been among the world's largest producers of rubberwood, but this trend had decline in late 1980 as planters claimed less turnover and moved to oil palm plantations [5].

This phenomenon also has significant impact to the timber industry as rubberwood is a common raw material for wood industry [6]. With the declining of rubberwood plantations, fiberboard industry has to search for a new fibre sources in order to sustain their operations in the future. Therefore, *Leucaena leucocephala* has been chosen as an alternative wood species to be mixed with rubberwood for the processing of new fibreboard. *Leucaena leucocephala* is one of fast growing species and is origin from Central America [7]. It has been introduced to various countries such as Africa [8], South America [9] and Southeast Asia [10]. Result of mechanical properties testing (bending, compression and toughness) shows that *Leucaena leucocephala* has excellent potentials [11]. The specific gravity (SG) of *Leucaena leucocephala* is in the range of 0.45 to 0.55 at the age of two years [12]. Besides, *Leucaena leucocephala* is among the best tropical hardwoods for pulp and paper product due to the suitably physical characteristics and good pulping qualities [13]. Therefore, the objective of this study is to investigate the use of *Leucaena leucocephala* and rubberword for the fibreboard production and the synergistic effect on the physical-mechanical properties of boards produced.

2. Methods

Leucaena leucocephala wood and rubberwood were used as raw material and urea melamine formaldehyde (UMF) resin was used as binder. The board dimension is 350 mm x 350 mm with a thickness of 3 mm. The experimental design of study is presented in Table 1 while Fig. 1 shows the flow process of fibreboard making.

Manufacturing process of fibreboard start from *Leucaena leucocephala* log is cut into small size. Before that, the logs must be debarked. Manual debarking was carried out by a machete. The logs were cut into size about 5 cm to 7 cm in width to fit the chipper using band saw. Chipping was done using chipper machine by cutting the billet into small piece of chip. The billets were fed manually to the chipper machine. Samples were collected as the chip dropped from the chipper out feed. After chipping process, the entire chips were left under a covered open area to dry.

Table 1: Properties of Fibreboard

Source of Variance (SOV)	Lev-el	Variance
Age of *Leucaena leucocephala* (Year)	2	3 and 5
Ratio of *Leucaena leucocephala* : Rubberwood	3	20:80, 50:50 and 80:20
Resin content (%)	3	15, 18 and 20

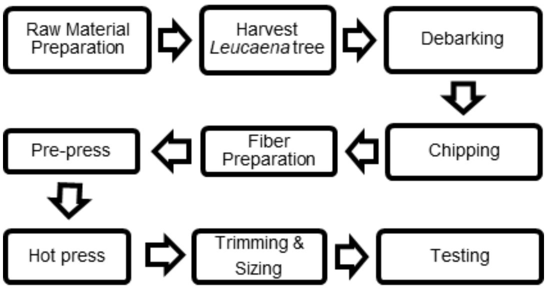

Fig. 1: Fibreboard making process

Wood chip were then been soak in water for 24 hours to soften the wood chip and give easily for fibre preparation. After all the preparation of defibration were ready, open the steam supply valve for chip cooking. Chip were been cook for 6 minutes. After the chip cooking was finish, fibre was been dryer using two stages of dryer fan. Firstly, drying at 97°C and follow with 142°C. Lastly, put the plastic bag at the bottom of rotary feeder for fibre collection. Fibres being dried in an oven at 75°C to 80°C until the particle reach the desired moisture content.

Then, blend the fibres with resin before place the resonated fibre into the mould to form a single layer mat. When the box was full with the resonated fibre, the fibre was manually compacted. This process also calls as a pre-press. After pre-press process, the mat was then transferred to hot press with temperature of 160 °C. After hot pressing, the boards were left to cool down before trimming and cut into required size.

Fibreboard samples were destructively tested for bending, tensile strength and thickness swelling properties. Sampling and cutting test specimens were carried out according to JIS A 5905 [14]. Factors affecting the manufacture of fibreboard such as age, ratio and resin content were analysed using ANOVA, DMRT and Independent Sample T-Test to determine their significant level of influences. The significance level chosen was 0.05.

3. Results and Discussions

Physical and Mechanical properties of fibreboard made from *Leucaena leucocephala* and rubberwood are shown in Table 2. For fibreboard made from rubberwood mixture with three year *Leucaena leucocephala*, with an increment of ratio of *Leucaena leucocephala* from 20:80 to 80:20, the mechanical properties (MOR, MOE and IB) exhibit an increasing trend but for physical properties (WS and TS) showed the decreasing trend. The treatment with 80:20% at 20% resin content shows the highest value for mechanical properties with MOR (28.44MPa) and IB (1.36MPa) but treatment made from 20:80 at 20% resin content show the highest value of MOE (2522 MPa). Better physical properties were recorded from treatment of 20:80 at 20% resin content (19.49%). Mostly fibreboards made from rubberwood mix with 3 year of *Leucaena leucocephala* meet the requirement of JIS A 5905 (2003) - Type 25 standard for mechanical properties except board from ratio of 50:50. Although for physical properties, all type of board not meets the minimum requirement of standard.

Table 2: Properties of Fibreboard

Age (Year)	*Leucaena leucocephala*: Rubberwood (%)	Resin (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
3	20:80	20	25.06	2522	1.18	19.49
3	50:50	15	18.85	2172	1.07	25.52
3	50:50	18	20.50	2287	1.12	23.16
3	50:50	20	23.30	2410	1.21	22.00
3	80:20	15	25.62	2117	1.13	23.39
3	80:20	18	27.12	2223	1.22	22.39
3	80:20	20	28.44	2450	1.36	22.07
5	20:80	20	24.71	2473	1.13	20.12
5	50:50	15	26.15	2395	0.77	26.20
5	50:50	18	28.13	2391	1.00	23.29
5	50:50	20	28.24	2530	1.01	22.43
5	80:20	15	27.44	2327	0.87	25.79
5	80:20	18	28.63	2397	0.89	23.86
5	80:20	20	28.83	2540	0.94	21.47
JIS A 5905 (2003)			≥ 25	≥2000	≥0.4	≤17

Notes: MOR=Modulus of Rupture, MOE=Modulus of Elasticity, IB=Internal Bond, TS=Thickness Swelling

Fibreboard made from mixture of rubberwood with five year-old of *Leucaena leucocephala* shows that expansion the ratio of *Leucaena leucocephala* from 20% to 80% was raise the mechanical properties of fibreboard except for IB. The highest value of MOR and MOE was from the treatment of 80:20 at 20% resin content with values of 28.83MPa and 2540MPa respectively. Highest value of IB (1.13MPa) was from the treatment of 20:80 with 20% resin content. Superior physical properties (20.12%) were also from treatment 20:80 at 20% resin content. Fibreboard made from mixture of rubberwood and five year-old of *Leucaena leucocephala* already passes the minimum requirement of JIS A 5905 (2003) - Type 25 standard for mechanical properties except for MOR from board treatment of 20% *Leucaena leucocephala*.

3.1. Effects of Age

The effects of age on mechanical properties are given in Table 3. The MOR and MOE showed higher value with increase in *Leucaena leucocephala* age.

Table 3: Effects of Age on Fibreboard Properties

Age (Year)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
3	23.42b	2284a	1.18a	22.77a
5	27.40a	2428a	0.93b	23.34a

Notes: MOR=Modulus of Rupture, MOE=Modulus of Elasticity, IB=Internal Bond, TS=Thickness Swelling, a,b = Significant at $p < 0.05$

T-test shows that the MOR is significantly different, while, MOE shows insignificant result. By increasing age of *Leucaena leucocephala* from three year-old to five year-old, the MOR increase with 16.99% and MOE value was increase with 6.30%. Correlation analysis (Table 4) indicated that the properties of MOR and MOE increased with age of *Leucaena leucocephala* (r = 0.436** and 0.23ns respectively). Observation on fibre morphology shows that *Leucaena leucocephala* of three year-old have a thin cell wall than five year-old *Leucaena leucocephala*. [15], thin cell wall can cause the collapse of board structure and contribute to mechanical damage that reduced MOR. The internal bond exhibits reserve trend to bending properties with significant effect (Table 3). The correlation analysis (Table 5) further revealed a negative correlation between *Leucaena leucocephala* age and internal bond strength (r = -0.505*) existed.

Leucaena leucocephala of 3 year-old have lower specific gravity than *Leucaena leucocephala* 5 year-old may indicated that the higher compression ratio obtained. Lower specific gravity of wood generally results in lower bulk density of the fibre furnish and high compression ratio at given panel density, higher compression ratio promotes more intimates between fibres [16]. This may indicate that the resin penetration was easier for the lower density than higher density, and thus had some effects on improving bond strength

The statistical analysis shows insignificant difference in the thickness swelling of the boards. The correlation analysis (Table 4) further revealed that the thickness swelling shows positive correlation with increased age of *Leucaena leucocephala*, however, the correlation was not significant (r = 0.118ns). Boards with 5 year-old *Leucaena leucocephala* show the ability to absorb more water than 3 year-old. A possible explanation for this behaviour relates to chemical properties of *Leucaena leucocephala* fibre, *Leucaena leucocephala* 3 year-old maybe have lower content of free hydroxyl group than *Leucaena leucocephala* 5 year-old due to the lower amount of lignin and holocellulose present in the fibre. Lower amount of lignin and cellulose cause the fibre more stable toward water [17].

3.2. Effects of Wood Ratio

The influences of ratio in the mechanical properties of fibreboard were shows in the Table 4. MOR and IB testing result show that treatment of 20:80 does not have different with treatment of 50:50 and 80:20, but treatment of 50:50 have significant difference with 80:20. MOE testing shows there no difference between all treatments. The correlation analysis (Table 5) further revealed that there is positive correlation but insignificant between ratio with MOR and IB (r = 0.276ns and r = 0.03ns respectively), while there is negative correlation between ratio and MOE (r = -0.153ns). IB increase as the rubberwood increase because the inherent stiffness of the fibre may positively contribute to the overall stiffness of the board. The board from ratio of 50:50 was lowest mechanical properties. This might be due to different pH of *Leucaena leucocephala* and rubberwood which has effect on buffering capacity.

The buffering capacity is the action of an agent that changes the field of acidity that eventually leads to less reactive fields, thus affecting resin flow [17].Table 4 also shows fibreboard made from the highest percentage of rubberwood was gaining the highest physical properties. Fibreboard made from the most percentage of rubberwood (20:80) also shows significant result than other two types of ratio. Fibreboard made from equivalent percentage of *Leucaena leucocephala* and rubberwood (50:50) show the worse physical properties (24.17%), but not significant differences with the result of fibreboard made from 80% of *Leucaena leucocephala*. The correlation analysis (Table 5) further revealed that the physical properties showed insignificant (r = 0.258ns) correlation with increased the ratio of *Leucaena leucocephala*. The result showed that treatment of fibreboard from 50% *Leucaena leucocephala* and 50% rubberwood showed higher thickness swelling as compared to others. Tthis might due to the poor distribution of UMF resin and fibre which cause formation of fibre lumps. Khalil et. al. [18] also shows same phenomena when do the research about hybrid fibreboard.

Table 4: Effects of Ratio on Fibreboard Properties

Ratio	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
20:80	24.85a	2492a	1.15a	19.97a
50:50	22.99a	2366a	1.03a	24.17b
80:20	27.43b	2320a	1.20b	23.17b

Notes: MOR=Modulus of Rupture, MOE=Modulus of Elasticity, IB=Internal Bond, TS=Thickness Swelling, a,b=Significant at $p < 0.05$

Table 5: Correlations Coefficients Analysis of the Fibreboard Properties

SOV	MOR	MOE	IB	TS
Age	0.436^{**}	0.230^{ns}	-0.505^{**}	0.118^{ns}
Ratio	0.276^{ns}	-0.153^{ns}	0.030^{ns}	0.258^{ns}
Resin	0.188^{ns}	0.320^{*}	0.343^{*}	-0.727^{**}

Notes: SOV- source of variance, ns – not significant, * significant at $p < 0.05$, MOR=Modulus of Rupture, MOE=Modulus of Elasticity, B=Internal Bond, TS=Thickness Swelling

3.3. Effects of Resin Content

The effects of resin content on properties of fibreboard are given in Table 6. The mechanical properties (MOR, MOE and IB) showed increasing trend with increase in resin content. The statistical analysis shows insignificant difference in MOR (r = 0.188ns). MOE and IB show significantly positive with increase of resin contents (r = 0.320* and r = 0.343* respectively. Higher resin content causing the increasing fibre bonding area hence the number of fibre-fibre contacts points might develop covalent bonds between resin and wood furnish [19]. Wan Mohd Nazri et. al. [20] also recorded the same trend for particleboard.

Table 6: Effects of Resin Contents on Fiberboard Properties

Resin (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	TS (%)
15	23.50a	2171a	0.97a	25.40a
18	25.22a	2290ab	1.21b	23.29b
20	26.18a	2472b	1.18b	21.03c

Notes: MOR=Modulus of Rupture, MOE=Modulus of Elasticity, IB= Internal Bond, TS=Thickness Swelling, a,b,c=Significant at $p < 0.05$

Meanwhile, Table 6 also shows resin significant difference with increasing the resin content on physical properties (TS). The correlation analysis (Table 5) further revealed that a negative correlation between resin content and thickness swelling (r = -0.727**). Basically the board experiences dimensionally instability when immersed in water and with the increase in resin content improves the board stability against water exposure. Borchmann et. al. [21] reported that normally, board decreases in thickness-swell with increase of resin content.

4. Conclusion

From the study, it is found that bending properties of fibreboard is in relation to the age of *Leucaena leucocephala*. The increase in the resin content has a significant influence to the enhancement physical properties of fibreboard. However, the studied wood ratio of *Leucaena leucocephala* and rubberwood did not showed significant improvement on the properties of fibreboard. This study showed that the use of juvenile wood of *Leucaena leucocephala* can fulfil the mechanical properties requirement of Japanese Standards Association (JSA) (JIS A 5905:2003) for fibreboard with a minimum percentage of 15% resin content. This study also has demonstrated that the juvenile wood of *Leucaena leucocephala* has a potential to be fulfilled wood chips supply with short rotation of harvesting.

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