PROPERTIES OF SMALL DIAMETER ACACIA HYBRID LOGS FOR BIOCOMPOSITES PRODUCTION

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ABSTRACT. *This study was conducted to determine the feasibility of using juvenile Acacia hybrid in manufacturing biocomposite boards. The mechanical, physical and fungal resistance properties of the boards produced were determined. The four year-old Acacia hybrid was obtained from several clones. The particleboards and medium density fibreboards (MDF) were manufactured at a target density of 750 kg/m^3 and resin levels of 6, 8 and 10%. The results indicated that all particleboards and MDF complied with the Particleboard-specifications (BS EN 312:2010) and the Fibreboard specifications: Requirement for dry process boards (MDF) (BS EN 622-5: 2009, respectively. The fungal resistance properties of particleboard and MDF showed better in resistance compared to particleboard. The mechanical and physical properties of the particleboard were compared with the A. mangium particleboards.*

KEYWORDS. Acacia hybrid, particleboard, medium density fibreboard, mechanical and physical properties, fungal resistance

INTRODUCTION

The increasing difficulty in obtaining solid wood materials, the utilization of wood-based panel (WBP) products as substitutes are enhanced, as these products represent a more efficient way of utilizing wood and other resources. To date, the Malaysian wood-based industries comprise of approximately 1019 sawmills, 183 plywood/veneer mills, and 373 moulding factories, 32 particleboard mills, 15 MDF mills and several hundred other factories. In an effort to increase awareness of the importance of the biocomposite products, the raw materials have been researched widely.

Acacia mangium Willd. and *Acacia auriculiformis* are both fast growing timber species, which have the potential for timber and pulp production. The hybrid between these two species may occur either naturally (Skelton, 1987), or can also be produced through biclonal orchards (Wickneswari, 1989) and controlled crosses (Sedgley *et al*., 1992). Acacia hybrid inherits the better stem straightness of *A. mangium* and the self-pruning ability and better stem roundness of *A. auriculiformis*. It possesses intermediate physical and mechanical properties between both parents' species. The hybrid's height and diameter increments are significantly better and it also appears to be more resistant to heart rot (Lemmens *et al*, 1995). Henceforth, these hybrids, upon appropriate exploitation, could become a potential alternative raw material for wood based industry. The present study was to determine the feasibility of using small diameter *Acacia* hybrid logs for particleboard and MDF manufacture.

MATERIALS AND METHODS

Acquiring of raw materials

Four-year-old *Acacia* hybrid was obtained from Negeri Sembilan, Malaysia. Four clones of *Acacia* hybrid namely M2, M4, M5 and C14 were selected for the study. For each clone, three trees to be removed for first thinning process were designated and felled. A total of three trees of 4-year-old *A. mangium* were also taken for comparison purposes. Approximately 25 mm thick disc samples were taken at the bottom and top most of the tree (before first branch). The logs were cut into billets of 2 m length and converted into wood particles and fibres for particleboard and MDF manufacture.

Specific gravity and strength property tests (green condition)

The specific gravity and strength property tests of the *Acacia* hybrid wood were conducted according to the British Standard procedure (BS 373:1957).

Particleboard manufacture

The billets were debarked and split-cut into planks before disintegrated by a Pallmann drum-chipper and by a knife ring flaker; turning the wood material into wood chips and flakes respectively. The particles were dried and screened by using a vibrating screen to remove the fines from coarse particles. The selected wood particles were dried in an oven at 70 °C to moisture content 5% and below prior to particleboard manufacture. The single-layered particleboard were produced at a target density of 750 kg/m^3 and three levels of resin urea formaldehyde (UF) were used at 6, 8 and 10% level of admixtures. A measured quantity of particles was put in a batch mixer and sprayed with a resin mix of urea formaldehyde, hardener and wax emulsion. The resinated flakes were laid in a wooden square mould and prepressed at 350 kg/cm^2. The consolidated particle mat was finally pressed to 12 mm metal stops between two stainless steel caul plates in an electrically heated hydraulic press maintained at 160 °C for six minutes until the resin completely cured.

MDF manufacture

Acacia hybrid billets were sawn separately into planks and converted into wood chips by using Taihei chipper. For the preparation of MDF fibres, acceptable chips of size of 2.0 x 2.5 x 0.2 cm were used. The wood chips were steamed at pressure of 70 kg/cm^2 for 5 min and subsequently refined at disc clearance of 0.381 mm in the Sprout-Bauer Pressurised Refiner. The dried fibres were screened and only fibres retained on the screen with slot size between 0.5 and 1.0 mm were collected for MDF manufacture. These fibres were dried in the oven to achieve low moisture content of 5% and below. The UF resin was used for this study. One series of single-layered MDF comprised of four panels were set at a target density of 750 kg/m^3 and resin levels of 6, 8 and 10% were used. The dried fibres were sprayed and blended with resin and wax before being consolidated into a wooden mould of dimensions 34 x 34 x 1.2 cm. The fibre mat was pre-pressed at 350 kg/cm^2 for about 1 minute before the wooden mould was taken out. The consolidated mat was pressed to the desired thickness in a hot press maintained at 190 °C for about 4.5 min.

Physical and mechanical tests of particleboard and MDF

The physical appearance of the boards was evaluated prior being cut into test pieces and conditioned at temperature of 20±2°C and 65± 5% RH. The test pieces were tested according to the European Standards specification for testing particleboard and MDF. The tests include the physical test such as thickness swelling (TS) (BS EN 317:1993) as well as mechanical tests, which include modulus of rupture (MOR), modulus of elasticity (MOE) (BS EN 310:1993) and internal bond (IB) (BS EN 319:1993).

Fungus test of particleboard and MDF

The fungus tests on the composite products were conducted according to the BS EN 350-1: 1994 standard. The test samples were cut into smaller dimensions of 25 (width) x 50 (length) x 15 (thickness) mm. Forty replicates from each sample group were used. The sterilised and conditioned samples were exposed to local wood decay fungi where fungus cultures were grown in sterilized glass culture vessels. The incubation of fungi in culture vessels was carried out for twelve weeks in the culture room of controlled environment of 25 °C and 85% relative humidity. After the exposure period, the control and test pieces were removed and examined. The pieces were weighed and reweighed after drying in the oven at 100 °C for 18 hours. The individual test sample was weighed to the nearest 0.01g (T1) just before sterilization. After incubation of 12 weeks, samples were brought to moisture equilibrium in the conditioning room and weighed (T2). The weight loss was calculated from the conditioned weight of sample before and after testing as follows:

Weight loss (%) = $\left(\frac{T1-T2}{T2}\right) \times 100$

The loss in dry weight (difference in initial and final dry weight) is a measure of the decay that has occurred expressed in percentage.

RESULTS AND DISCUSSION

Table 1 illustrates the comparative strength properties of 4-year-old *Acacia* hybrid and 4-year-old *A.mangium* timbers (green condition). While M4 showed the highest shear strength, the highest compression value was recorded by C14. This study indicated that the overall strength properties of *Acacia* hybrid were slightly higher than those of *A. mangium* especially for modulus of elasticity and compression. The modulus of rupture and shear parallel to grain were almost similar between both species. These results supported the earlier findings reported by Mohd Shukari *et al*. (2002).

Table 1: Specific gravity and strength properties of *A. mangium* and A. hybrid

	Clone	Specific gravity	Modulus of rupture (Nmm^{-2})	Modulus of elasticity (Nmm^{-2})	Compression parallel to grain (Nmm^{-2})	Shear parallel to grain (Nmm^{-2})
Acacia hybrid	M5	0.44	71.85	8280	35.10	9.88
	M2	0.49	76.76	8587	36.19	10.79
	M4	0.48	77.00	8381	35.27	10.97
	C14	0.46	70.37	8526	36.51	10.18
A. mangium		0.48	73.84	7784	32.34	10.75
Average		0.50	74.00	8312	35.10	10.50
Standard deviation		0.02	2.93	3.19	1.64	0.46

The physical and mechanical properties of particleboard manufactured from 4-year-old *Acacia* hybrid and *A. mangium* are presented in Table 2. Generally, the modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB) of the boards increased as the resin content increased. This is due to the fact that adequate resin to form better bonding with wood particles under high degree of compaction ratio. Hence, better internal bond between the resin and wood particle was formed within the board. However, in the case of *Acacia* hybrid particleboard, an optimum MOR, MOE and IB were achieved when the board produced up to 8% resin level. Further increment of the resin content to 10% did not enhance the physical and mechanical properties of the board. In fact, the strength properties of the board started to decline beyond 8% resin content.

The thickness swelling decreased as the resin content level was increased. Boards produced at high resin content resulted in improved inter-particle bonding with better water resistance (Razali *et al*., 1993). In the case of particleboard manufactured from *A. mangium,* the result indicated that all board complied to the standard specifications, In general, the average MOR and MOE values of *A. mangium* particleboard were slightly higher than those of *Acacia* hybrid at similar density and resin content. However, the statistical analysis of t-test indicated there was no significant effect on the MOR, MOE and IB values of the boards between the two species at 95% confidence level. Hence, the mechanical strength of particleboard produced from *A. mangium* was almost similar compared to *Acacia* hybrid. The only significant difference however, probably on the thickness swelling values between the two species at 95% confidence level. The result indicated that the thickness swelling of *A. mangium* lower than *Acacia* hybrid. Thus, particleboard produced from *A. mangium* was more dimensionally stable compared to those of *Acacia* hybrid. Nevertheless, in general all the particleboard produced from both species exceeded the minimum requirements for the mechanical strength properties of boards for interior fitments (including furniture) for use in dry conditions (Type P2) as stipulated in BS EN 312: 2010.

Table 2: The physical and mechanical properties of particleboard produced from 4-year-old *Acacia* hybrid and *A. mangium* at a target density and various resin levels.

Sample	Target density (kg/m^3)	Resin level (%)	MOE (MPa)	MOR (MPa)	Internal Bond (MPa)	Thickness Swelling (%)
Acacia hybrid	750	6	2474 (315)	16.13 (1.83)	0.71 (0.12)	21.38 (1.57)
		8	2707 (337)	19.50 (3.60)	0.95 (0.09)	16.53 (2.58)
		10	2238 (229)	16.29 (1.75)	0.93 (0.13)	12.97 (1.90)
Acacia mangium	750	6	2993 (251)	26.46 (2.10)	0.60 (0.26)	11.86 (1.46)
		8	2850 (193)	24.44 (2.43)	0.93 (0.34)	11.38 (2.12)
		10	3371 (231)	27.40 (2.56)	1.49 (0.33)	10.59 (1.93)
BS EN 312: 2010			1800	11	0.40	na

The result of the board testing on the medium density fibreboard (MDF) produced from *Acacia* hybrid fibres processed by laboratory thermo-mechanical pulping (TMP) is given in Table 3. The table indicated that most of the board strength properties complied with the standard specification for MDF (BS EN 622-5: 2009) except for MDF produced using 6% resin level. The internal bond values for all boards were slightly lower than the standard specification. Obviously, the internal bond of the boards could be improved by using appropriate type of resin and board density.

Table 3: The physical and mechanical properties of MDF produced from 4-year old A. hybrid

Sample		MOE (MPa)	MOR (MPa)	Internal Bond (MPa)	Thickness Swelling (%)
Density (kg/m^3)	Resin level (%)				
750	6	2411 (195)	24.51 (1.84)	0.45 (0.09)	7.73 (0.36)
	8	2595 (328)	27.06 (3.59)	0.58 (0.08)	6.17 (0.58)
	10	2689 (232)	29.56 (1.98)	0.59 (0.15)	6.16 (0.40)
BS EN 622-5: 2009		2500	22	0.60	15

Table 4 shows the results on the fungus tests carried out on the *Acacia* hybrid particleboard and MDF. The test pieces after 12 weeks exposure were freed from adhered mycelium. Both the particleboard and MDF were examined for alteration in appearance and observed to have fungal decay, Further test done by indenting with finger nail on all the samples was done. Particleboard samples were easily indented compared to MDF samples. The moisture content calculated was found to be favorable to fungal growth. The weight loss figure proved that the test samples were susceptible to fungal decay.

The laboratory test indicated that all the particleboard and MDF samples were affected by fungus; the difference is only the degree of fungal attack based on the weight loss. It seems that as the level of resin increased, the resistance towards fungal attacks also increased. Overall the results showed that MDF was found to be better in resisting fungal attack compared to particleboard. The MDF produced using 10% resin level showed better resistance compared to the rest of the boards. Particleboard with 6% resin content had the highest weight loss (14.73%) indicating the test samples were very susceptible to decay.

Table 4: Weight loss measurements after 12 weeks exposure caused by decay of *Acacia* hybrid particleboard and MDF

Samples	Target Density (kg/m^3)	Resin level (%)	Average weight loss (%)	Moisture content (%)
Particleboard	750	6	14.73	8.27
		8	12.56	8.43
		10	11.85	8.40
MDF	750	6	11.12	8.04
		8	8.80	7.28
		10	7.93	7.58

In this study, UF resin was used as the adhesive for the production of particleboard and MDF. It is well known that the resin is widely applied in the wood based industry due to its low price and good strength properties of glue lines under dry conditions despite its low water resistance. Further studies have been carried out to utilize UF resin modified with melamine to enhance its water resistance property. Data will be published in the next publication.

Keys

BS 373:1957	Procedures and Method for Testing Small Clear Specimen of Timber
BS EN 312: 2010	Particleboards - Specifications
BS EN 622-5: 2009	Fibreboards specifications –Requirements for dry process boards (MDF)
BS EN 310:1993	Wood-based panels – Determination of modulus of elasticity in bending and of bending strength
BS EN 317: 1993	Particleboards and fibreboards – Determination of swelling in thickness after immersion in water
BS EN 319: 1993	Particleboards and fibreboards – Determination of tensile strength perpendicular to the plane of the board
BS EN 350-1: 1994	Durability of wood and wood based products

- Number in parenthesis ( ) is the standard deviation value
- MOR : Modulus of Rupture
- MOE : Modulus of Elasticity
- IB : Internal Bond
- na : data not available

CONCLUSIONS

The results of the preliminary trials on the manufacture of single-layered particleboard from *Acacia* hybrid are encouraging. This study revealed that particleboard produced at 750 kg/m^3 could meet the minimum requirement for the mechanical and physical properties of the European Standards (BS EN 312: 2010). Slight increment of resin content to 8% had improved the strength properties of the particleboard using juvenile tree from both species of Acacia hybrid and *A. mangium*. Thus both species are very promising alternative raw material for particleboard manufacture eventhough at 4-year-old grown. The utilisation of Acacia hybrid for MDF manufacture need further investigation as the boards slightly satisfied to the standard specification as stipulated in BS EN 622-5 (2009) despite having average fibre length >1 mm. The fungal resistance property of MDF was better compared to particleboard. It was also found that the increased of resin content improved the resistance of the boards towards fungal attack.

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REFERENCES

Lemmens, R. H. M. J., Soerianegara, I., & Wong, W. C. 1995. Plant Resources of South-East Asia No. 5(2): Timber Trees: Minor Commercial Timbers. Backhuys Publishers, Leiden: 655.

Mohd Shukari, M., Ab. Rasip, A.G., & Mohd Lokmal, N. 2002. Comparative Strength Properties of Six-year-old Acacia Mangium and Four-year-old Acacia Hybrid. *Journal of Tropical Forest Products*, **8(1)**: 115-117.

Razali, A. K., Abd Khalil, K. P. S., & Paridah, M. T. 1993. *Properties of particleboard manufactured from less-used species: Mallotus Macrostachys (Balek Angin)*. Conference on Forestry and Forest Products Research 1993: 193-199.

Sedgley M., Harbard, J., Smith, R. M., Wickneswari, R., & Griffin, A. R. 1992. Reproductive Biology and Interspecific Hybridisation of Acacia Mangium Willd and Acacia Auriculiformis A. Cunn. *Ex Benth Australian Journal of Botany*, **40**: 37-48.

Skelton, D. J. 1987. Distribution and Ecology of Papua New Guinea Acacias. ACIAR Proceedings, no. **16**: 38-44.

Wickneswari, R. 1989. Use of Isozyme Analysis in a Proposed Acacia Mangium x Acacia Auriculiformis Hybrid Seed Production Orchard. *Journal of Tropical Forest Science*, **2**:157-164.

Yamada, N., Khoo, K. C., & Mohd Nor, M. Y. 1992. Sulphate Pulping Characteristics of Acacia Hybrid, Acacia Mangium and Acacia Auriculiformis from Sabah. *Journal of Tropical Forest Science*, **4(3)**: 206-214.