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Properties of Particleboard Manufactured from Commonly Utilized Malaysian Bamboo (*Gigantochloa scortechinii*)

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ABSTRACT

Buluh semantan (Gigantochloa scortechinii), *one of the most widespread bamboo species in Peninsular Malaysia was investigated for its suitability as a raw material for particleboard production. A total of 120 bamboo culms from three different age group (1-,2 and 3-y-old) were harvested from managed bamboo clumps in FRIM. The bamboo particles produced from the flaking process were used in the making of single- and three-layer urea formaldehyde particleboards. The particleboard produced were then tested for their mechanical properties and dimensional stability according to British Standard Methods. The result showed that age, resin content and board density significantly affected the single-layer particleboard properties, while for three-layer particleboard the effect of age, core particle size and wax addition on the board properties were also found to be significant. Irrespective of bamboo age, particles of* Gigantochloa scortechinii *are suitable for the manufacture of urea formaldehyde particleboards.*

ABSTRAK

Buluh semantan (Gigantochloa scortechinii) *salah satu buluh yang terdapat secara meluas di Semenanjung Malaysia telah diselidiki akan kebolehgunaannya sebagai bahan mentah untuk penghasilan papan serpai. Sejumlah 120 batang buluh yang terhasil daripada proses pengempingan kemudian digunakan untuk pembuatan papan serpai. Papan serpai yang dihasilkan diuji sifat kekuatan dan kestabilan mengikut piawaian tatacara British. Keputusan ujian menunjukkan umur, kandungan perekat dan ketumpatan papan serpai mempengaruhi dengan ketara sifat papan serpai satu lapis manakala bagi papan serpai tiga lapis, kesan umur, saiz partikel kor dan penambahan lilin ke atas sifat papan serpai juga dipengaruhi secara ketara. Tidak kira peringkat umur buluh, partikel dari buluh semantan sesuai sebagai bahan mentah untuk penghasilan papan serpai urea formaldehid.*

INTRODUCTION

Malaysian bamboo is classified as a minor forest product and is traditionally considered as a weed interfering with the normal regeneration, development and maintenance of the main timber species (Medway 1973; Ng 1980; Salleh and Wong 1987). In the past, attempts were made to control their growth but now, due to the rapid extension of bamboo-based industries, they have become the second most important non-timber produce in Malaysia after rattan (Aminuddin Abd. Latif 1991). They played an important role in the lives of the local people, particularly those in the rural areas and are usually being used for making basket-ware, cords and toys, furniture and houses. The bamboo industry has developed into a multi-million dollar industry with their products enjoying very high demand domestically as well as internationally. However, in producing the various products, much bamboo wastes is generated, excluding those that are discarded during harvesting and transporting; and if no action is taken the bamboo would be heading towards its downfall. Therefore, the optimum use of this resource lies in the production of reconstituted products such as particleboard. With the abundant amount of bamboo resources that are currently being underutilized as well as the need to improve panel product properties and developement, particleboards offer tremendous potential and opportunity towards its fullest utilization. This paper highlights the properties of single - and three- layered urea formaldehyde particleboards produced from *G. scortechinii.* The effect of age, board density, core particle size and resin content on the board properties are discussed.

MATERIALS AND METHODS

Forty culms each from 1- 2- and 3-y-old *G. Scortechinii* were obtained from the bamboo plantation of Forest Research Institute of Malaysia (FRIM), Kepong, Selangor. All branches present were removed and the clean culms were subjected to longitudinal splitting. Each age group of bamboo splits were then fed into a Pallman drum chipper. The chips produced were then flaked in a Pallman knife-ring flaker and the particles produced were screened into 0.5, 0.5-1.0,1.0-2.0 and >2.0 mm sizes before being oven-dried at 60° C to a moisture content of about 5%.

Single-layer particleboard of 12 mm thickness of size 340× 340 mm was made at three density level (561, 641, and 721 kg/m^3 and three resin contents of 8, 10 and 12%. A measured quantity of flakes was sprayed with a resin mix containing urea-formaldehyde (solid content of 65%), hardener and water within a glue blender. The particles used consisted of 60% of 1.0-2.0 mm, 30% of 0.5-1.0 mm and 10% of > 2.0 mm particle size. The sprayed particles were then laid in a wooden mould and prepressed at 3.5 MPa for about 30 seconds. The consolidated mat was finally pressed for 6 minutes at 160°C in a Taihei hot-press at 120 kg/cm^2.

Three-layer particleboard of 12 mm thickness of size 340 × 340 mm at a density of 721 kg/m3 were made from two different particle size (1.0 and 2.0 mm) for the core materials and 0.5 mm particle size for the surface materials. Resin content of 12% was used for the surface materials and 10% for the core. An amount of 1% wax content (65% solid content) was added to the mixture. Three boards were produced for both the single- and three-layer particleboards for each combination of density level and resin content used.

The strength and dimensional properties, viz. thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB) were tested according to the British Standard: BS EN (1993). Screw-withdrawal edge (SWE) and screw-withdrawal surface (SWS) were tested according to the BS 5669 (1989).

RESULTS AND DISCUSSION

Single-layer Particleboard

The strength and dimensional properties of single-layer particleboard are shown in Table 1. All boards produced with a minimum resin content of 8% at a board density of 641 kg/m^3 were able to meet the minimum strength requirement of BS 5669. Boards made from one year-old bamboo particles with a 12% resin and a density of721kg/m^3 were observed to possess the highest values of MOR (28.52 MPa) and MOE (3613 MPa), two-year-old bamboo had the highest IB(1.11 MPa) while three-year-old having the highest SWS (957 N) and SWE (676 N) values. In general, bamboo particleboard produced from one year-old and older; and with the combination of more than 8% resin content (board density > 641 kg/m^3) surpassed the minimum strength requirement of the BS. However, only boards produced from one year-old bamboo at a density of 561 kg/m^3 and a resin content of 12% was able to meet the TS requirement of 8.0%. All other boards failed to do so.

The summary of analysis of variance (ANOVA) on the effect of age, resin content and board density on the particleboard properties are shown in Table 2. All the main variables of age, density and resin have significant effects on all the board properties.

Age showed a significant effect on all the board properties (Table 3). Jamaludin *et al.* (1997) also found a similar pattern in their study of particleboard from *Bambusa vulgaris.* Correlation analysis (Table 4) further revealed that the WA and MOR decreased insignificantly, while MOE and TS increased insignificantly with age. However, the strength properties of IB, SWS and SWE were observed to increase significantly with age. According to Moslemi (1974) the adhesive spread per unit area of the particles could be the controlling factor on the effect of age on the strength and dimensional properties of particleboard.

Increments of resin content showed significant effect on all the board properties (Table 3). The correlation analysis also indicates that MOR, MOE, IB, SWS, and SWE increased significantly while WA and TS decreased with an increase in resin content. With more resin available at higher resin content, more bonding sites are made available, thus improving the strength properties and increased their dimensional stability, significantly. Similar observations on the strength properties-resin contents relationship were also reported by other work on wood (Talbott & Maloney 1957, Moslemi 1974, Kelly 1976), bamboo (Chen *et al.* 1991) and oil palm fruit bunches (Shaikh *et al.* 1997).

The strength and dimensional properties of particleboard are directly influenced by board density (Moslemi 1974). This is particularly true since higher density is usually associated with higher strength properties. Table 3 shows that all the MOR, MOE, IB, SWS and SWE values increase with a linear increase in board density.

TABLE 1
Physical and strength properties of single-layer UF particleboards

Age (yrs)	Resin (%)	Board Density (kg/m^3)	MOR (MPa)	MOE (MPa)	IB (MPa)	SWS (N)	SWE (N)	WA (%)	TS (%)
1	8	561	9.18	1598	0.23	182	137	38.48	1077
	10		9.91	1675	0.32	2.15	163	36.41	8.50
	12		11.32	1734	0.44	249	169	34.22	7.31
	8	641	15.83	2480	0.39	539	417	63.57	24.46
	10		20.21	2759	0.59	458	461	51.89	13.84
	12		18.03	2649	0.67	598	526	49.39	11.57
	8	721	21.33	3059	0.50	535	458	52.31	23.88
	10		24.40	3330	0.68	684	545	42.91	15.08
	12		28.52	3613	0.69	719	622	36.33	12.42
2	8	561	9.77	1759	0.39	307	223	49.07	16.39
	10		11.27	1896	0.51	358	275	41.27	11.96
	12		13.37	2083	0.61	405	325	36.00	7.60
	8	641	17.87	2891	0.66	542	428	59.89	22.18
	10		20.98	3071	0.78	583	497	53.80	16.21
	12		21.04	2989	0.94	711	549	45.94	13.40
	8	721	17.37	2542	0.77	656	484	48.38	20.45
	10		23.94	3214	0.99	788	616	40.20	15.17
	12		22.04	3132	1.11	747	655	36.85	11.54
3	8	561	11.56	1985	0.48	489	358	52.68	17.16
	10		12.52	1959	0.45	476	376	45.75	11.07
	12		13.68	2168	0.67	531	381	34.93	9.17
	8	641	17.05	2538	0.58	629	459	46.43	17.81
	10		17.95	2684	0.72	558	497	39.52	11.60
	12		19.12	2913	0.86	663	471	34.09	10.55
	8	721	18.28	2696	0.71	724	576	42.40	20.94
	10		20.21	2934	0.88	803	574	37.16	12.69
	12		24.16	3544	1.04	957	676	34.05	11.80
BS 5669			min. 13.8	min. 2000	min. 0.34	min. 470	min. 360	n.a	max. 8.00

Values are average of six determinations

TABLE 2
Summary of the analysis of variance on the board properties

SOV	Df	MOR	MOE	IB	SWS	SWE	WA	TS
Age (a)	2	8.95*	3.2E6**	0.87**	3.6E5**	1.2E5**	216.9**	22.58**
Density (D)	2	1668.3**	2.2E7**	1.37**	1.6E6**	1.4E6**	1972**	514.7**
Resin (R)	2	197.60**	1.6E6**	0.66**	1.3E5**	1.0E5**	1517**	888.6**
A x D	4	58.30**	6.5E4**	0.00ns	3.3E4**	2.9E4**	443**	43.15**
A x R	4	6.81*	1.0E5**	0.32**	5122ns	5014ns	13.48ns	2.65ns
D x R	4	10.64**	1.0E5**	0.00ns	3.6E4**	1.1E4**	16.23ns	53.76**
A X D x R	8	0.77ns	0.00ns	0.01ns	5124ns	1806ns	46.78ns	15.24**

Note: ns- not significant, *- significant at P < 0.05 and **- highly significant at P < 0.01

TABLE 3
Summaries of the Duncan multiple range t-tests on the effect of age, density and resin on the board properties

Age (yrs)	MOR (MPa)	MOE (MPa)	IB (MPa)	SWS (N)	SWE (N)	WA (%)	TS (%)
1	17.50b	2524b	0.51c	473c	389b	44.78a	13.96b
2	18.31a	2708a	0.78a	592b	472a	46.16a	15.36a
3	17.17b	2602b	0.71b	648a	485a	40.78b	13.65b
Resin (%)	**MOR**	**MOE**	**IB**	**SWS**	**SWE**	**WA**	**TS**
8	15.10c	2354c	0.47c	484c	374c	50.73a	19.35a
10	18.20b	2620b	0.61b	520b	426b	43.47b	12.75b
12	19.27a	2736a	0.72a	593a	470a	38.84c	10.60c
Density (kg/m^3)	**MOR**	**MOE**	**IB**	**SWS**	**SWE**	**WA**	**TS**
561	10.88c	1782c	0.40c	303c	220c	38.92c	10.08c
641	18042b	2717b	0.61b	565b	474b	51.62a	16.09a
721	23.93a	3215a	0.76a	699a	564a	41.53b	16.10a

Means having the same letter down the column are not significantly different (P<0.05)

The increase in strength properties could be probably associated with higher compaction ratio at higher density. Other researchers (Chen *et al.* 1991; Chew *et al.* 1992; Shaikh *et al.* 1997)also reported similar findings. Table 4 also shows that board density has a high significant correlation with the strength properties. However, the increase in board density also leads to higher TS since a higher compressive set exists in higher density boards resulting in higher swelling as stresses are relieved (Gatchell *et al.* 1966 and Roffael and Rauch 1972).

Three Layer Particleboard

The properties of the three-layer particleboard are given in Table 5. Highest MOR (29.30 MPa)

TABLE 4
Correlation coefficients of age, density, and resin on the properties

SOV	MOR	MOE	IB	SWS	SWE	WA	TS
AGE	-0.01 ns	0.07 ns	0.43**	0.37**	0.25**	-0.13 ns	0.003 ns
DENSITY	0.87**	0.89**	0.64**	0.79**	0.83**	0.11 ns	0.46**
RESIN	0.29**	0.23**	0.45**	0.22**	0.23**	-0.48**	-0.67**

Note; SOV- source of variance, ns- not significant, * significant at P < 0.05,
** significant at P < 0.01

are exhibited by particleboard produced from 2-y-old bamboo with core particle size of 1.0 mm without wax while highest MOE (3977 Mpa) are shown by 3-y-old (1.0 mm core) with 1% wax addition. Two-year-old bamboo particles (1.0 mm core)and without wax produced particleboards with the highest IB (0.94 MPa), SWS (1013 N) and SWE (796 N) value. However they also exhibited the highest WA (70.17%). The highest TS (24.76%) value are shown by particleboards produced from 3-y-old bamboo (2.0 mm core) without wax addition. In general all boards with or without wax addition with core particles of 1.0 and 2.0 mm meet the minimum strength requirements of the BS 5669 but all boards regardless of age and wax addition failed to meet the 8% TS value stipulated in the BS 5669.

Table 6 shows the analysis of variance (ANOVA) of the board properties. All the main variables showed a significant effect on the board properties (except for core particle size on SWE and Wax on MOR). The effect of age on the dimensional and strength properties are shown in Table 7. Age had a significant effect on all the board properties. Three-year-old bamboo produces particleboard with worst WA and TS values but comparable strength properties with the other age groups. Table 8 further reveals the correlation coefficients of age on the board properties.

Core particle size (Psize) also showed a significant influence on the board properties.

TABLE 5
Strength and dimensional properties of three-layer formaldehyde-particleboard

Age (yrs)	Psize (mm)	Wax (%)	MOR (MPa)	MOE (MPa)	IB (MPa)	SWS (N)	SWE (N)	WA (%)	TS (%)
1	1	1	29.07	3717	0.75	836	566	29.15	10.15
2	1	1	29.33	3533	0.58	755	557	36.95	12.78
3	1	1	28.34	3977	0.49	772	543	35.16	14.13
1	1	0	28.90	3539	0.87	863	685	63.86	19.32
2	1	0	29.30	3475	0.94	1013	769	70.17	20.69
3	1	0	28.42	3910	0.89	831	724	64.44	23.73
1	2	1	24.00	3608	0.48	827	531	30.33	9.45
2	2	1	27.32	3626	0.70	800	615	26.88	10.05
3	2	1	27.21	3756	0.57	813	527	29.97	11.34
1	2	0	25.51	3462	0.63	970	701	64.01	21.30
2	2	0	26.77	3712	0.84	1005	760	59.84	16.54
3	2	0	27.48	3645	0.87	939	732	67.22	24.76
BS	5669		>13.8	>2000	>0.34	>470	>360	na	<8.00

Values are average of six determinations.
Psize - Core particle size

TABLE 6
Summaries of the ANOVA on the board properties

SOV	Df	MOR	MOE	IB	SWS	SWE	WA	TS
Age (A)	2	9.10*	3.8E5**	0.04*	1.5R4	1.6E*	29.11ns	79.70**
Psize (P)	1	93.4**	4.9Ens	0.07**	3.3E4*	190.8ns	192.2**	22.54**
Wax (W)	1	0.62ns	9.4E4	0.91**	2.8E5**	4.4E5**	1.7E4**	1423**
A x P	2	13.03*	2.1E5**	0.13**	3917ns	1668ns	168.6**	21.17**
A x W	2	1.03ns	3.9E4ns	0.05**	3.9E4**	3117ns	1.75ns	25.46**
P x W	1	0.63ns	7260ns	0.03ns	6998ns	22.82ns	18.63ns	10.74ns
A xP x W	2	1.68ns	1.1E4ns	0.02ns	9456ns	4771ns	31.13ns	9.47*

ns- not significantat P < 0.05, * - significant at P < 0.05 and ** highly significant at P < 0.01

TABLE 7
Effect of age, particle size and wax content on the board properties

Age (yrs)	MOR (MPa)	MOE (MPa)	IB (Mpa)	SWS (N)	SWE (N)	WA (%)	TS (%)
1	26.87b	3582b	0.68b	874ab	621b		15.06b
2	28.16a	3587b	0.77a	894a	676a	48.46a	15.02b
3	27.87ab	3822a	0.70b	838b	632ab	49.20a	18.49a
Psize(mm)							
1.0	28.88a	3692a	0.75a	845b	641a	49.96a	16.80a
2.0	26.38b	3635a	0.68b	892a	645a	46.38b	15.57b
Wax (%)							
0	27.73a	3624b	0.84a	937a	729a	64.92a	21.06a
1	27.53a	3703a	0.59b	800b	557b	31.41b	11.32b

Means having the same letter down the column are not significantly different

TABLE 8
Correlation analysis of age, particle size and wax content on the board properties

Variable	MOR	MOE	IB	SWS	SWE	WA	TS
Age	0.18ns	0.50**	0.04ns	-0.13ns	0.04ns	0.06ns	0.26*
Psize	-0.54**	-0.14ns	-0.20ns	0.22ns	0.02ns	-0.10ns	-0.11ns
Wax	-0.04ns	0.20ns	-0.69**	-0.63**	-0.76**	-0.96**	-0.88**

Particleboards produced using 1.0 mm size particle gives better MOR and IB but higher WA and TS values when compared with cores produced using 2.0 mm particle size. The higher WA and TS are due to the higher surface area of the core particles produced using 1.0 mm particle size size thus increasing its capacity to absorb more water. Correlation analysis from the Table 8 showed that particle size significantly decreases the MOR while the other board properties were insignificantly affected.

Wax is used to confer a degree of water repellency on the board. Table 6 shows that addition of 1% wax gives better WA and TS values. Addition of 1% wax decreases more than 50% the WA and TS. However, wax addition also decreases all the strength properties. Jamaludin *et al.* (1997) also reported a similar trend in their strudy. The descrease in strength properties is probably due to the resistance wax offers during gluing. Table 8 further revealed the correlation effect of wax on the board properties.

CONCLUSIONS

In the manufacture of single-layer particleboard, age, resin content and board density are found to significantly affect board properties. Particleboards produced from all age groups at a density of over 641 kg/ m^3 and at all resin contents were able to meet the strength requirements specified in BS 5669. Age, core particle size and wax affect the properties of three-layer particle board significantly. All boards made from all age groups surpassed all the strength and physical properties studied (MOR, MOE, IB, SWS and SWE) as stipulated in BS 5669. Particleboards of core particlesize of 1.0mm showed higher WA and TS values compared to particleboard of core particle size of 2.0 mm. However with 1% wax addition, the WA and TS were greatly reduced.

In terms of strength properties, all the bamboo particles from all age group of *G. schortehinii* are suitable for particleboard manufacture. However, the high values obtained for 24-hour thickness swell would require further studies before this species could be used for particleboard production.

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