EFFECTS OF VARYING PARTICLE SIZE, RESIN AND WAX CONTENT ON THE PROPERTIES OF HOMOGENOUS MELAMINE UREA FORMALDEHYDE PARTICLEBOARD FROM BAMBOO (*GIGANTOCHLOA SCORTECHINII*)

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ABSTRACT

In the study of high moisture resistant particleboard from bamboo (*Gigantochloa scortechinii*), homogenous melamine urea-formaldehyde particleboard was produced. An increase in resin content was accompanied by an increase in the mechanical and improvement in water absorption and thickness swelling properties. Varying the particle sizes also showed differences in the mechanical and physical properties. Wax addition increased the board stability towards water exposure but decreased the mechanical properties of the boards. All boards surpassed the minimum requirement of the BS for the mechanical and physical properties. Particles from three-year-old Gigantochloa scortechinii were suitable for the making of homogenous urea-formaldehyde particleboard.

INTRODUCTION

The particleboard industry was established due to the need to dispose of large quantities of wood waste produced by other wood industries. At present all particleboard industry in Malaysia uses the dry process, where air or mechanical formers are used to distribute the particles prior to pressing. At present many wood industries are reutilizing their wood wastes as boiler fuel, thus, prompting researchers to seek alternative sources of raw materials for the particleboard industry.

In Malaysia, of the 50 bamboo species found, 13 are being widely used in the various bamboo industries. Buluh semantan (*Gigantochloa scortechinii*) is the commonest bamboo found in the wild and presently are used in large quantities in the manufacturing of baskets, higo products, incense sticks and parquetries (Abd. Latif 1987). The basic properties of *G. scortechinii* have been reported by Abd. Latif *et al.* (1994) and Abd. Latif (1996). However, no published report on its utilization in the making of composite products has been found.

This paper discusses the particleboard properties of homogenous layer particleboard produced with melamine urea formaldehyde (MUF) resins. The influences of particle size, resin content and wax addition are included in the discussion.

MATERIALS AND METHODS

Sixty bamboo clums from three-year-old bamboo (*Gigantochloa scortechinii)* were harvested from managed bamboo clumps in FRIM, cut into 2m length and splitted longitudinally using a bamboo splitter. The bamboo splits were fed into the Pallmann drum chipper and the chips produced were then flaked in the Pallmann drum flaker. After flaking the particles were air-dried for one week to reduce the moisture content prior to oven-drying and were subsequently placed in an oven at 60°C until the moisture reaches about five percent. The oven-dried particles were then screened into less than 0.5, 0.5-1.0, 1.0-2.0 and more than 2.0mm sizes using a circular vibrating screen.

In the manufacturing of homogenous board, three different resin contents were applied; 8, 10 and 12% using three different particle sizes of 0.5-1.0, 1.0-2.0 and > 2.0mm. One percent wax was added while no wax was used for the controlled boards. The melamine urea-formaldehyde resin used in the study had a solid content of 65%. The hardener (ammonium chloride) solution with a concentration of 20% was used. The amount of hardener added was equivalent to 3% of the weight of the resin solution used.

For board manufacturing, a weighted amount of particles was placed in the Drais glue mixer and sprayed with a resin mix containing resin, hardener, wax and water. The glue mix was sprayed as a fine mist at an air pressure of 0.4 MPa in order to obtain an even distribution of resin over the bamboo particles. After spraying, the sprayed particles were then manually laid in a wooden mould over a caul plate with a dimension of 34 x 34cm and then pre-pressed with a cold press at 3.5 MPa for 30 seconds. The consolidated mat was then finally pressed to the required thickness of 12mm at 160°C for 6 minutes with the maximum pressure at the metal stops at 120kgcm-2. The target density was approximately 721kgm^{-3}. A total of three boards were produced for each condition.

All the boards produced were cut according to a cutting plan adopted from BS EN 326-1: 1994 (Anonymous 1994) made to obtain a random selection of test samples throughout the board size of 340 x 340 mm. The test samples were tested for its mechanical: modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB), and physical properties: water absorption (WA) and thickness swelling (TS) according to British Standard BS EN: 1993 (Anonymous 1993). Screw withdrawal (SWE & SWS) tests were conducted according to BS 5669 (Anonymous 1989). All the mechanical tests were conducted using an Instron Universal Testing Machine Model 4204.

RESULTS AND DISCUSSIONS

Physical and Mechanical Properties of Homogenous MUF Particleboard

The properties of homogenous MUF particleboard produced from three-year-old *G. scortechinii* are shown in Table 1. Boards produced from particles of greater than 2.0mm with 12% resin and 1% wax gave the highest MOR (29.72 MPa) while those produced by PS 0.5-1.0mm with 12% resin and wax had the highest MOE (4795 MPa). The highest IB (1.16 MPa) was shown by boards made from PS of 1.0-2.0 mm with 12% resin without the addition of wax while boards produced from PS 0.5-1.0mm had the highest SWS (1042 N) and SWE (932 N). The lowest TS1 (1.49%), TS24 (7.29%), WA1 (3.76%) and WA24 (19.95%) are produced from PS of 0.5-1.0 mm with 12 % resin and 1% wax.

Table 1: Properties of MUF Single-layer Particleboard from Three-y-old *G. scortechinii*

PS (mm)	Wax (%)	Resin (%)	Density (kg/m^3)	MOR (MPa)	MOE (MPa)	IB (MPa)	SWS (N)	SWE (N)	TS1 (%)	TS24 (%)	WA1 (%)	WA24 (%)
0.5-1.0	0	8	743	22.04	2920	0.83	814	738	4.28	16.44	16.27	62.12
		10	760	24.54	3309	1.02	1004	824	3.25	11.51	12.16	47.30
		12	750	28.22	3596	1.04	1042	932	2.63	9.48	10.23	34.69
1.0-2.0	0	8	736	22.13	3167	0.75	705	687	8.33	23.59	33.17	74.37
		10	735	24.15	3336	0.94	874	810	5.93	17.07	22.11	58.65
		12	719	26.03	3639	1.16	979	904	3.93	12.57	14.93	51.69
>2.0	0	8	768	22.67	3115	0.80	786	727	4.39	21.19	20.22	60.16
		10	781	25.87	3468	1.04	1003	884	3.39	15.52	17.23	46.64
		12	766	28.38	3830	1.14	945	900	2.37	11.19	11.23	36.68
0.5-1.0	1	8	758	23.04	3978	0.71	765	722	2.31	9.97	5.49	27.20
		10	762	25.85	4530	1.04	842	770	1.96	8.09	4.00	21.33
		12	763	28.00	4795	1.05	890	859	1.49	7.29	3.76	19.95
1.0-2.0	1	8	746	22.03	3259	0.74	713	581	3.10	11.88	6.92	29.97
		10	735	23.96	3615	0.90	746	648	2.54	9.90	6.01	29.17
		12	764	27.15	3781	0.94	794	665	1.99	8.07	5.21	24.32
>2.0	1	8	765	22.81	3388	0.58	803	660	2.67	14.01	7.44	30.30
		10	787	27.51	4017	0.70	902	745	2.02	10.59	6.51	26.29
		12	784	29.72	4317	0.91	922	825	1.63	7.59	5.29	20.73
BS	**5669**			**min. 13.8**	**min. 2000**	**min. 0.34**	-	**min. 360**	**max. 8.00**	-	-	-

Note: PS = Particle size, MOR = Modulus of Rupture, MOE = Modulus of Elasticity, IB = Internal Bond, SWS = Screw Withdrawal surface, SWE = Screw withdrawal edge, TS1 = Thickness swelling after 1 hour, TS24 = Thickness swelling after 24 hours, WA1= Water absorption after 1 hour, WA24 = Water absorption after 24 hours

Statistical Significance

Table 2 shows the ANOVA table for the effects of particle size, resin and wax contents on the properties of the particleboard produced. All the board properties were significantly affected by the varying particle size resin and wax content (except for wax on MOR).

Table 2: Analysis of Variance on the Effects of Varying Particle Size, Resin and Wax Content on the Particleboard Properties

SOV	MOR	MOE	IB	SWS	SWE	TS	WA
PS	5.82*	17.43*	22.50*	20.82*	24.30*	982.41*	664.13*
RES	83.70*	65.51*	226.14*	76.83*	87.21*	901.22*	712.97*
WAX	2.35ns	133.03*	130.32*	68.19*	122.58*	3537.99*	7214.81*
PS*WAX	0.42ns	38.17*	32.01*	5.83*	14.27*	435.99*	415.01*
PS*RES	0.97ns	1.17ns	4.61*	1.82ns	1.08ns	57.83*	62.75*
WAX*RES	0.57ns	1.67ns	1.33ns	13.01*	5.22*	190.52*	356.03*
PS*WAX*RES	0.36ns	0.19ns	10.75*	1.96ns	2.15ns	42.58*	63.01*

SOV- Source of variance
Note: * -F-values are significant at $p<0.05$, ns- not significant at $p<0.05$

Effect of Particle Size

Table 3 shows the effects of varying particle size on the board properties. Generally, bigger PS showed better MOR, WA and TS values but lower IB, SWS and SWE values. Higher MOR with the larger PS could be attributed to the ability of larger PS to distribute stress over a larger surface per unit weight and the increase in total glue bonded area. Internal bond and screw withdrawal values on the contrary decrease with increment of PS. The higher IB and SW with smaller PS can be due to the fact they can be well intermeshed and well bonded to give gap-free boards. The internal discontinuity factor also gives the board higher IB and SW values. However, the dimensional stability of the boards is reduced since with bigger PS the existence of larger voids leads to easier intake of water into the board. Furthermore, since bigger PS possesses higher bending strength, the stress levels becomes higher and once released would increase the water absorption capability and, thus, give rise to higher WA and TS. Shaikh (1991) also reported similar trends in the WA and TS properties of big particles.

Table 3: Effect of Varying Particle Size on the Board Properties

PS (mm)	MOR (Mpa)	MOE (Mpa)	IB (Mpa)	SWS (Mpa)	SWE (Mpa)	TS (Mpa)	WA (Mpa)
0.5-1.0	24.69ab	3763a	0.93a	872b	788a	2.59b	8.47c
1.0-2.0	23.86b	3423c	0.89b	792a	708c	4.25a	14.58a
>2.0	25.24a	3558b	0.83c	861b	762b	2.65b	10.93b

Means having the same letter down the column are not significantly different at $p<0.05$

Effect of Varying Resin Content

Table 4 shows the effects of increasing resin content on the board properties. From the table, an increase in resin content exhibited an increasing trend for the strength properties and improved the board stability towards water exposure. This is obvious since at higher resin content more resin are available for inter-particle bonding thus increasing the mechanical and physical properties

Table 4: Effects of varying resin content on the board properties

Resin (%)	MOR (Mpa)	MOE (Mpa)	IB (Mpa)	SWS (Mpa)	SWE (Mpa)	TS (Mpa)	WA (Mpa)
8	21.98c	3234c	0.72c	748c	671c	4.10a	14.64a
10	24.57b	3616b	0.92b	872b	760b	3.11b	11.07b
12	27.24a	3895a	1.01a	907a	828a	2.29c	8.28c

Means having the same letter down the column are not significantly different at $p<0.05$

Effect of Wax Addition

Table 5 shows the effects of wax addition on the board properties. With wax addition the strength properties of MOR and MOE showed slightly higher values but decreased the IB, SWS and SWE. The reduction in mechanical properties is probably due to the resistance characteristics of wax, which reduced the particles ability to bond intimately. The dimensional stability of the boards was shown to greatly improved with the presence of wax.

Table 5: Effect of Wax on the Board Properties

Wax (%)	MOR (Mpa)	MOE (Mpa)	IB (Mpa)	SWS (Mpa)	SWE (Mpa)	TS (Mpa)	WA (Mpa)
0	24.34a	3308b	0.95a	887a	806a	4.20a	17.18a
1	24.85a	3854a	0.82b	796b	699b	2.13b	5.47b

Means having the same letter down the column are not significantly different at $p<0.05$

CONCLUSION

In general, all the boards produced from three-year-old *G. scortechinii* particles surpassed the minimum requirement of the BS and MS standards and the particles are, therefore, suitable for the manufacturing of MUF particleboards.

REFERENCES

Anonymous. (1989). *British Standard Methods for Particleboard: BS 5669: Specification for Wood Chipboard and Methods of Test for Particleboard.* London : British Standards Institution.

Anonymous. (1993). *British Standard BS EN 310, 317, 319, 322 & 323: 1993. Wood-based Panels : Mechanical and Physical Tests.* London : British Standards Institution.

Anonymous. (1994). *British Standard Methods BS EN 326-1: 1994.* London : British Standards Institution.

Abd. Latif Mohmod. (1987). *Guidelines on Blinds and Satay Production. FRIM Technical Information* 2.

Abd. Latif, M., Khoo, K. C., Jamaludin, K. and Abd. Jalil, Hj. A. (1994). *Fibre morphology and chemical properties of Gigantochloa scortechinii.* Journal of Tropical Forest Science, 6 (4) : 397-407.

Abd. Latif, M. (1996). *Some Selected Properties of Two Malaysian Bamboo Species in relation to Age, Height, Site and Seasonal Variation.* Unpublished PhD Thesis, Universiti Putra Malaysia, Serdang, Selangor.

Shaikh Abdul Karim, Y. (1991). *The Effect of Compaction Ratio and Particle Geometry on Particleboard Properties.*, University of Wales, Bangor, Gwynedd, United Kingdom.