BAMBUSA VULGARIS FOR UREA AND CEMENT-BONDED PARTICLEBOARD MANUFACTURE

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CHEW, L.T., RAHIM SUDIN & JAMALUDIN KASIM. 1992. *Bambusa vulgaris* for urea and cement-bonded particleboard. *Bambusa vulgaris*, a common Malaysian bamboo, was used in the manufacture of urea and cement-bonded particleboards. The urea-formaldehyde particleboards must have a minimum density of 600 *kg* m^{-3} and 8% resin content to meet the requirements of Type I Standard Board, British Standards. In the manufacture of cement-bonded particleboards of density 1250 *kg* m^{-3}, fresh chips of the bamboo had to be pretreated to reduce its total sugars content. The cement-bonded particleboards must have a wood:cement ratio of 1:2.75 by weight and 2% of either aluminium sulphate or an admixture of sodium silicate and aluminium sulphate by weight of the cement to meet the requirements of the Malaysian Standard for cement-bonded particleboard.

Key words: *Bambusa vulgaris* - urea-formaldehyde particleboards - cement-bonded particleboards

Introduction

Bambusa vulgaris is one of the 45 species of bamboo found in Peninsular Malaysia. It is a perenial woody grass, belonging to the family Gramineae and to the sub-family Bambusoidae (Watson & Wyatt Smith 1961, Chin 1977). *B. vulgaris* is the most common Malaysian village bamboo and grows everywhere, often on riverbanks. It thrives and matures quickly. As it is a fast-growing plant, it could possibly be a ready source of ligno-cellulosic material for the manufacture of urea (UF-boards) and cement-bonded particleboards (CBP). This paper examines the properties of UF-boards and CBP from *B. vulgaris.*

Method

Sample collection

Thirty-two culms of *B. vulgaris* were harvested from a riverside in Kampung Benus, in the state of Pahang. The average length, diameter and wall thickness of the culms were 7.50, 7 and 1 *cm*, respectively. Culms with the nodes removed were then chipped by a Taihei chipper. The chips were subsequently processed for fibre analysis and board manufacture.

Fibre analysis

The chips were reduced to matchstick-size particles before being macerated accordingly to the method of Wise *et al.* (1946). After maceration, the fibres were stained with safarin-C and mounted on slides. Three hundred fibres were measured for their length, width and lumen width by a visopan projection microscope.

Sugar content analysis

About 500 *g* of the flakes for CBP manufacture were ground by a Fritz-Pulverizier to about 200 mesh size. Four hundred milligrams of the 200 mesh sawdust were soaked in 40 *ml* of a methanol/water mixture of ratio 3:1 by volume. The solution was then shaken in a lab-line shaker for 24 hours. The solution was then increased to 50 *ml* before being filtered. Twenty-five millimeters of the filtrate were evaporated to dryness before being dissolved in 3 *ml* of distilled water. The aqueous solution was filtered by 0.45 μ prep-disc membrane filter into a sampling bottle before being injected into a HPLC system (Model HP 1084 B). The sugars were then detected by RI detector with Aminex HPX-87 P column and double distilled water as the eluting solvent.

Flake preparation for UF-board manufacture

Chips of dimensions 30 × 30 × 5 *mm* were flaked by a Pallmann knife-ring flaker with cutting knives set to produce 0.6 *mm* thick flakes. As the resultant flakes were of suitable dimensions for boardmaking, no further processing was necessary. Sieve analysis (on a 50-*g* sample) and bulk densities of the flakes were determined.

Flake preparation for CBP manufacture

The *B. vulgaris* chips were soaked in water for a week before being processed by a Pallmann knife-ring flaker using a 2 × 2 *cm* screen. The flakes were screened into various particle sizes. The flakes that were retained at the 0.5 *mm* screen were used as the surface/fine materials while those retained at the 1.0 *mm* screen were used as the core material in the CBP manufacture. A 50-*g* sample of flakes was used before the screening process for sieve analysis. The flakes were first dried to 5% moisture content (m.c.).

Board manufacture

Manufacture of UF-board

Measured quantities of flakes and fines for the production of 19 *mm* UF-boards of varying densities and resin contents were sprayed in a Drais mixer with a resin mix containing urea-formaldehyde, hardener and water. The sprayed particles and fines at a controlled m.c. of 12% were laid in a mould and pre-pressed at 3.5 *kg* m^{-3}. The consolidated mat was finally pressed to the required thickness at 160° *C* for 6 *min.* A total of three boards were made for each condition.

Manufacture of CBP

CBP of density of 1250 *kg* m^{-3} were manufactured with varying wood:cement (w:c) ratios of 1:1.25, 1:2.75 and 1:3.00 and different mineralising chemicals of 2% by weight of cement (calcium chloride, magnesium chloride, aluminium sulphate and an admixture of sodium silicate and aluminium sulphate). The CBP were mat-formed on caul plates in wooden moulds and the mats were then stacked on top of one another until there were five mats on each clamp. Two thickness bars of 10 *mm* thick were placed at the opposite sides of each mat to control the thickness of the boards which were clamped under pressure for 24 *h* in a hardening chamber maintained at a temperature range of 60 to 65° *C*. The pressure on the CBP was released after 24 *h* and the CBP were allowed to cure for 28 days at room temperature. A total of five panels were made for each condition.

Board evaluation

UF-board

All the boards were cut into test pieces and conditioned in a constant temperature and humidity room (20° *C* and 65% relative humidity). Strength and dimensional stability tests were carried out according to BS 5669:1979 "Specification for wood chipboard and methods of test for particleboard" (Anonymous 1979).

CBP

All the CBP were also cut into test pieces and conditioned at 27° *C* and 65% relative humidity. Strength and dimensional stability tests were carried out according to MS 934:1984 "Malaysian Standard Specification for Wood Cement Board" (Anonymous 1984).

Results and discussion

Particle classification of the flakes

Table 1 gives the percentage by weight of the flakes of various sizes for the manufacture of UF-board and CBP.

The average bulk density of the flakes for UF board manufacture was 197 *g* l^{-1} at 5% moisture content while the average density of the green *B. vulgaris* was 630 *kg* m^{-3}.

Table 1. Particle classification of the flakes

Sieve size (*mm*)	Percentage by weight (%)	
	UF-board flakes	CBP flakes
< 0.25	3	2
0.25	6	5
0.50	18	16
1.00	12	17
1.40	22	20
2.00	19	21
2.80	6	6
3.35	14	13

Fibre morphology

The fibre characteristics of *B. vulgaris* from Malaysia and the Philippines (Tamolang 1957) are compared in Table 2. The Malaysian fibres were quite long and slender, averaging 2.82 *mm.* The fibre diameter and lumen width averaged 0.013 and 0.003 *mm* respectively. The Malaysian fibre dimensions were comparable to those of the Philippines *B. vulgaris.*

Table 2. Fibre dimensions of *Bambusa vulgaris*

	Bambusa vulgaris	
	Malaysia	Philippines
Fibre length(*mm*)	2.82	2.33
Fibre width(*mm*)	0.013	0.017
Lumen width(*mm*)	0.003	0.004
Cell-wall thickness(*mm*)	0.005	0.007

Sugar content analysis

The sugar content analysis of fresh *B. vulgaris* showed that the main sugar components were glucose, fructose and sucrose which averaged 2.37, 2.07 and 0.50%, respectively, based on oven-dry wood. The total sugars present in *B. vulgaris* averaged 4.94%, which was high for CBP manufacture as the maximum amount of sugars in the wood aggregate should be 0.5% only (Simatupang 1986, Schwarz 1988). However, when the chips were soaked in water for a week, the total sugars content was significantly reduced to 0.28 %.

UF-board

Table 3 gives the strength and dimensional stability properties of UF-boards from *B. vulgaris.*

Table 3. Properties of 19 *mm* UF-boards from *Bambusa vulgaris*

Sample	Resin content (%)	Density ($kg\ m^{-3}$)	Bending strength (*MPa*)	Internal bond (*MPa*)	Screw withdrawal (*N*)	Thickness swell (%)
A	6	550	12.7	0.15	489	7.6
B	6	610	17.6	0.27	671	9.3
C	6	710	27.9	0.36	777	9.5
D	8	540	11.8	0.31	418	4.0
E	8	610	16.9	0.49	528	5.2
F	8	690	21.3	0.74	697	4.4
G	10	610	20.7	0.52	650	5.7
H	10	660	27.3	0.62	670	6.3
I	10	720	27.4	0.85	881	7.6
British Standards			min	min	min	
Type 1	-	-	13.8	0.34	360	< 12.0

UF-boards of densities above 600 $kg\ m^{-3}$ and with resin contents of 6 to 10% met the bending strength(MOR) requirements of Type 1 Board as specified in the British Standards. For the internal bond(IB) requirement, a minimum resin content of 8% and density of 600 $kg\ m^{-3}$ were necessary; with a higher density of 700 $kg\ m^{-3}$, a lower resin content of 6% could satisfy the IB of the British Standards. Increased resin content and board density considerably improved all the strength properties of the UF-boards. All the UF-boards satisfied the screw withdrawal (SW) requirements and had thickness swellings (TS) well below the stipulated maximum rate of 12% in the British Standards.

Table 4 gives the ANOVA and the effect of resin level (%) on the properties of UF-boards.

Table 4. Analysis of variance and effect of resin level(%) on the properties of UF-boards from *Bambusa vulgaris*

	Degrees of freedom	MOR	IB	TS	SW	Density
Resin	2	NS	*	**	NS	NS
Mean		20.40	0.49	6.62	642.33	633.33
Standard deviation		6.20	0.23	2.00	144.33	65.76
Resin(%)		**MOR**	**IB**	**TS**	**SW**	**Density**
6		19.40a	0.260b	8.800a	645.7a	623.33a
8		16.67a	0.513ab	4.533c	547.7a	613.33a
10		25.13a	0.663a	6.533b	733.7a	663.33a

Mean squares *, **, NS are significant at 5 and 1% probability levels and Not Significant, respectively. Means having the same letter down the column show non-significant differences according to the Waller-Duncan multiple range test

The analyses showed that the effects of changes in the resin levels on IB and TS were significant at 5 and 1% probability levels. The resin levels of the UF-boards did not appear to have significant effects on the MOR or SW values.

Table 5 gives the ANOVA and the effect of the density on the properties of UF-boards.

Table 5. Analysis of variance and effect of density on the properties of UF-boards

	Degrees of freedom	MOR	IB	TS	SW
Density	6	*	NS	NS	*
Mean		20.40	0.48	6.62	642.33
Standard deviation		6.20	0.23	2.00	144.33
Density (*kg m*$^{-3}$)		MOR	IB	TS	SW
720		27.4a	0.85a	7.60a	881.0a
710		27.9a	0.36a	9.50a	777.0ab
690		21.3ab	0.74a	4.40a	697.0ab
660		27.3a	0.62a	6.30a	670.0ab
610		18.4ab	0.42a	6.73a	616.3ab
550		12.7b	0.15a	7.60a	489.0ab
540		11.8b	0.31a	4.00a	418.0b

Mean squares * , NS are significant at 5% and Not Significant respectively. Means having the same letter down the column show non-significant differences according to the Waller-Duncan multiple range test

The analyses showed that the effects of different board densities on MOR and SW were significant at 5% probability level. The board density did not appear to have significant effects on the TS and IB values.

CBP

Table 6 gives the properties of 10 *mm* CBP made from *B. vulgaris* flakes.

Table 6. Properties of 10 *mm* CBP from *Bambusa vulgaris*

Sample	Wood: cement	Additive	Bending strength (*MPa*)	Internal bond (*MPa*)	Water absorption (%)	Thickness swelling (%)
A	1:2.50	-	2.19	0.05	27.81	1.94
B	1:2.75	-	3.64	0.10	26.10	1.16
C	1:3.00	-	5.15	0.18	20.39	1.27
D	1:2.75	calcium chloride	5.48	0.17	24.65	2.24
E	1:2.75	magnesium chloride	7.64	0.40	15.97	1.37
F	1:2.75	aluminium sulphate	9.05	0.57	14.40	0.86
G	1:2.75	sodium silicate/ aluminium sulphate	9.10	0.70	13.27	1.03
MS 934		-	9.00	0.50	-	< 2.00

The MOR and IB values of the CBP manufactured without any additives (Samples A, B & C) increased with increased w:c ratios but the values could not meet the specifications of the Malaysian Standard MS 934. CBP with a w:c ratio of 1:2.75 and additives of 2% calcium or magnesium chloride by weight of cement (Samples D & E) gave better strength values than CBP with the same w:c ratio but without any additives (Sample B). Only CBP with a w:c ratio of 1:2.75 and additives of 2% of aluminium sulphate or an admixture of sodium silicate and aluminium sulphate by weight of cement (Samples F & G) satisfied all the requirements of MS 934. However, all the CBP, except Sample D had thickness swellings well below the maximum 2% stipulated in MS 934.

Table 7 gives the ANOVA and the effect of wood-cement ratios of the CBP on the properties on CBP.

Table 7. Analysis of variance and effect of wood:cement ratios of the CBP on the properties of CBP

	Degrees of freedom	MOR	IB	WA	TS
Ratio	2	**	**	**	**
Mean		3.78	0.14	25.16	1.53
Standard deviation		1.56	0.07	5.3	1.14
Wood:cement ratio		MOR (*MPa*)	IB (*MPa*)	WA (%)	TS (%)
1:2.50		2.439c	0.0678c	28.99a	2.153a
1:2.75		3.867b	0.120b	26.09b	1.171b
1:3.00		5.036a	0.231a	20.40c	1.264a

Mean squares ** is significant at the 1 % probability level. Means having the same letter down the column indicate that they are not significantly different

The analyses showed that the effects of w:c ratios on MOR, IB, TS and WA were significant at the 1% probability level.

Table 8 gives the ANOVA and the effect of chemical additive on the properties of CBP.

Table 8. Analysis of variance and the effect of chemical additive on the properties of the CBP

	Degrees of freedom	MOR	IB	WA	TS
Chemicals	4	**	**	**	**
Mean		6.99	0.43	18.22	1.20
Standard deviation		2.54	0.26	5.64	0.76
Chemical additive		MOR (*MPa*)	IB (*MPa*)	WA (%)	TS (%)
Sodium silicate & aluminium sulphate		9.405a	0.7662a	12.571d	0.824b
Aluminium sulphate		9.254a	0.6250b	13.433d	0.756b
Magnesium chloride		6.990b	0.4325c	15.950c	0.756b
Calcium chloride		5.477c	0.1938d	23.686b	2.260a
No chemical additive		3.910d	0.1188e	25.444a	1.047b

Mean squares ** is significant at the 1% probablility level. Means having the same letter down the column indicates that they are not significantly different

The effects of the various chemical additives on all the properties of the CBP were significant at 1% probability level.

Conclusion

B. vulgaris was found to be a suitable species for the manufacture of medium density UF-boards as the UF-boards with 8% resin content and density 600 $kg\,m^{-3}$ met the requirements of Type 1 Board, Standard Board, as specified in the British Standards. Although fresh *B. vulgaris* had a high total sugars content of 4.94%, the total sugars content was significantly reduced after seven days' soaking in water. This pre-treatment of the fresh chips enabled *B. vulgaris* to be a suitable raw material for CBP manufacture, provided the CBP had a w:c ratio of 1:2.75 and 2% by weight of cement of either aluminium sulphate or an admixture of sodium silicate and aluminium sulphate.

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