Effects of Bamboo Density and Chemical Properties on the Properties of Particleboard Produced from *Gigantochloa Scortechinii*

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ABSTRACT

Density and chemical properties of 1-, 2- and 3-y-old Gigantochloa scortechinii *were determined and their effects on the particleboard properties were investigated by means of correlation analysis. Predictive equations of the board variables viz; age, particle size, resin and wax content on the board properties were also derived by regression analysis. From the study, density was found to increase with bamboo age and culm portion. Only the chemical properties of cold water, hot water and alkali soluble were significantly affected by increased age and culm height. Holocellulose on the other hand only showed an increasing trend with age. Bamboo density only affected the modulus of elasticity of the particleboard. The chemical properties of cold, hot water soluble, ash and holocellulose content showed positive correlation with screw withdrawal (edge). The physical properties of 1-hr and 24-hrs thickness swelling were negatively correlated with the chemical properties of cold, hot water, alkali solubles and holocellulose content. All the regression equations derived in the study were found to be significant at* $p < 0.05$ *with correlation of determination (*R^2*) of over 50%. The equations could be used as a primary device to predict the properties of particleboard produced from other sources manufactured under the same conditions used in this study.*

Keywords: Gigantochloa scortechinii *particleboard, density, chemical properties, predictive equations*

Introduction

Properties of wood composites varied depending on the conditions used in the manufacturing process. Nelson (1973) reported that to have a better understanding of variation in board properties, the effects of the raw material and processing variables on the board properties must be determined. In this study, the factor of certain bamboo quality factors (density and chemical properties) and the particleboard processing variables were analysed. Jamaludin et al. (2000) reported the suitability of *G. scortechinii* particles for the manufacture of urea-formaldehyde particleboard. The effects of the bamboo properties and processing variables of age, particle sizes, resin and wax content were also discussed. In this paper, predictive equations of the board properties are derived, the correlation effects of bamboo density and chemical properties on board properties are also reported.

Materials and Methods

Materials Preparation

A total of 150 bamboo culms from the ages of 1-, 2- and 3-y-old bamboo were harvested from managed bamboo clumps in FRIM, Kepong. For the studies on density and chemical properties, 3 cm width specimens were collected randomly from the first internode of each height portion from 10 bamboo culms. For density measurements, two specimens measuring 2 cm x 3 cm x Y thickness were taken from the middle section of each selected bamboo portion. A total of 180 samples were taken for density measurements. All other samples not used in the experiment were then reduced to bamboomeal using a Wiley's mill. The bamboomeal was screened and those retained on the BS 60 mesh size were used in the determination of chemical properties following the TAPPI standards (Anon 1978). Holocellulose content was, however, determined by the method employed by Wise et al. (1946). The procedure used in the manufacture of particleboard and their evaluation are reported in Jamaludin et al. (2000).

Statistical Analysis

The effects of age and culm portion on the density and chemical properties were analysed by the analysis of variance (ANOVA), Duncan Multiple Range T-tests (DMRT) and correlation analysis. Predictive equations were constructed by the use of the SPSS statistical package software. The main factors that affect the properties of the particleboard according to the results of the ANOVA and correlation analysis were choosen as independent variables in multiple regressions constructed for predicting particleboard properties. These regressions were derived from the model, $Y = a + bX1 + cX2 + dX3 + ..nXn$, where Y is board property and X, the variables of bamboo age, particle size, resin and wax content. The effects of the density and chemical properties towards board properties were also determined through correlation analysis.

Results and Discussion

Bamboo Density

Table 1 gives the average values of the oven-dry density according to age and culm portion. Oven-dry density was observed to show an increasing trend with age and culm portion. The results of the DMRT and correlation analysis in Table 2 and 3, respectively indicated that the highest and lowest average oven-dry density occurred in the older than the younger culm and at the top than the basal portion. The increase of density with age could be due to the thicker fibre wall within the older culm while the increase in density with culm portion is probably due to

Table 1: Oven-dry Density According to Age and Culm Portion

Culm Portion	Density(gcm^{-3})		
	Age(yrs)		
	1	2	3
Basal	0.48	0.53	0.66
Middle	0.60	0.64	0.75
Top	0.72	0.73	0.83
Average	0.60	0.63	0.75

Note: Values are averages of 20 measurements the decrease in parenchyma cells (a higher frequency of vascular bundles distribution) (Abd. Latif *et al.* 1995, 1996, Espiloy 1987, Liese 1987). Jamaludin *et al.* (1993) also found a similar pattern of variation.

Table 2: Summary of DMRT on the Effects of Age and Portion on the Oven-dry Density

Age	Density	Portion	Density
1	0.60c	Basal	0.55c
2	0.63b	Middle	0.66b
3	0.75a	Top	0.75a

Note: Means with the same letter down the column are not significantly different at $p < 0.05$

Chemical Properties

The approximate chemical properties of *Gigantochloa scortechinii* according to age and culm portion is indicated in Table 3. The effects of age and culm portion and their correlation analysis are given in Table 4 and 5, respectively. The CW, HW and alkali solubles were shown to be significantly different between the age group and culm portion (Table 4) and the correlation analysis (Table 5) further revealed that they have a positive correlation with age and culm portion. For AB, ash and lignin content, the DMRT and correlation analysis determined that their increase are insignificantly affected by age and culm portion. Holocellulose content, on the other hand, showed an increasing trend with age but not with culm portion.

Effects of Age, Particle Size, Resin and Wax Content – Predictive Equations

The regressions equations are shown in Table 6. The equations obtained, can be used to provide a predictive device to obtain estimates of particleboard properties. These equations, however, should only be used to predict values within the ranges of the properties from which they are derived. They can, in fact, be used to predict the properties of boards manufactured in generally similar fashion to the process used in this study.

Table 3: Chemical Properties of *G. scortechinii* According to Age and Bamboo Portion

Age (yrs)	Bamboo portion	CW (%)	HW (%)	NaOH (%)	AB (%)	Ash (%)	Lignin (%)	Holo (%)
1	Basal	1.11	2.40	11.23	2.49	1.12	26.05	66.15
	Middle	3.66	5.60	15.21	3.69	1.10	25.35	65.61
	Top	3.02	4.23	18.45	3.30	1.32	23.80	65.83
	Average	2.60	4.08	14.96	3.16	1.18	25.06	65.86
2	Basal	5.57	6.48	17.90	3.10	1.10	24.90	67.93
	Middle	6.80	7.82	20.15	3.02	1.39	24.50	67.00
	Top	8.02	10.20	21.93	3.45	1.38	26.00	66.62
	Average	6.80	8.16	19.99	3.19	1.29	25.13	67.18
3	Basal	4.46	5.98	18.30	3.41	1.05	26.00	67.61
	Middle	5.86	7.25	22.81	3.32	1.33	25.75	65.84
	Top	7.65	8.38	25.52	3.65	1.18	25.10	69.39
	Average	6.00	7.20	22.21	3.46	1.19	25.62	67.61

Values are averages of three determinations, CW: Cold water solubles, HW: Hot water solubles, AB: Alcohol benzenes solubles, Holo: Holocellulose, NaOH: Alkali solubles

Table 4: Effects of Age and Culm Portion on the Chemical Properties

Age	CW	HW	AB	NaOH	Ash	Lignin	Holocellulose
1	2.60c	4.08c	3.16a	14.97c	1.18a	25.07a	65.87b
2	6.80a	8.18a	3.19a	19.99b	1.29a	25.13a	67.18a
3	6.00b	7.21b	3.46a	22.21a	1.19a	25.62a	67.61a
Portion	**CW**	**HW**	**AB**	**NaOH**	**Ash**	**Lignin**	**Holocellulose**
Bottom	3.72b	4.95c	3.00a	15.81c	1.09a	25.65a	67.23a
Middle	5.44b	6.91b	3.34a	19.40b	1.27a	25.20a	66.15a
Top	6.23a	7.60a	3.46a	21.97a	1.29a	24.97a	67.28a

Note: Different letters down the column indicates significance at $p < 0.05$

Table 5: Correlation Coefficients of Density and Chemical Properties with Age and Culm Portion

Properties	Age	Portion
Density	0.55**	0.73**
Cold water solubles	0.64**	0.47**
Hot water solubles	0.58*	0.49*
1% NaOH solubles	0.73**	0.62**
Alcohol-benzenes solubles	0.28ns	0.43ns
Ash content	0.01ns	0.37ns
Lignin content	0.16ns	-0.20ns
Holocellulose content	0.52*	0.02ns

ns-means are not significant at $p < 0.05$ * - means are significant at $p < 0.05$
** - means are highly significant at $p < 0.01$

Table 6: Regression Equations of the Board Properties

Property	Regression Equations	F-ratio	R^2(%)
MOR	$Y = 7.86 + 0.35A + 1.45P + 1.33R - 1.72W$	98.92**	0.60
MOE	$Y = 1174 + 79.48A + 400.75P = 168.37R - 283.12W$	93.56**	0.58
IB	$Y = 0.33 + 0.013A - 0.19P + 0.071R - 0.12W$	229.24**	0.78
SWS	$Y = 428.98 - 27.09A - 17.46P + 43.62R - 29.64W$	73.35**	0.53
SWE	$Y = 352.95 + 8.28A - 35.03P + 35.92R - 79.35W$	75.53**	0.53
TS1	$Y = 20.75 - 1.05A + 1.47P - 1.01R - 6.86W$	67.82**	0.51
TS24	$Y = 48.54 - 1.92A + 5.09P - 2.47R - 8.28W$	137.00**	0.67
WA1	$Y = 57.08 - 0.20A + 5.11P - 2.52R - 28.14W$	230.60**	0.78
WA24	$Y = 105.12 - 0.58A + 7.41P - 4.19R - 30.33W$	693.28**	0.91

A - Age (yrs), P - Particle size (mm), R - Resin level, W - Wax content,
** - significant at $p < 0.05$

All the regression equations were significant at $p < 0.05$ and were accompanied with correlation of determination (R^2) of over 50% suggesting the existence of a relationship between the variables with the board properties. From the table, optimum regressions (WA24) were associated with up to 91% of the observed variation in the particleboard properties. All the variables used in the regressions analysis were related with the particleboard properties.

Effects of the Density and Chemical Properties on the Board Properties

The relationship between the physical and chemical properties and board properties was analysed and tabulated in Table 7. The MOR of the particleboard was found to increase insignificantly with density and chemical properties of *G. scortechinii*. This implies that the MOR value of particleboard does not depend on the basic properties but is more dependent on the particle size and resin content used in the study. Nelson (1973) reported that the material density and its chemical properties had little contributions towards increasing the board properties. In the analysis on MOE, only density (r = 0.16) had a significant effect. With higher density, the particles are harder (Jamaludin et al. 1997) and, thus, increases the board stiffness.

The mechanical and physical properties of IB, SWS and WA1, WA24, respectively are insignificantly correlated with either density and chemical properties. SWE was seen to be affected with an increase in CW (r = 0.27), HW (r = 0.27), ash content (r = 0.16) and holocellulose content (r = 0.16). The increase in SWE values with increasing CW and HW could be accounted for the available starchy materials that might provide good bonding between particles and prevent the easy withdrawal of screws. Panshin and De Zeeuw (1970) suggested the increase in extractives content could stiffen and harden the individual cells within the woody materials and, thus, give rise to increases in its strength properties. The increase with ash content could also be accounted for the stiffness or hardness imparted to the bamboo particles which might increase the resistance during screw withdrawal.

Table 7: Correlation Coefficients of Physical and Chemical Properties with the Properties of UF-Board

Property	MOR	MOE	IB	SWS	SWE	TS1	TS24	WA1	WA24
Density	0.13ns	0.16*	0.03ns	-0.12ns	-0.04ns	-0.04ns	-0.06ns	0.04ns	-0.01ns
CW	0.11ns	-0.07ns	0.11ns	-0.02ns	0.27**	-0.24**	-0.25**	-0.10ns	-0.07ns
HW	0.11ns	-0.08ns	0.11ns	-0.01ns	0.26**	-0.24**	-0.24**	-0.10ns	-0.07ns
AB	0.07ns	0.13ns	0.02ns	-0.08ns	-0.05ns	-0.03ns	-0.02ns	0.03ns	-0.01ns
Ash	0.09ns	-0.09ns	0.08ns	0.09ns	0.16*	-0.11ns	-0.11ns	-0.07ns	-0.04ns
NaOH	0.13ns	0.07ns	0.07ns	-0.10ns	0.12ns	-0.16*	-0.19**	-0.03ns	-0.04ns
Lignin	0.02ns	0.06ns	-0.00ns	-0.12ns	-0.05ns	-0.03ns	-0.02ns	0.02ns	-0.10ns
Holo	0.06ns	0.01ns	0.04ns	-0.10ns	0.16*	-0.14*	-0.17*	-0.04ns	-0.03ns

Note: ns - not significant, * - significant at $p < 0.05$, ** - highly significant at $p < 0.01$
CW - Cold water solubles, HW- Hot water solubles, AB - Alcohol benzenes solubles, NaOH - 1% Alkali solubles, Holo - Holocellulose content

The physical properties of TS1 and TS24 were observed to improve insignificantly with density, AB, ash and lignin content. The TS1 and TS24 are negatively correlated with CW, HW, NaOH soluble and holocellulose content. The decrease in both the physical properties with an increase in the water soluble is due to the ability of the water soluble to form hydrogen bonds with the cell wall materials, stiffening them and reduce the uptake of water, thus, reducing its thickness swelling.

Conclusion

Density was observed to increase significantly with increasing age and culm portion. The chemical properties of cold, hot water and alkali soluble were shown to be significantly different between the age group and culm portion. Alcohol benzenes, ash and lignin content were found to increase insignificantly with age and culm portion while holocellulose increased with age but not with culm portion.

The regression equations obtained were shown to be highly significant (at $p < 0.05$) with correlation of determination of better than 50%. The equations can be used as an initial device to obtaine estimates of particleboard properties manufactured in the same way as in this study.

In the correlation analysis of the effects of density on the board properties, only MOE was shown to have a significant correlation with bamboo density. The mechanical propertie of SWE was significantly affected by the cold, hot water soluble, ash and holocellulose content. The physical properties of 1 hr and 24 hr thickness swelling were improved significantly with the chemical properties of cold, hot water, alkali solubles and holocellulose content.

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